Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Urban Water Sustainability in a Rapidly Growing City: Stakeholder Perspectives, Governance Gaps and Management Priorities in Parramatta, Sydney, Australia

Niruban Chakkaravarthy Dhanasekaran
Western Sydney University
Basant Maheshwari
b.maheshwari@westernsydney.edu.au
Western Sydney University
Michelle Donovan-Mak
Western Sydney University
Samsul Huda
Western Sydney University

Research Article

Keywords: Urban, Water sustainability, Stakeholder perspectives, Water governance, Stormwater, SDGs

Posted Date: July 16th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10268571/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Urban water sustainability in rapidly growing cities depends not only on infrastructure and technical monitoring, but also on how diverse stakeholders understand, govern and respond to water-related pressures. This study examines key informant perspectives on urban water sustainability in Parramatta, Sydney, a fast-growing urban region facing pressures from population growth, stormwater pollution, land-use change, ageing infrastructure and fragmented governance. Semi-structured interviews with 15 stakeholders from government agencies, utilities, community organisations and environmental groups were analysed using thematic analysis. The findings show that stakeholders define water sustainability broadly, linking water quality, ecosystem health, equitable access, community awareness, Indigenous knowledge and long-term governance. Participants identified urban development, stormwater pollution, sedimentation, infrastructure constraints and weak institutional coordination as major barriers to sustainability. Although local initiatives in restoration, monitoring, water efficiency, and community engagement are underway, current actions are widely viewed as insufficient, fragmented, and reactive. The study highlights the need for integrated, place-based water governance that aligns councils, state agencies, utilities, catchment groups and communities around shared indicators, stronger accountability and explicit links to SDGs 6, 11, and 15. The findings provide practical guidance for improving urban water management in Parramatta and comparable rapidly urbanising cities.

1. Introduction

Urban landscape activities depend on water as a vital resource for their functioning (Rietveld et al. 2016). Globally, cities face growing water management challenges, including scarcity, flooding, and water-quality issues caused by altered hydrology, land-use changes, and pollutant loads (Ferdowsi et al. 2024). Climate change further exacerbates extreme weather events, heatwaves, and sea-level rise, underscoring the need for adaptive urban water strategies (UN Water 2022). Understanding water sustainability is therefore crucial for effective management. Beyond these challenges, urban areas also face threats from overuse, rapid population growth, industrial activities, impervious surfaces, and social disconnection (Das et al. 2024).

Most research on urban water sustainability emphasises technical and biophysical factors, thereby overlooking the social, cultural, and governance dimensions of water systems (Hurlimann et al. 2017). Urban water systems are also often managed in fragmented ways across multiple agencies and levels of government, making a holistic understanding essential. While quantitative assessments of water quality, supply, and infrastructure are well established, the perspectives of practitioners, community advocates, and institutional leaders, those who directly manage and experience urban water challenges, remain underexplored (Holland et al. 2023). Understanding how these key informants define, prioritise, and respond to water sustainability challenges is critical for bridging the gap between technical knowledge and on-the-ground governance.

Sydney's water management history mirrors that of many expanding cities, transitioning from a small settlement to a major metropolis (Davies and Wright 2014). This study focused on Parramatta, a crucial part of Sydney's western growth within the Sydney Basin. Its water management choices considerably influence the Parramatta River catchment and downstream aquatic ecosystems. This region has faced various challenges, including drought, bushfires, floods, pollution, and institutional and governance challenges (City of Parramatta 2017). Parramatta represents one of Australia’s more complex urban water governance contexts, where rapid growth, catchment pressures, infrastructure demands and fragmented institutional responsibilities intersect. Water supply, catchment management, stormwater, waterways and land-use planning are dispersed across multiple agencies and levels of government, creating coordination challenges (Davies et al. 2017; Tawfik 2016). Although co-governance frameworks for urban water have been extensively developed in European and North American contexts, empirical work in Australia remains comparatively limited (Rijke et al. 2013). However, no study has systematically examined how the diverse practitioners, community advocates, and governance actors working in this region define, assess, and respond to water sustainability challenges. This is a significant gap, given that governance fragmentation and community engagement are widely recognised as central barriers to effective urban water management.

This study addresses this gap through semi-structured interviews with 15 key informants from government agencies, utilities, community organisations and environmental groups in the Parramatta region. By examining how these stakeholders define water sustainability, identify challenges, use indicators, engage with governance and relate their work to the Sustainable Development Goals, the study provides a practitioner-grounded account that complements existing technical and biophysical assessments. The Parramatta case is used to show how stakeholder perspectives can reveal governance gaps, institutional barriers and management priorities that are not always captured through technical indicators alone.

Specifically, the study addresses the following three research aims:

(1) To examine how key informants across government, utilities, community organisations, and environmental groups understand and define urban water sustainability in the Parramatta region of the Sydney Basin.

(2) To identify the major challenges, governance gaps, and human pressures affecting water sustainability in the study region, as perceived by key informants.

(3) To explore stakeholder priorities, collaborative action, and alignment with the United Nations Sustainable Development Goals (SDGs 6, 11, and 15) as a basis for informing integrated urban water governance.

2. Methodology

This study adopts a qualitative, interpretivist approach, grounded in the view that understanding urban water sustainability requires engaging with the meanings, experiences, and priorities of those directly involved in its governance and management (Arnott and Lemos 2021; Braun and Clarke 2022). Rather than measuring water sustainability solely through fixed indicators, the study aims to understand how different stakeholders construct and make sense of water sustainability in their everyday professional and community contexts. A systems-level perspective guides the analysis, recognising that water governance in urban areas involves multiple interacting actors, institutions, and pressures that cannot be understood in isolation.

2.1 Study Area

Parramatta is a rapidly expanding urban hub situated at the heart of Sydney's metropolitan area. This emerging satellite city lies 24 km from Sydney's Central Business District (CBD) and uniquely balances development with conservation of its natural landscapes (Rauscher and Momtaz 2017). As Australia's second-oldest city, Parramatta has roots dating back to the Dharug people. The name 'Parramatta' comes from the Aboriginal word 'Burramatta,' meaning 'place where the eels lie down' in the Dharug language (City of Parramatta 2024). The study area is shown in Fig. 1, and the Parramatta River is the city's main waterway, draining a 266 km² catchment and connecting to 65 km of creeks and tributaries that support many habitats and ecosystems. Parramatta also has 13.4 km of open channel waterways. Its current population exceeds 245,000 and is projected to reach 400,000 by 2036, a 60% increase.

2.2 Research Design and Stakeholder Background

Key informants were identified through a systematic outreach process as follows. Formal interview invitations were sent to all major water-related government departments, utilities, community organisations, and environmental groups operating in the Parramatta region and across relevant NSW agencies. This approach ensured structural coverage of the governance landscape rather than arbitrary selection. A total of 49 key informants were contacted via email, with regular follow-ups. Once most relevant organisations had been reached, the invitation process ended. However, of the twenty-four who responded, some were unavailable. Consequently, the final sample (n = 15), as shown in Table 1, was selected based on relevance, availability, and willingness to participate. The present study sample of 15 is consistent with established precedent in qualitative governance research, where purposively selected samples of 9–20 specialised participants are widely considered sufficient to generate meaningful analytical depth, as mentioned in relevant studies (Hennink and Kaiser 2022; Malterud et al. 2016; Palinkas et al. 2015; Robinson 2014). All participants were properly informed and provided written consent in accordance with ethical guidelines before interviews commenced. Although the lead researcher had professional connections within the broader water sector, these were primarily outside the Parramatta region, and the researcher was relatively new to the local governance landscape. In this context, professional familiarity helped identify relevant organisations and initial contacts, while the risk of interpretive bias towards a specific local narrative remained limited. To manage the interpretive dimension of familiarity, four strategies were employed: (1) invitations were issued broadly across all relevant sectors rather than selectively through known contacts; (2) transcripts were anonymised before analysis; (3) themes were developed through systematic, repeated review of the full dataset rather than from prior assumptions, and (4) the thematic framework was independently reviewed by the supervisory team. As a result, the diversity of stakeholder perspectives ultimately captured, from senior government officials to community volunteers, supports confidence in the breadth of the findings.

Table 1
Demographic and professional background of key informants participating in the study (*n* = 15)

Age Range	Number of Participants	Male	Female	Education Level	Occupational Category	Experience Range (Years)	Share (%)
20s – 30s	2	1	1	Undergraduate(2)	Environmental / Technical Professionals	3–7 years	13.3%
30s – 40s	2	1	1	Undergraduate(1), Postgraduate(1)	Community Advocates / Volunteers	8–12 years	13.3%
40s – 50s	2	1	1	Postgraduate(2)	Managerial / Leadership Roles	13–18 years	13.3%
50s – 60s	6	4	2	Undergraduate(1), Postgraduate(4) and Postgraduate Diploma(1)	Environmental / Technical Professionals & Leadership Roles	20–30 years	40.0%
60s – 70s	3	2	1	Undergraduate(3)	Community Advocates / Volunteers	30–40 years	20.0%
Total (*n*)=	15	9	6				100%

The key informants ranged in age from 27 to 66 years, encompassing both early- and senior-career professionals. The majority fall within the 40–60-year-old bracket, indicating a mature professional cohort. The sample reflects a moderate gender balance, ensuring meaningful inclusion of female perspectives in urban sustainability and governance contexts. The key informants are a highly qualified group, with an even split between those holding undergraduate and postgraduate degrees (each 46.7%), and one participant with a postgraduate diploma. Nearly two-thirds hold environmental and leadership roles, while the remainder represent community organisations involved in urban water governance. This diverse composition captures both top-down and bottom-up viewpoints, balancing strategic insights with grassroots observations.

2.3 Data Collection and Analysis

This exploratory research aimed to understand and assess the current state of water sustainability in the urban landscape and to gain deeper insights into perceptions, issues, and challenges within the study region. Interviews were completed over the course of one year (September 2023 to September 2024). Adequate time was allocated for each interview, and the interviewer remained flexible to follow participant-led discussions. Nearly 90% of the interviews were conducted face-to-face, with the remainder conducted via online applications, lasting an average of 45 to 75 minutes. All data collection and analysis were performed with the approval of the Western Sydney University Human Research Ethics Committee (Protocol: H16103).

Interview audio recordings were first transcribed using both the Rev application and manual methods. All transcripts were kept anonymous during analysis. Transcription quality was carefully verified three times using both recorded and manually produced data. Subsequently, this study employed thematic analysis to interpret the interview data, following Braun and Clarke's six-phase framework (Braun and Clarke 2022). Following that, the analysis began with repeated readings of the transcripts to become familiar with the data. Initial codes were generated using both NVivo (15.5.0) software and manual coding, with an Excel spreadsheet used to organise raw responses under preliminary topics. Thematic categories were first developed based on the interview questions and research objectives, covering conceptual understanding, current status, indicators, governance practices, ecosystem conditions, sustainability commitments, issues, challenges, priorities and actions. For reporting, these categories were consolidated into seven broader themes aligned with the study aims. The interview guide was structured around the study's research objectives. Also, this provides a framework for systematically comparing participant responses. Thematic saturation was reached within the scope of the interview guide, with no substantively new themes emerging in the final interviews. This indicated that the sample was sufficient to capture the range of perspectives relevant to the study's aims. Regarding coding consistency, all coded transcripts were manually reviewed by the lead researcher against the full thematic framework. The thematic structure was shared with and reviewed by academic supervisory team members. This is a peer debriefing process that provides an independent check of the coding framework's logic and validity (Lincoln and Guba 1985). While both Excel and NVivo supported data management and organisation, the identification, interpretation,

and refinement of themes was conducted manually through repeated review of interview responses and comparison with the original data. For data visualisation, Excel and RStudio (2026.04.0 + 526) were used.

3. Results

During the interviews, key informants offered a range of perspectives on water sustainability. Each perspective is unique, reflecting their expertise, work, daily experiences, and priorities. Information is organised into several themes to assess the current state of water sustainability, including definitions, current conditions, signs of decline, indicators, communication, Indigenous knowledge, ecosystem health, and understanding of the SDGs. Each theme is detailed and illustrated in the sections below.

3.1 Stakeholder Understandings and Perceptions of Urban Water Sustainability

Water is a complex resource with various stakeholders involved for different purposes, and their understanding varies by profession and use. Supplementary Table S1 captures the different views of water sustainability held by all 15 key informants.

The key informants provided a multidimensional perspective on water sustainability. Figure 2 illustrates the themes that emerged from this topic. Multiple participants defined water sustainability as the long-term availability of clean water for both people and ecosystems. One informant emphasised the importance of maintaining clean, safe, and unpolluted waterways, with particular focus on water quality. Other participants stated that water sustainability is defined by the integrity of natural systems rather than technical efficiency. While some framed sustainability as responsible consumption and resilient use of water resources, particularly in the context of climate variability, community representatives defined sustainability in terms of social connection, fair access, and cultural meaning. Despite contextual differences, most definitions highlight the need to balance human needs with ecological health to ensure future generations have access to viable water resources. Many participants rejected narrow, supply-focused perspectives and instead emphasised an integrated approach. Overall, water sustainability is viewed as a governance principle that combines environmental health, equity, and future security within the catchment. These elements are interconnected and inseparable, consistent with dimensions identified in existing literature (Bai et al. 2022; Dean et al. 2016c; Juwana et al. 2012; Mendes et al. 2021).

Building on these definitions, participants were asked about the current state of water sustainability in the region. The key informants shared mixed opinions about the current state of water sustainability in the Parramatta region, as shown in Supplementary **Fig.** S1. Nearly half the participants felt ambivalent about the situation, recognising improvements, especially in planning, monitoring, and restoration, while also pointing out ongoing environmental and institutional challenges.

In general, participants recognised ongoing restoration programmes and institutional efforts, but remained concerned about worsening water quality, fragmented governance, and the pressure of fast-paced development. One key informant noted:

Impacts are increasing faster than our ability to address them; we're trying to play catch-up while also increasing those demands from population and urban growth

Another participant mentioned:

The current status is not sustainable with our growing population, and we [authorities] are planning accordingly

One senior leader stated that urban water sustainability is 'not a main priority' of government and is 'not well managed' in certain aspects, especially stormwater and waterways, adding:

There was more focus back in the nineties about water sustainability, but not now

Approximately one-fifth of the key informants reported witnessing improvements in the region. One noted:

A lot of good work to improve and make us more sustainable

Another confirmed that pollution in the Parramatta River has been controlled compared to the past, and one commented positively on the water supply aspects:

Doing a lot now for the future to ensure reliable supply

In contrast, several respondents noted that progress in urban water sustainability is slow and not keeping pace with rising pressures. They cited ageing infrastructure and rapid development outpacing upgrades as the main reasons, and described current strategies as insufficient to protect sensitive species such as the platypus. A community advocate expressed:

Fragmented, a lot of people working really hard in different catchments to fix it, but lacking coordination and consistent progress

Two informants pointed out:

I do not know the current status; I don't think any data is there to show the current status

In summary, although awareness and initiatives are growing, water sustainability in the Parramatta region has not yet met expectations. Governance was a recurring theme, often described as *"historically siloed and reactive, though slowly moving toward integration"*. Several informants used the term 'fragmented' to describe current governance and emphasised the need for more holistic, catchment-wide planning, consistent with findings from similar studies (Rijke et al. 2013; Tawfik and Chesterfield 2020). Supplementary **Fig. S2** illustrates the key factors influencing current water sustainability discussed in this context.

Furthermore, key informants also identified several observable signs of declining water sustainability in the region. Water quality and the health of waterways were identified as the most apparent signs by nearly all respondents, who reported visible deterioration, including pollution, foul odours, and discolouration, especially after storm events. Nutrient loads and sedimentation from construction sites were cited as worsening factors. One key informant described:

Erosion, undercutting of banks, weed infestation, loss of riparian habitat, algal blooms, visible litter, and odour in local creeks

Another highlighted:

Fish developing lesions (red spot disease) from poor fresh flow, turbid creeks carrying sediment after land clearing, or faecal contamination spikes after sewer overflows

Urban runoff and stormwater impacts were another pressing issue. Participants confirmed that heavy rainfall carries debris and oil directly into the river, and several informants observed large amounts of litter in waterways, including plastics and even derelict boats, after flood events. The declining flora and fauna were also identified as clear warning signs:

We don't see frogs or native vegetation around the creeks anymore

Key informants expressed concern about the decreased water availability during droughts and increased flow during floods, aggravated by climate change. Participants also noted that ageing infrastructure is a visible sign, with one informant stating:

The system is overcapacity; too much runoff and not enough treatment

Governance gaps and community neglect were further identified, with one respondent noting: *"Policy appears effective on paper but is poorly enforced"*. Participants also pointed to public littering and ignorance about stormwater drains as social indicators of decline. These signs are consistent with findings reported in studies on urban water challenges (Coles et al. 2012; McGrane 2016).

3.2 Indicators, Assessment Frameworks and the Need for Integrated Monitoring

Key informants identified four main categories of indicators used to assess water sustainability, as shown in Supplementary **Fig.** S3. Almost all participants mentioned water quality parameters, including pH, turbidity, nutrient levels (nitrate and phosphate), and contamination, as tangible measures of sustainability (ANZECC 2000). Most also highlighted the significance of recreational safety, specifically, whether a river is suitable for swimming, assessed using National Health and Medical Research Council (NHMRC) guidelines.

Water-use metrics were the second most commonly cited indicators. Participants noted the need for a proper data measurement system, including tracking per-household water consumption, per capita water usage, and the breakdown of water sources (potable use, recycled water usage, and alternative water use). A group of key informants emphasised flow, rainfall, and storage capacity as important physical metrics (Damkjaer and Taylor 2017), noting that:

Flow levels and seasonal water availability tell us whether systems are sustainable

Key informants also highlighted biodiversity monitoring, including macroinvertebrate surveys, riparian vegetation assessments, and indicators of creek and wetland health, as important ecological measures. One noted: *"Biodiversity around creeks is the first sign of improvement or decline"*. Participants also referenced reuse rates, leak reduction, and stormwater infrastructure performance as technical indicators. The efficiency of these interventions is considered a vital indicator of water sustainability (Turak and Bickel 1994).

Governance and institutional indicators were also highlighted (Pires et al. 2017), along with public participation activities such as Streamwatch, education programmes, and awareness levels as qualitative measures. One key informant concluded:

Different aspects require different metrics, and the challenge is they are often fragmented: people will be measuring different things for different reasons, they might not be using the same metrics or assessment models, which complicates creating a clear overall assessment

In summary, respondents proposed a basket of indicators capturing different aspects of water sustainability, with biophysical and water-use indicators most commonly used, followed by technical, institutional, sociocultural, and economic indicators. Despite this range, participants acknowledged that no single metric captures sustainability as a whole (Juwana et al. 2012).

Regarding assessment frameworks, key informants identified nine different approaches used in practice, as shown in Supplementary **Fig**. S4. Many participants indicated they had not personally used a formal assessment framework, admitting they are

not really familiar with specific frameworks that are uniformly applied in practice

Several environmental and technical professionals mentioned the Water-Sensitive Cities framework, which provides a comprehensive index for evaluating water management across multiple objectives, economic, community, and environmental. One informant clarified that the framework is adopted into their strategy to guide actions rather than as a fixed assessment tool. Other frameworks mentioned included Integrated Water Resources Management (IWRM) and Catchment Management approaches, described as conceptually influential yet unevenly integrated in practice due to institutional fragmentation. Emerging frameworks such as ecosystem services, natural capital, and community-based monitoring were also recognised.

Utility-focused informants explained that they use their own strategies. One informant mentioned *'supply-demand modelling'*, which projects population growth against reservoir capacity, providing a basic framework for assessing water supply sustainability. Furthermore, key informants at the planning level referenced structured approaches, such as land-use planning, development control plans (DCPs), and stormwater management guidelines, as a de facto framework. A group of community advocates mentioned they are *"not really familiar with specific frameworks, only news mentions of water quality assessments by government bodies"*. This suggests that formal assessment frameworks have not become widespread at the community level, noting:

We haven't used any specific framework; there's no peak body promoting a standard approach

In summary, various frameworks are discussed for assessing water sustainability, but no single, universally accepted framework exists in the region to understand the current status. However, key informants rely on a combination of indicator monitoring, planning guidelines, and emerging tools such as the Water Sensitive Cities index to evaluate aspects of water sustainability.

Key informants called for more usable assessment approaches, as illustrated in Supplementary **Fig.** S5. Several key informants highlighted the need for a systems thinking approach. Further, they mentioned that the system approach should integrate both top-down and bottom-up knowledge and capture the whole urban water system, including its physical and human dimensions, rather than siloed components. Participants called for moving beyond the current *"engineering and pollution-centric focus to include social, cultural, and value aspects in assessments"*.

Many community advocates emphasised the importance of data collection from trusted sources and called for community-based monitoring to complement government data. Key informants highlighted governance fragmentation as a major challenge, suggesting the need for enhanced assessment protocols and clearly defined roles and shared metrics among councils, utilities, and state agencies. They also suggested conducting *'policy gap analyses'* to identify where existing regulations are lacking, and called for assessment tools that are *'easy and widely applicable'*. Participants also recommended incorporating predictive modelling using

climate models and rainfall patterns, rather than relying solely on historical data. These recommendations reinforce the findings of Juwana et al. (2012). As one participant summarised:

"Having that clear definition and clear purpose for assessment makes sure we get clear, purposeful monitoring and reporting".

3.3 Communication, Indigenous Knowledge and Community Engagement

Key informants identified communication as a critical but underperforming dimension of water sustainability governance. Supplementary Table S2 presents the full details of the analysis, including participant quotes and effective communication platforms in urban landscapes. In the context of Parramatta, effective communication of water sustainability is perceived as a multilayered process that combines local engagement, digital visibility, and institutional collaboration. Community engagement events and digital platforms are the most common communication methods, followed by collaborative forums and education programmes. Traditional media and citizen science initiatives remain active but secondary modes, while cultural storytelling and policy briefs represent emerging specialised forms.

The effectiveness of current communication strategies is mixed. Key informants noted that communication tends to focus primarily on specific issues, such as water supply during droughts, while environmental water needs receive less attention. One informant noted: *"We have quite good water literacy in Sydney regarding water restrictions; that's understood and accepted"*. However, another added: *"I don't think we do well on the environmental water side; many stakeholders lack information on issues such as river health and flooding".*

Also, the key informants noted, *"Students and politicians, they really like the facts, numbers, and statistics"*, indicating that presenting complex data and progress indicators in an accessible way is important for these groups. Therefore, publishing clear metrics, such as how many megalitres are recycled and water quality grades at the local, catchment and state levels, can influence policy and academic discussions. They also recognised that visual storytelling, such as graphs, maps, and dashboards, helps make data more understandable to the public.

Key informants emphasised that education is fundamental. Several suggested starting at the school level, noting: *"Having a really good understanding from a school age about the water cycle is important because many people aren't very water literate".* Social media was frequently mentioned as a powerful channel, though some cautioned that misinformation can also spread. Community events like *'River Fest'* and site tours to water treatment facilities were highlighted as valuable for making sustainability tangible and relatable. One senior leader summarised:

So many distractions to get the community is a challenge, particularly in urban space, and people just turn the tap on, water is cheap and abundant, so not much pressure to engage until something happens

Key Informants also noted that multicultural communities may have other pressing priorities, particularly recent immigrants, emphasising the need for sustained, long-term campaigns and 'soft power' approaches such as rebates for rainwater tanks and water-saving workshops. A related challenge concerns the integration of Indigenous knowledge, another form of water knowledge that remains underrepresented in current governance frameworks.

In the Australian context, Indigenous knowledge, as a distinctive form of social learning, plays a crucial role in ensuring sustainable water management (Ayre and Mackenzie 2013). Both Western scientific understandings and Indigenous knowledge are vital for effective water management (Stefanelli et al. 2017). There was strong agreement among informants that traditional knowledge is valuable and should be integrated, though some acknowledged practical challenges. The themes that emerged are illustrated in Supplementary **Fig.** S6. Most respondents emphasised cultural recognition as the foundation of integration, going beyond token acknowledgment to call for the spiritual, historical, and ethical inclusion of Indigenous values in water governance, reflecting a transition from *'consultation' to relational inclusion'.* One key informant stated:

"We need to genuinely respect Indigenous relationships with Country and not treat it as symbolic"

Several respondents recognised the practical ecological knowledge of traditional custodians embedded in the management of wetlands, riparian zones, and seasonal cycles. They advocated for a common platform for Traditional Ecological Knowledge (TEK). Many interviewees called for formalised co-governance structures that share responsibility between councils, agencies, and Indigenous groups. One key informant noted that incorporating diverse knowledge systems is key:

"It is important to value the Indigenous knowledge, of course, we should, but also to incorporate the values of all the multicultural societies living here in our region".

Current challenges include the fragmented and historically displaced status of Sydney's Indigenous groups, making it *'hard to know which groups to talk with and how'*. There are also capacity constraints at the council level. Participants also acknowledged that while Indigenous knowledge will not resolve all challenges, its core principles need to be embedded in water governance (Thompson et al. 2024).

3.4 Ecosystem Condition and Future Risks

The clear majority of participants perceive water-related ecosystems in Parramatta as poor, degraded, or non-sustainable, as shown in Supplementary **Fig.** S7 (DPIE 2020). Only a small minority view conditions as improving or reasonably good, with just over a quarter describing mixed conditions. One key informant stated:

Urban creeks are heavily polluted and degraded; water quality is poor

Common issues included habitat loss (e.g., platypus no longer present in some streams), concreted channels with limited ecological function, and continual stress from sewer overflows and stormwater. Participants described how Western Sydney creeks that were once pristine now face massive amounts of development, leaving only semi-functional wetland remnants. These impacts have historical precedents, such as the destruction of large wetland and mangrove systems at Sydney Olympic Park during 20th-century industrial activities, which were only partially rehabilitated for the 2000 Olympics.

Despite these difficulties, key informants acknowledged meaningful restoration action. Wetland restoration along the Parramatta River was noted as producing positive results, though the overall outlook remains cautious:

We're taking it from a low base, and it's getting better, momentum is in the right direction, even if people argue it's too slow

Constraints on space for new green and blue habitats in the built environment were identified as a key ongoing challenge. In summary, the water-related ecosystems are under significant stress, but current initiatives, including stormwater treatment, wetland restoration, and stricter regulations, are beginning to show localised results. Participants were also asked to consider the potential consequences if these conditions continue to decline over the next 5 to 30 years. Furthermore, the themes and supporting quotes are presented in Supplementary Table S3.

Alongside the consequences mentioned in the table, some key informants offered a more hopeful perspective, suggesting that *"if we can slow down or reverse the deterioration, these severe outcomes might be prevented"*. One key informant was particularly optimistic, believing that momentum is heading in the right direction and that *"if good practices continue, you'll have a healthier river"*. However, key informants recognised the critics who say progress is too slow and that more resources should be allocated now to accelerate improvements. This clearly indicates that, although adverse outcomes are not guaranteed, the window for action is closing; otherwise, in a decade, the problems will become more costly and harder to address (Grafton et al. 2025). Their future-focused responses strengthen the case for taking proactive measures today, framing sustainability not as an abstract ideal but as something that directly impacts the quality of life in the Parramatta region.

3.5 Localising the SDGs in Urban Water Governance

Key informants were asked about their understanding of SDGs 6, 11, and 15, as well as the commitments they would make to support them. These three SDGs were deliberately chosen for their alignment with the study's aims. Supplementary Table S4 presents participants' levels of understanding of the SDGs. The responses display varying levels of familiarity with the SDGs. More than 70% of participants had a basic-to-deep understanding of sustainability as reflected through the SDG lens. Participants in strategic roles were aware of the SDGs and their relevance, describing them as *'great goals and targets'* and emphasising the need to integrate global goals with local action. One key informant provided a concrete perspective, noting that their council's strategy involves taking locally specific actions aligned with our vision and then comparing these actions with the global goals.' In practice, this informant noted *that "Parramatta has almost 100% access to drinking water and sanitation, meeting core SDG 6 targets"*, a finding consistent with the Australian Infrastructure Audit (Infrastructure Australia 2019).

At the community or operational level, several informants were less familiar with the SDGs by name, though they often naturally addressed those themes in their work. For example, one informant working to reduce pollution and improve water reuse was

effectively promoting SDG 6 without labelling it as such. No interviewees described specific institutional or personal commitments to the SDGs beyond continuing current projects. Participants noted that the SDGs have not yet been sufficiently localised into actionable targets at the city scale, limiting direct pledges. These statements highlight the importance of the SDGs while also revealing a gap in practical application at the local level. At the personal level, most commitments were modest; one participant honestly admitted they needed to *"go read about the goals again"* to consider them more explicitly in their work. This demonstrates an openness to using the SDGs as a checklist for personal and professional practices. They also considered their institutional commitments set out in policy and planning, ensuring that new developments and major projects align with sustainability goals and incorporate SDG principles into the city strategy.

In summary, all respondents, even if unfamiliar with specific SDG numbers, expressed support for the principles of global sustainability goals. There is a general desire for access to clean water, sustainable cities, and healthy terrestrial ecosystems. However, the interviews reveal limited direct engagement and awareness of the UN SDG framework at the individual and institutional levels. A few participants mentioned, *"We are already working on initiatives that align with those goals, even if we do not label them as SDG efforts"*. There is an opportunity to increase awareness and translate SDG targets into local government and community actions, which could inspire more coordinated commitments. Currently, participants noted that their organisations, such as councils, state departments, utilities, and catchment groups, are beginning to recognise these global goals and aspire to achieve them. However, most responses did not show concrete commitments, such as setting SDG targets or monitoring SDG indicators. The primary focus has been on advocacy, education, and the implementation of best practices in water sustainability. This area offers growth potential, ensuring that Parramatta's urban water efforts explicitly support global sustainability standards and that stakeholders understand how their actions relate to the SDGs.

3.6 Human Pressures on Urban Water Sustainability

To examine current issues, challenges, factors, and actions related to water sustainability, insights were gathered from key informants across the urban landscape. This section focuses on identifying major human activities and governance issues affecting water sustainability in the Parramatta region, as well as stakeholder priorities and the specific actions they believe are necessary to achieve sustainable outcomes.

Key informants expressed a strong consensus that multiple intersecting pressures are shaping water sustainability. One participant stated:

Everything from development to climate to pollution is putting pressure on the waterways; we're stretching the system too far

Urban development is identified as the most influential pressure, with strong connections to both the Stormwater Pathway and the Habitat Pathway. One key informant stated:

Continuous construction, hard surfaces affect the whole catchment and remove the ecosystem services

Climate variability affects both the Stormwater and Habitat pathways, representing the combined effects of heavy rainfall, flooding, and drying cycles on systems already under stress. Governance gaps and infrastructure strain were identified as additional shared pressures, with participants expressing concerns about fragmented responsibilities, ageing assets, and limited system capacity:

Different departments not coordinating well; slow, sometimes unclear policy responses to emerging issues

Community behaviour, population growth, and environmental degradation were also emphasised as contributing pressures. Published literature supports these findings (Infrastructure NSW 2012; Pinto et al. 2024; Williams et al. 2019). Key human activities driving these pressures are shown in Supplementary **Fig.** S8.

Urban development was identified as the dominant human activity, not simply as an increase in buildings, but as a transformative force that reconfigures the natural hydrological system. The second most commonly cited activity was sediment and siltation generated by construction, with excavation, clearing, and earthworks identified as major contributors to sediment-laden runoff entering creeks and stormwater networks. Stormwater was described as the key mechanism linking human activity with water degradation, acting as a conveyor of rubbish, household chemicals, detergents, animal waste, oils, and microplastics. Community behaviour was identified as an important but often-overlooked contributor:

People don't understand how their actions affect water

Other notable themes included land-use change, ageing stormwater systems, insufficient sediment controls around construction sites, and commercial activities from small businesses.

3.7 Current Initiatives, Collaboration and Management Priorities

Key informants identified a wide range of current initiatives, including ecological restoration, pollution control, public awareness campaigns, water efficiency and reuse, governance reforms, regulation, monitoring and citizen science. These initiatives show that substantial activity is already underway, although participants repeatedly noted that efforts remain fragmented, unevenly evaluated and insufficient at the system scale.

Several participants emphasised the role of on-the-ground environmental actions, which have accounted for the majority of actions taken in this area. Particularly in enhancing riparian health, stabilising creek banks, and restoring ecological function. These activities represent some of the most visible and community-engaged initiatives. In addition, riparian protection was repeatedly described as highly effective, with one participant explaining:

Fencing cattle out of riparian areas is the cheapest, most impactful thing we can do, and even better when paired with native tree planting

Sewer treatment upgrades, stormwater management, and catchment-focused interventions were identified as the second-most-impactful set of actions. Sediment and erosion management has also become a priority, with 27 councils working on sediment control. The stormwater levy, charging $25 per household, was highlighted as a key funding mechanism for water-quality improvements.

Campaigns have become a significant third category, showing increased efforts to promote water sustainability. This reflects initiatives to engage the wider community and improve awareness of catchment processes. One participant noted that the three primary campaigns, *'Get the Site Right*', *'Love Your Waterways'*, and *'Rain is Only for the Drain'*, focus on how everyday actions impact rivers. Participants observed that these campaigns seek to connect people both emotionally and practically to their waterways.

Participants highlighted that significant investments in water efficiency and diversification of water supply are underway. All council buildings have water-efficient fixtures and rainwater harvesting, and new developments must install rainwater tanks. Additionally, a group of informants emphasised that new initiatives, especially in purified recycled water and community education on recycled water, should be pursued soon. They also highlighted the Purified Recycled Water Discovery Centre at Quakers Hill, which helps demonstrate to the different stakeholders what recycled water is. It also functions as an important tool and is essential for steadily developing acceptance. Most notably, respondents also observed that acceptance is slowly increasing. They mentioned that *"Purified recycled water for drinking is probably in the future, we're on that journey, but it takes time"*. Overall, these initiatives reflect a long-term commitment to diversifying the city's water resources. Behavioural initiatives are considered crucial, though measuring their impact remains difficult. Key informants also said that household behaviour and awareness are essential for long-term sustainability.

Several participants referred to governance reforms, regulatory models, and planning-based initiatives as essential components of effective water management. Most participants highlighted many governance-based initiatives that worked well, but also noted the challenges. One key informant mentioned that the Victorian governance model was admired as a good example for governance. The informant also stated that NSW should consider adopting a similar approach. Another participant said further, *"They have a really strong regulator in the Victorian EPA and clear roles and responsibilities"*. In addition, the council-based key informants discussed local planning and its support for positive environmental outcomes. They referenced their Development Control Plan (DCP), stating, *"We've introduced controls through our DCP, but there's no evaluation yet to show how effective they've been"*. Additionally, some key informants from the water utilities emphasised that their integrated strategy emphasises long-term planning alignment. As they stated, *"we're implementing an integrated water security and ecosystem health strategy with some wins and some actions still unfunded"*. Overall, these perspectives show that while there have been successes, strong institutions and clear regulations are still needed to maintain positive results.

Monitoring projects play a key role in gathering data for management decisions. Participants pointed to both citizen-science efforts and official government reporting systems. Many informants emphasised the value of having Streamwatch groups at the catchment or sub-catchment level. One participant explained that being involved in *"Streamwatch and reporting local environmental incidents demonstrates grassroots vigilance"*. However, senior-level informants questioned data quality, with one noting: *"It's collecting data, but we aren't sure how effective it is yet"*. Overall, while monitoring is extensive, it should be structured as a more meaningful, coordinated,

community-driven, and institutional process. While many local initiatives and successes were identified, participants noted recurring gaps in systemic monitoring, institutional alignment, and resourcing. The most effective initiatives appear to be those that combine community involvement, clear governance, and practical on-ground environmental action.

Short, Medium, and Long-Term Actions:

Short-term actions focused on stabilising current problems, including repairing leaking pipes, addressing sewer-stormwater cross-connections, improving creek maintenance, reducing bureaucratic delays, strengthening monitoring and improving community water literacy. Medium-term actions focused on system integration, including stronger inter-agency collaboration, clearer roles and responsibilities, improved planning controls, greater use of recycled water, investment in blue-green infrastructure and upgrades to stormwater systems. Long-term actions focused on institutional and cultural change, including stable catchment-scale governance, planning beyond election cycles, wider acceptance of purified recycled water, ecosystem restoration, stronger partnerships across agencies and a deeper community understanding of the value of urban water.

Stakeholder Collaboration:

Participants emphasised that no single organisation can improve water sustainability alone. Effective action requires coordinated roles for community groups, local councils, catchment organisations, environmental groups, state government departments, Sydney Water, businesses and industry. Community groups were viewed as important for education, local ownership and behavioural change, while councils and catchment groups were seen as key connectors between local action and broader governance structures.

Community action was recognised as the broadest and most influential force across nearly all themes. Participants emphasised education, water literacy, ownership, multicultural sensitivity, and inclusivity. One participant stated:

If they think about the waterway as something that belongs to them, then they really care about the environment

Local councils are the primary driver of environmental actions at the regional level, while catchment groups serve as connectors, filling coordination gaps. The state government and Sydney Water align heavily with governance, technical guidance, regulation, and incentives. Key informants expressed high expectations for the state government to provide clearer roles and a more effective governance platform. Participants also emphasised the need to include business and industry as partners rather than adversaries:

You don't have to treat business like the enemy; if you get people on side, they can operate more efficiently with less impact

In essence, improving Parramatta's water sustainability requires a whole-of-system, collaborative architecture that integrates each stakeholder's strengths into a coherent model of shared responsibility, long-term planning, and collective impact.

Sufficiency of Current Actions:

Despite recognising a range of positive initiatives, most participants considered current actions insufficient to address the scale of urban water sustainability challenges. As shown in Fig. 4, nine out of fifteen participants viewed existing measures as inadequate, poorly coordinated or misaligned with long-term sustainability outcomes.

Participants attributed this insufficiency to persistent governance challenges, limited funding, weak policy enforcement and ageing infrastructure. One participant stated: *"There is a lack of regulation and coordination, and stormwater and waterways are not well managed"*. Another noted: *"An insanely small amount is spent on environmental restoration; most money goes to planning instead of doing"*. Overall, the dominant view was that current actions remain fragmented, reactive and inadequate for the scale of change required.

Responsibility was viewed as shared (53.3%) across the different stakeholders. Specifically, the state government was most frequently named (40%) for its control over legislation and regulation, while councils (33%), Sydney Water (27%), and the community (26%) were all identified as essential actors, as shown in Fig. 5.

Current Research Priorities

Key informants identified seven broad research priority areas: stormwater and non-point pollution, natural area and habitat health, governance and collaboration, community behaviour and social acceptance, water supply and reuse, infrastructure condition, and

economics, valuation and equity. These priorities span biophysical, institutional, behavioural, infrastructural and economic dimensions, reinforcing the need for integrated and cross-sectoral research. Supplementary Table S5 provides the full set of themes, participant codes and disciplinary scope.

4. Discussion

This study examined urban water sustainability through the perspectives of 15 key informants in the Parramatta region of the Sydney Basin. The findings provide a multidimensional account of how practitioners, community advocates and institutional leaders understand, experience and seek to address water sustainability challenges. Three findings are particularly significant. First, governance fragmentation, rather than lack of knowledge or commitment, emerged as the primary structural barrier to integrated water management. Second, many stakeholders are already undertaking SDG-aligned work without formal SDG recognition or reporting, suggesting a labelling gap rather than a practice gap. Third, Indigenous and community knowledge is widely acknowledged as important, but remains outside the formal evidence base for water management decisions. Together, these findings point to the need for a more integrated, inclusive and long-term approach to urban water governance.

4.1 Understanding Water Sustainability: Beyond Technical Definitions

A central finding of this study is that key informants consistently defined water sustainability in holistic, multidimensional terms. Their definitions encompass ecological health, equitable access, cultural meaning, and long-term governance rather than in purely technical or supply-focused terms. This mirrors conceptual frameworks identified in the broader literature that emphasise the integration of environmental, social, and economic dimensions (Crespo et al. 2022; Di Vaio et al. 2021; Juwana et al. 2010; McIlwain et al. 2023). Most participants explicitly rejected supply-centric narratives, aligning with the argument that urban water sustainability requires moving beyond engineering-focused problem-solving towards a systems-level understanding of water's role in society (Brown et al. 2009; Hurlimann et al. 2017).

This convergence is notable given the diversity of stakeholder roles. Whether from government utilities, councils, or community organisations, participants shared a broadly integrated understanding of sustainability. Such cross-sectoral alignment builds adaptive capacity through shared knowledge systems (Almazán-Casali et al. 2021; Pollard et al. 2023). This clearly suggests that, at least at the conceptual level, there is a foundation of shared purpose on which more coordinated action could be built.

4.2 Governance Fragmentation as a Persistent Barrier

The most consistent finding across all stakeholder groups was governance fragmentation. Participants repeatedly described the current governance landscape as 'siloed,' 'reactive,' and characterised by unclear responsibilities across councils, utilities, state agencies and catchment groups. This reflects a well-documented tension in polycentric and multilevel governance systems, where decentralised actors with different mandates and priorities can struggle to coordinate effectively (Avazpour et al. 2023; Ostrom 1990; Pahl-Wostl 2009). Similar barriers have been reported in urban water governance, including poor alignment between local, state and federal water strategies and structural mismatches between planning frameworks and catchment-scale management needs (Van de Meene et al. 2016)

Notably, however, the perspectives of different stakeholder groups diverged on who bears primary responsibility for this fragmentation. State government employees and senior utility staff tended to attribute coordination gaps to the complexity of multi-agency responsibilities and resource constraints. At the same time, community advocates were more likely to frame fragmentation as a failure of political prioritisation. This divergence in causal framing reflects a well-documented pattern in governance research, in which actors at different levels of a system tend to attribute coordination failures to different causes. This reflects structural complexity at the institutional level and political will at the community level (Rijke et al. 2013; Van de Meene et al. 2016). Addressing fragmentation will therefore require not only structural reform, such as the co-governance models admired in Victoria, but also deliberate efforts to align different stakeholders' perceptions of responsibility.

4.3 Human Pressures and Ecosystem Decline

Urban development, stormwater pollution, sediment loading, and infrastructure ageing emerged as the dominant human pressures on water sustainability in the Parramatta region, findings consistent with broader urban hydrology literature (Coles et al. 2012; Ferdowsi et al. 2024; McGrane 2016; Paton and Haacke 2021; Urrutiaguer 2016). Participants described these pressures not as separate issues but as deeply interconnected, supporting Pinto et al.'s (2024) argument that deterioration in urban river health results from cascading

interactions among land-use change, infrastructure limitations, and governance failures. This can be seen in Sydney catchments, where increased impervious surfaces increase pollutant runoff and erosion by altering how water moves through the area (Coombes and Roso 2019).

Participants also described ecosystem deterioration through habitat loss, declining biodiversity and the disappearance of sensitive indicator species such as the platypus. These observations are consistent with NSW estuary water quality data (DPIE 2020) and the Parramatta River governance review (Davies et al. 2017). The forecasted consequences identified in this study, summarised in Supplementary Table S3, include flooding, erosion, health impacts and cultural loss, which align with broader projections for urban catchments under climate change (Das et al. 2024; Grafton et al. 2025).

4.4 Indicators, Frameworks, and the Need for Integration

The indicator landscape identified by participants was broad, encompassing biophysical, technical, institutional, sociocultural, and economic dimensions. However, a recurring concern was the fragmented application of these indicators across different agencies and purposes. This sectoral silos challenge is compounded by inconsistent weighting/aggregation methods (Pires et al. 2017). This observation aligns with Juwana et al. (2012), who reported that no single comprehensive indicator framework currently exists for urban water sustainability.

The Water Sensitive Cities Index (Rogers et al. 2020) was the most widely recognised formal framework among participants, though its uptake was uneven. Community-level informants were largely unfamiliar with formal frameworks, suggesting that assessment tools have not effectively reached beyond technical practitioners. This awareness gap hinders inclusive monitoring, mirroring participatory barriers in urban water transitions (Wong and Brown 2009). This finding has important implications for participatory governance: if communities and frontline advocates do not share the same evaluative language as institutions, collaborative decision-making becomes more difficult. Participants' calls for systems-thinking-based approaches, collaborative monitoring, and predictive modelling align with the transdisciplinary direction advocated by Zuniga-Teran et al. (2022) and Webster et al. (2025).

4.5 Communication, Indigenous Knowledge, and Community Engagement

Communication emerged as a key lever for advancing water sustainability. Key informants across all groups emphasised the importance of tailored, multilayered communication strategies that reach diverse community segments, from schoolchildren to multicultural communities to policymakers. These findings are consistent with Dean et al. (2016a); Dean et al. (2016b), who found that community knowledge about water is highly uneven and that targeted engagement strategies are essential for improving water literacy and behaviour change.

There is a strong consensus around the importance of integrating Indigenous and Traditional Ecological Knowledge (TEK). This clearly reflects a broader shift in Australian water governance discourse towards relational inclusion and co-governance (Ayre and Mackenzie 2013; Stefanelli et al. 2017). However, participants observed that current co-governance arrangements are frequently ad hoc rather than formalised, and that limited capacity constrains meaningful engagement. These findings are consistent with Thompson et al. (2024), who argue that genuine Indigenous integration in water management requires institutional commitment beyond symbolic consultation. This is seen in Victorian models, but uneven nationally (Jackson et al. 2014). The additional call by one participant to also incorporate the values of multicultural communities reflects the specific social complexity of the Parramatta region, which adds a dimension not always foregrounded in Indigenous water governance literature.

4.6 SDG Alignment: From Aspiration to Action

The SDG findings reveal a nuanced picture that goes beyond a simple gap between aspiration and practice. Most participants expressed genuine support for the principles underlying SDGs 6, 11, and 15, but the majority lacked detailed knowledge of specific targets or mechanisms for local implementation. This pattern is consistent with documented challenges in Australian cities, where SDG awareness tends to remain concentrated among technical and planning professionals rather than being embedded across governance levels and community groups (Biermann et al. 2017; Ningrum et al. 2024). However, the more significant finding is not the awareness gap itself, it is what lies beneath it. Many participants were actively engaged in work that directly advances SDG targets, yet they did not use SDG language or frameworks to describe it. This suggests that SDG progress in cities like Parramatta may be systematically underreported, and that the disconnect between global commitments and city-level action (Grafton et al. 2025) is at least partly a labelling problem rather than a practice problem.

On the positive side, Parramatta has almost universal access to drinking water and sanitation, meeting a core SDG 6 target, consistent with the Australian Infrastructure Audit (Infrastructure Australia 2019). Nevertheless, participants identified gaps in other SDG-related areas, particularly ecosystem health (SDG 15), emerging contaminants such as PFAS (SDG 6.3), and equitable access to green and blue spaces (SDG 11). These gaps point to areas where stronger governance and dedicated resourcing are needed. A key opportunity is to translate implicit SDG-aligned practice into explicit local commitments. Informants noted that the SDGs have not yet been translated into actionable city-scale targets, leaving governance actors without a clear framework for connecting existing project work to global goals. Making these connections explicit through local SDG mapping, accessible reporting tools, and clearer communication between councils and community groups could strengthen accountability, motivate further action and provide stakeholders with a shared language for describing progress. This approach aligns with broader calls to localise SDG indicators in ways that translate global objectives into city-scale strategies (Grafton et al. 2025; Sánchez-Rivero et al. 2023).

4.7 Towards Integrated Urban Water Governance: A Synthesised Perspective

Taken together, the findings show that urban water sustainability in Parramatta is constrained less by a lack of technical knowledge than by structural and institutional conditions that limit coordinated action. Governance fragmentation, uneven knowledge systems, short political time horizons and limited community participation are interconnected features of a system that does not yet treat water holistically. Addressing these challenges requires a clearer distribution of responsibility, knowledge and authority across the urban water governance system. Four priorities emerge from the evidence.

The study indicates that governance reform is the most urgent priority. Across all stakeholder groups in this study, governance fragmentation was the single most consistent finding. Participants described responsibilities as divided, reactive, and poorly coordinated across councils, state agencies, utilities, and catchment groups. This is not a new observation in the literature (Rijke et al. 2013; Tawfik and Chesterfield 2020), but this study adds important local detail: in Parramatta, fragmentation is experienced differently depending on where a stakeholder sits. Community advocates frame it as a failure of political will, while institutional actors attribute it to resource constraints and structural complexity. Any governance reform must therefore address both the structural design, moving towards a unified framework that treats water as a single interconnected system, and the cultural dimensions of how different actors understand their own roles and responsibilities. The Victorian governance model, cited approvingly by several participants, offers one reference point, though direct transfer would require adaptation to NSW's specific institutional context.

Knowledge integration across scales is a second priority. This study found that the gap between technical assessments and community understanding is not simply a communication problem; it reflects bigger differences in how water sustainability is framed and valued across stakeholder groups. Community advocates and grassroots organisations consistently offered insights about lived experience, cultural meaning, and local ecological change that are absent from formal planning documents. Similarly, participants' call to formalise Indigenous and multicultural knowledge alongside scientific data reflects the specific social complexity of the Parramatta region, where water has deep cultural significance for both First Nations and diverse migrant communities. Assessment frameworks need to be redesigned to be accessible and meaningful across governance levels, not just to technical professionals.

A third priority is sustained political attention and funding. Participants noted that government priorities are often dominated by immediate pressures such as housing, health, transport and other infrastructure needs, leaving proactive water sustainability planning underfunded and reactive. As one senior leader observed, water sustainability receives attention only 'when something happens'. Moving from reactive to strategic water governance will require sustained commitment, adequate funding and longer planning horizons.

Finally, community engagement must be genuine and inclusive rather than a one-way communication exercise. A notable finding of this study is that community groups and catchment organisations, the actors furthest from formal governance, consistently offered some of the most grounded and actionable insights about local water conditions, behavioural drivers, and cultural connections to waterways. This suggests that current planning processes are not only missing community voices but also a form of knowledge that technical assessments cannot easily replicate. Moving towards co-designed, place-based approaches, where communities help shape priorities rather than simply receive information, is both a governance imperative and a practical necessity for the Parramatta region.

Together, these four priorities show that integrated urban water governance requires action across institutions, knowledge systems, funding priorities and community engagement. The study contributes to the literature by grounding these priorities in the lived

experience and professional judgement of stakeholders directly involved in urban water management.

4.8 Implications for Urban Water Management

Building on the four governance priorities identified above, this section translates the findings into practical implications for water managers, councils, utilities, state agencies and community organisations. This study provides practical implications for urban water management in Parramatta and comparable rapidly growing cities.

First, urban water governance needs to move from fragmented sector-based management towards a catchment-based approach. Participants repeatedly noted that stormwater, waterways, wastewater, drinking water, planning and community engagement are managed by different institutions with limited alignment. A more integrated governance arrangement would clarify responsibilities, reduce duplication and align investment with catchment-scale priorities.

Second, councils, utilities, and state agencies need a shared set of water sustainability indicators that are understandable and usable across technical, policy, and community settings. Current indicators are valuable but fragmented, with different organisations measuring different aspects of water quality, infrastructure, ecosystem condition, water use, and community engagement. A practical indicator framework should combine biophysical measures, such as water quality, flow, biodiversity, and stormwater performance, with governance and social indicators, such as community participation, inter-agency coordination, and public reporting, making sustainability legible across all stakeholder groups.

Third, community and Indigenous knowledge should be treated as part of the evidence base for urban water management, not only as an engagement activity. Local communities often observe changes in creek condition, litter, erosion, habitat loss, and waterway access before these changes become visible in formal reporting systems, offering an early-warning capacity that technical assessments alone cannot provide. Similarly, Indigenous knowledge can strengthen place-based understanding of water, Country, seasonal change, and long-term stewardship. Formal mechanisms are needed to include these forms of knowledge in planning, monitoring, and restoration decisions.

Fourth, local water initiatives should be explicitly linked to the SDGs, particularly SDGs 6, 11, and 15. Many actions identified by participants, including waterway restoration, pollution reduction, recycled water planning, community education, and habitat protection, already support these goals. However, because these links are not always made explicit, local contributions to global sustainability targets may remain invisible. Mapping existing programmes against SDG targets would provide a simple way to improve accountability, strengthen communication, and support more coordinated action.

Finally, the findings suggest that urban water sustainability should be treated as a long-term public investment rather than a reactive response to droughts, floods, or pollution events. Participants recognised that many current actions are positive but insufficient. Stronger institutional leadership, stable funding, transparent monitoring, and sustained community partnerships will be needed if Parramatta is to protect waterway health while accommodating continued urban growth. This requires governance conditions that cannot be met through crisis-driven budget cycles alone, sustained strategic commitment is essential.

Collectively, these five practical implications point to a governance transformation that is structural, epistemic, and cultural in nature. They are grounded directly in the lived experience and professional judgement of practitioners, community advocates, and institutional leaders who engage with urban water sustainability in Parramatta every day. Implementing them will require coordinated effort across councils, state agencies, utilities, and community organisations, but the evidence gathered in this study suggests that the knowledge, willingness, and shared purpose to do so already exists within the region.

4.9 Limitations

This study is limited by its qualitative design and small purposive sample (n = 15) within a single urban region. The study focuses specifically on the Parramatta region, which has its own historical, institutional, and environmental context. As a result, the findings may not be directly transferable to other urban regions with different governance structures or environmental conditions. Although the sample was diverse and included a range of stakeholder roles, the findings may not be fully generalisable to other urban water governance contexts. Involving a diverse range of key informants who engage with the water sector is challenging due to availability, departmental guidelines, and other constraints. Potential interviewer familiarity bias was described in section 2.2 and mitigated through the four strategies, but it cannot be entirely eliminated. The research relies on qualitative interview data that capture perceptions and experiences rather than direct measurements of water sustainability indicators. Although these perspectives provide

valuable insights into governance processes and stakeholder priorities, they should be interpreted alongside biophysical and technical assessments of water systems. Moreover, some stakeholders indicated that reliable monitoring data on certain aspects of water sustainability remain limited or fragmented. This constraint highlights the broader challenge of developing comprehensive indicators and integrated assessment frameworks for urban water sustainability.

5. Conclusion

This study set out to understand how key informants across government, utilities, community organisations, and environmental groups in the Parramatta region define, experience, and respond to urban water sustainability challenges. The findings show that water sustainability is understood in broadly holistic terms across stakeholder groups, encompassing ecological health, governance, cultural meaning, and long-term security, but that this shared understanding has not translated into coordinated action. The central barrier is not a lack of knowledge or commitment, but the governance arrangements required to act on it, meaning that no single authority connects or coordinates.

The findings show clear signs of stress across the region. Major human pressures, including urbanisation, stormwater pollution, ecosystem degradation and land-use intensification, are outpacing institutional capacity to respond. Creeks are deteriorating, infrastructure is ageing, stormwater systems are overwhelmed and sensitive species are declining. Participants perceived that government attention is often directed towards immediate pressures such as housing, health, transport and other infrastructure needs, leaving water sustainability at risk of being underfunded and addressed reactively rather than strategically.

At the community level, the problem is one of invisibility; water arrives at the tap, and waste disappears down the drain, leaving most residents with no awareness of what happens in between, or of the pressures their daily behaviour places on the system:

Most of the time, people turn on the tap and water comes out. But I know a lot of people who say, well, they flush the toilet, they have no idea what happens after it disappears. The problem's gone

Stormwater, sewage, rivers, drinking water, catchment management, community engagement, and land-use planning are each managed by different actors with different priorities and accountability structures. Until these are brought together under a unified, well-resourced governance framework, one that treats water as a single interconnected system, progress will remain fragmented and reactive.

Three practical steps emerge from this study. First, governance structures need to move beyond sector-based management towards coordinated, place-based approaches that align institutional responsibilities with catchment-scale realities. Second, SDG linkages should be made explicit at the local level: many stakeholders in this study are already doing SDG-aligned work, and mapping these connections to SDGs 6, 11, and 15 would strengthen accountability, improve visibility of progress, and provide practitioners with a shared framework for collective action. Third, community and Indigenous knowledge need to be formally integrated into water governance, not as consultation add-ons, but as a recognised and funded component of planning and assessment.

While the findings are specific to the Parramatta context, the approach offers a transferable model for qualitative investigation of urban water governance in other rapidly urbanising regions. Key informant interviews, systematically analysed across diverse stakeholder groups, can reveal governance gaps, knowledge asymmetries, community priorities and management constraints that technical and biophysical assessments alone may not capture. In this sense, the study shows the value of stakeholder analysis as a practical complement to conventional water monitoring and infrastructure assessment.

As cities face growing water pressures under climate change and rapid urbanisation, urban water sustainability will depend not only on monitoring water quality or expanding infrastructure, but also on aligning institutions, communities and ecological knowledge around shared responsibilities. Integrating these perspectives into planning, policy and assessment frameworks will be essential for strengthening urban water governance and advancing the water-related Sustainable Development Goals.

Declarations

Data availability: The interview data analysed in this study are not publicly available due to participant confidentiality and ethics approval conditions. De-identified extracts and summary tables supporting the findings are included in the article and supplementary material.

Author Contributions: N.C.D.: Conceptualisation, Methodology, Software, Formal Analysis, Investigation, Writing- Original Draft, Writing-Review and Editing and Visualisation; B.M.: Conceptualisation, Methodology, Review and Editing, and Supervision; M.D.-M.: Review and Supervision; and S.H.: Writing-Review and Supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Commonwealth through an Australian Government Research Training Program Scholarship [DOI: https://doi.org/10.82133/C42F-K220].

Competing interests: The authors declare no competing interests.

Ethics approval: All participants were provided with study information and gave written informed consent before interviews commenced, in accordance with Western Sydney University Human Research Ethics Committee approval H16103.

References

1. Almazán-Casali, S, Puga, BP and Lemos, MC (2021) Who Governs at What Price? Technocratic Dominance, Ways of Knowing, and Long-Term Resilience of Brazil's Water System. Frontiers in Water, Volume 3 - 2021. https://doi.org/10.3389/frwa.2021.735018
2. ANZECC (2000) Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, 1, 1-314
3. Arnott, JC and Lemos, MC (2021) Understanding knowledge use for sustainability. Environmental Science & Policy, 120, 222-230. https://doi.org/10.1016/j.envsci.2021.02.016
4. Avazpour, B, Osmond, P and Corkery, L (2023) The dynamic challenges of mainstreaming water sensitive cities in our built environment: Lessons from Australia. Cities, 143, 104615. https://doi.org/10.1016/j.cities.2023.104615
5. Ayre, M and Mackenzie, J (2013) “Unwritten, unsaid, just known”: the role of Indigenous knowledge(s) in water planning in Australia. Local Environment, 18, 753-768. https://doi.org/10.1080/13549839.2012.665864
6. Bai, W, Yan, L, Liang, J and Zhang, L (2022) Mapping knowledge domain on economic growth and water sustainability: A scientometric analysis. Water Resources Management, 36, 4137-4159. https://doi.org/10.1007/s11269-022-03245-7
7. Biermann, F, Kanie, N and Kim, RE (2017) Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals. Current Opinion in Environmental Sustainability, 26-27, 26-31. https://doi.org/10.1016/j.cosust.2017.01.010
8. Braun, V and Clarke, V (2022) Thematic analysis: A practical guide. SAGE Publications, London.
9. Brown, RR, Keath, N and Wong, TH (2009) Urban water management in cities: historical, current and future regimes. Water Science Technology, 59, 847-855. https://doi.org/10.2166/wst.2009.029
10. City of Parramatta (2017) A Great City Grows Better Every day - Environmental Sustainability Strategy 2017. Parramatta, NSW, pp 1–57
11. City of Parramatta (2024) State of our City Report 2021-2024. Parramatta, pp 1-23
12. Coles, JF, McMahon, G, Bell, AH, Brown, LR, Fitzpatrick, FA, Eikenberry, BCS, Woodside, MD, Cuffney, TF, Bryant, WL and Cappiella, K (2012) Effects of urban development on stream ecosystems in nine metropolitan study areas across the United States. US Geological Survey, pp 1-152
13. Coombes, PJ and Roso, S (2019) Runoff in urban areas. In Australian Rainfall and Runoff — A Guide to Flood Estimation. Geoscience Australia, Commonwealth of Australia,
14. Crespo, D, Albiac, J, Dinar, A, Esteban, E and Kahil, T (2022) Integrating ecosystem benefits for sustainable water allocation in hydroeconomic modeling. PLOS ONE, 17, e0267439. https://doi.org/10.1371/journal.pone.0267439
15. Damkjaer, S and Taylor, R (2017) The measurement of water scarcity: Defining a meaningful indicator. Ambio, 46, 513-531. https://doi.org/10.1007/s13280-017-0912-z
16. Das, S, Choudhury, MR, Chatterjee, B, Das, P, Bagri, S, Paul, D, Bera, M and Dutta, S (2024) Unraveling the urban climate crisis: Exploring the nexus of urbanization, climate change, and their impacts on the environment and human well-being - A global perspective. AIMS Public Health, 11, 963–1001. https://doi.org/10.3934/publichealth.2024050
17. Davies, P, Hazleton, J, Barach, L and Joei, C (2017) Parramatta River Governance Review 2017. Macquarie University, pp 69

18. Davies, PJ and Wright, IA (2014) A review of policy, legal, land use and social change in the management of urban water resources in Sydney, Australia: A brief reflection of challenges and lessons from the last 200 years. Land Use Policy, 36, 450–460. https://doi.org/10.1016/j.landusepol.2013.09.009
19. Dean, AJ, Fielding, K, Newton, F and Ross, H (2016a) Community engagement in the water Sector: An outcome-focused review of different engagement approaches. Cooperative Research Centre for Water Sensitive Cities Ltd, Clayton, Vic, Australia, pp 50
20. Dean, AJ, Fielding, KS and Newton, FJ (2016b) Community Knowledge about Water: Who Has Better Knowledge and Is This Associated with Water-Related Behaviors and Support for Water-Related Policies? PLOS ONE, 11, e0159063. https://doi.org/10.1371/journal.pone.0159063
21. Dean, AJ, Lindsay, J, Fielding, KS and Smith, LDG (2016c) Fostering water sensitive citizenship – Community profiles of engagement in water-related issues. Environmental Science & Policy, 55, 238-247. https://doi.org/10.1016/j.envsci.2015.10.016
22. Di Vaio, A, Trujillo, L, D'Amore, G and Palladino, R (2021) Water governance models for meeting sustainable development Goals: A structured literature review. Utilities Policy, 72, 101255. https://doi.org/10.1016/j.jup.2021.101255
23. DPIE (2020) NSW Estuary Water Quality Compilation: 2007–2020. Department of Climate Change, Energy, the Environment and Water. https://portal.data.nsw.gov.au/arcgis/rest/services/Hosted/NSW_Estuary_Water_Quality_Compilation_2007_2020/FeatureServer. Accessed 04/04/2026
24. Ferdowsi, A, Piadeh, F, Behzadian, K, Mousavi, S-F and Ehteram, M (2024) Urban water infrastructure: A critical review on climate change impacts and adaptation strategies. Urban Climate, 58, 102132. https://doi.org/10.1016/j.uclim.2024.102132
25. Grafton, RQ, Fanaian, S, Horne, J, Katic, P, Nguyen, N-M, Ringler, C, Robin, L, Talbot-Jones, J, Wheeler, SA, Wyrwoll, PR, Alvarado, F, Biswas, AK, Borgomeo, E, Brouwer, R, Coombes, P, Costanza, R, Hope, R, Kompas, T, Kubiszewski, I, Manero, A, Martins, R, McDonnell, R, Nikolakis, W, Rollason, R, Samnakay, N, Scanlon, BR, Svensson, J, Thiam, D, Tortajada, C, Wang, Y and Williams, J (2025) Rethinking responses to the world's water crises. Nature Sustainability, 8, 11-21. https://doi.org/10.1038/s41893-024-01470-z
26. Hennink, M and Kaiser, BN (2022) Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Soc Sci Med, 292, 114523. https://doi.org/10.1016/j.socscimed.2021.114523
27. Holland, M, Demaree, K and Thomas, E (2023) Investigating technology opportunities toward improved Colorado water monitoring: Insights from key informant interviews and stakeholder surveys. PLOS Water, 2, e0000054. https://doi.org/10.1371/journal.pwat.0000054
28. Hurlimann, A, Wilson, E and Keele, S (2017) Framing Sustainable Urban Water Management: A Critical Analysis of Theory and Practice. In Bell, S, Allen, A, Hofmann, P and Teh, T-H (eds) Urban Water Trajectories. Springer International Publishing, Cham, pp. 53-68
29. Infrastructure Australia (2019) Australian Infrastructure Audit 2019: Water. Sydney, NSW, Australia, pp 596-646
30. Infrastructure NSW (2012) 20-Year State Infrastructure Strategy – Water Infrastructure Background Report. GHD, pp 1-29
31. Jackson, S, Moggridge, B and Robinson, C (2014) Literature Review: Indigenous Water Values, Rights, and Interests. Canberra, ACT, pp 1-215
32. Juwana, I, Muttil, N and Perera, BJC (2012) Indicator-based water sustainability assessment - A review. Science of the Total Environment, 438, 357–371. https://doi.org/10.1016/j.scitotenv.2012.08.093
33. Juwana, I, Perera, BJC and Muttil, N (2010) A water sustainability index for West Java. Part 1: Developing the conceptual framework. Water Science and Technology, 62, 1629 –1640. https://doi.org/10.2166/wst.2010.452
34. Lincoln, YS and Guba, EG (1985) Naturalistic inquiry. Sage, Newbury Park, California.
35. Malterud, K, Siersma, VD and Guassora, AD (2016) Sample Size in Qualitative Interview Studies: Guided by Information Power. Qual Health Res, 26, 1753-1760. https://doi.org/10.1177/1049732315617444
36. McGrane, SJ (2016) Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. Hydrological Sciences Journal, 61, 2295-2311. https://doi.org/10.1080/02626667.2015.1128084
37. McIlwain, L, Holzer, JM, Baird, J and Baldwin, CL (2023) Power research in adaptive water governance and beyond: a review. Ecology and Society, 28. https://doi.org/10.5751/ES-14072-280222
38. Mendes, JP, Ferreira, DHL and Sugahara, CR (2021) Periurban Settlements. In Encyclopedia of the UN Sustainable Development Goals: Sustainable cities and communities. Springer International Publishing, pp. 88-99

39. Ningrum, D, Malekpour, S, Raven, R, Moallemi, EA and Bonar, G (2024) Three perspectives on enabling local actions for the sustainable development goals (SDGs). Global Sustainability, 7, e22. https://doi.org/10.1017/sus.2024.20
40. Ostrom, E (1990) Governing the commons: The evolution of institutions for collective action. Cambridge university press,
41. Pahl-Wostl, C (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Global Environmental Change, 19, 354-365. https://doi.org/10.1016/j.gloenvcha.2009.06.001
42. Palinkas, LA, Horwitz, SM, Green, CA, Wisdom, JP, Duan, N and Hoagwood, K (2015) Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. Adm Policy Ment Health, 42, 533-544. https://doi.org/10.1007/s10488-013-0528-y
43. Paton, E and Haacke, N (2021) Merging patterns and processes of diffuse pollution in urban watersheds: A connectivity assessment. Wiley Interdisciplinary Reviews: Water, 8, e1525. https://doi.org/10.1002/wat2.1525
44. Pinto, U, Dickens, C, Babel, M and Maheshwari, B (2024) Urban river health assessment and management. In Shinde, VR, Mishra, RR, Bhonde, U and Vaidya, H (eds) Managing Urban Rivers. Elsevier, pp. 283-299
45. Pires, A, Morato, J, Peixoto, H, Botero, V, Zuluaga, L and Figueroa, A (2017) Sustainability Assessment of indicators for integrated water resources management. Science of The Total Environment, 578, 139-147. https://doi.org/10.1016/j.scitotenv.2016.10.217
46. Pollard, SR, Riddell, E, du Toit, DR, Retief, DC and Ison, RL (2023) Toward adaptive water governance: the role of systemic feedbacks for learning and adaptation in the eastern transboundary rivers of South Africa. Ecology and Society, 28. https://doi.org/10.5751/ES-13726-280147
47. Rauscher, RC and Momtaz, S (2017) Planning in Greater Sydney – Parramatta City Case Study. In Rauscher, RC and Momtaz, S (eds) Cities in Global Transition: Creating Sustainable Communities in Australia. Springer International Publishing, Cham, pp. 179-198
48. Rietveld, LC, Siri, JG, Chakravarty, I, Arsénio, AM, Biswas, R and Chatterjee, A (2016) Improving health in cities through systems approaches for urban water management. Environmental Health, 15 Suppl 1, 31. https://doi.org/10.1186/s12940-016-0107-2
49. Rijke, J, Farrelly, M, Brown, R and Zevenbergen, C (2013) Configuring transformative governance to enhance resilient urban water systems. Environmental Science & Policy, 25, 62-72. https://doi.org/10.1016/j.envsci.2012.09.012
50. Robinson, OC (2014) Sampling in interview-based qualitative research: A theoretical and practical guide. Qualitative research in psychology, 11, 25-41. https://doi.org/10.1080/14780887.2013.801543
51. Rogers, BC, Dunn, G, Hammer, K, Novalia, W, de Haan, FJ, Brown, L, Brown, RR, Lloyd, S, Urich, C, Wong, THF and Chesterfield, C (2020) Water Sensitive Cities Index: A diagnostic tool to assess water sensitivity and guide management actions. Water Research, 186, 116411. https://doi.org/10.1016/j.watres.2020.116411
52. Sánchez-Rivero, MV, Bote Alonso, I, Domínguez Serrano, MV and Montalbán Pozas, B (2023) SDG monitoring framework for rural settlements mapping interactions with the Spanish Urban Agenda. Sustainable Cities and Society, 93, 104514. https://doi.org/10.1016/j.scs.2023.104514
53. Stefanelli, RD, Castleden, H, Harper, SL, Martin, D, Cunsolo, A and Hart, C (2017) Experiences with integrative Indigenous and Western knowledge in water research and management: a systematic realist review of literature from Canada, Australia, New Zealand, and the United States. Environmental Reviews, 25, 323-333. https://doi.org/10.1139/er-2016-0114
54. Tawfik, S (2016) Pursuing Sustainable Urban Water Management through Co-Governance: A Case Study of Marrickville Council. Cities, CRCfWS, Melbourne, Australia, pp 1-53
55. Tawfik, S and Chesterfield, C (2020) Facilitating water sensitive urban development through planning integration-A discussion paper. Melbourne, Australia, pp 1-31
56. Thompson, R, Duncan, P, Hobbs, M, Livingstone, J, Moggridge, B and Poelina, A (2024) Principles and Practice for Indigenous Engagement in Water Management. Australian Water Partnership, Canberra, pp 1-20
57. Turak, E and Bickel, D (1994) Using biological indicators to monitor the health of freshwater ecosystems. NSW, Australia, pp 69
58. UN Water (2022) Water and Climate Change. https://www.unwater.org/water-facts/water-and-climate-change.
59. Urrutiaguer, M (2016) Management of the ecological impacts of urban land and activities on waterways. Melbourne Water, pp 76
60. Van de Meene, S, Head, BW and Bettini, Y (2016) Toward effective change in urban water policy: the role of collaborative governance and cross-scale integration. Cooperative Research Centre for Water Sensitive Cities: Melbourne, Australia
61. Webster, AJ, Lin, YC, Scruggs, CE, Bixby, RJ, Crossey, LJ, Huang, K, Johnson, A, de Lancer Julnes, P, Kremer, CA, Morgan, M, Mulchandani, A, Rotche, L, Stone, AB, Tsinnajinnie, LM and Stone, MC (2025) Facilitating convergence research on water resource

management with a collaborative, adaptive, and multi-scale systems thinking framework. Ecology and Society, 30. https://doi.org/10.5751/ES-15586-300123

62. Williams, M, Kookana, RS, Mehta, A, Yadav, SK, Tailor, BL and Maheshwari, B (2019) Emerging contaminants in a river receiving untreated wastewater from an Indian urban centre. Science of The Total Environment, 647, 1256-1265. https://doi.org/10.1016/j.scitotenv.2018.08.084
63. Wong, TH and Brown, RR (2009) The water sensitive city: principles for practice. Water Science Technology, 60, 673-682. https://doi.org/10.2166/wst.2009.436
64. Zuniga-Teran, AA, Fisher, LA, Meixner, T, Le Tourneau, FM and Postillion, F (2022) Stakeholder participation, indicators, assessment, and decision-making: applying adaptive management at the watershed scale. Environmental Monitoring and Assessment, 194, 156. https://doi.org/10.1007/s10661-021-09741-4

Figures

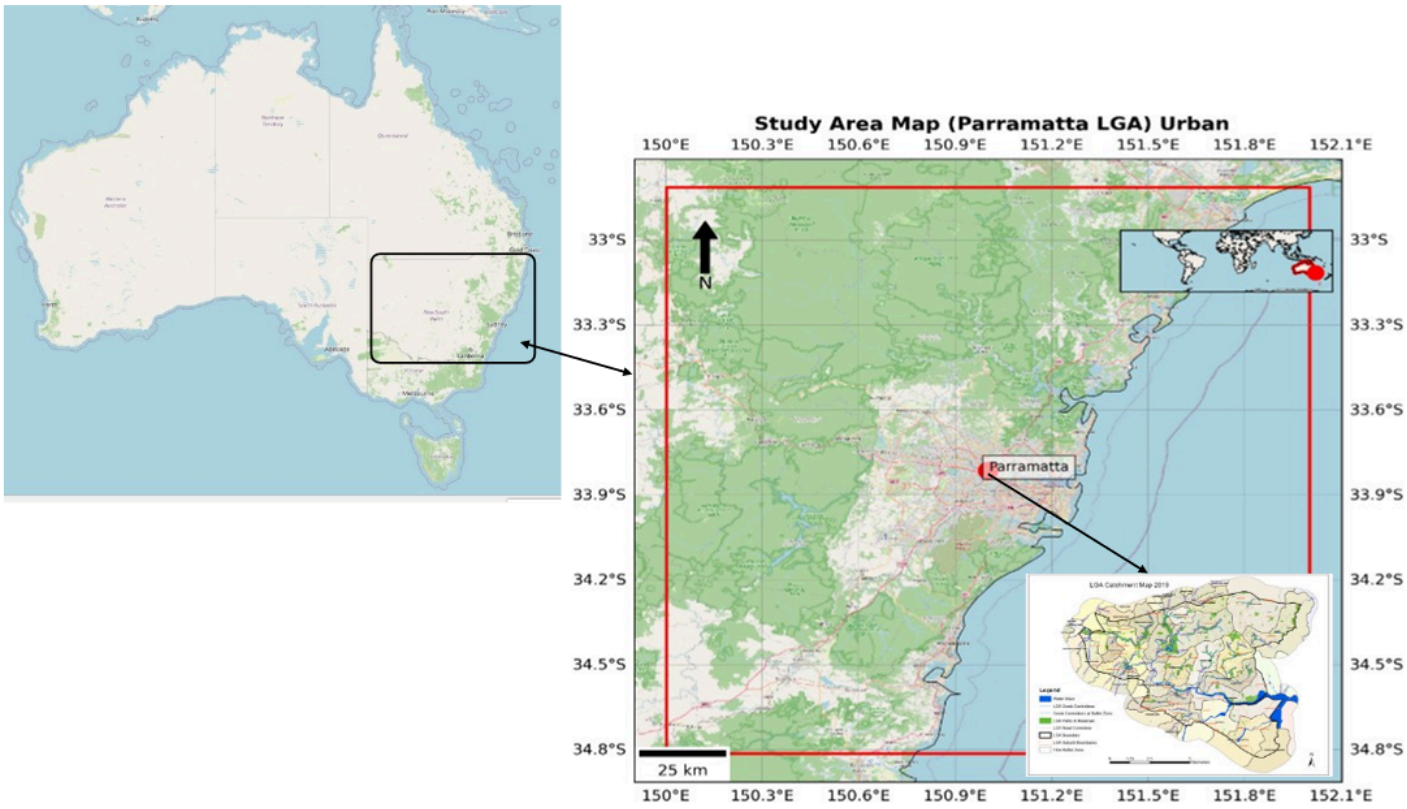


Figure 1

Location of the study area: Parramatta LGA, New South Wales, Australia

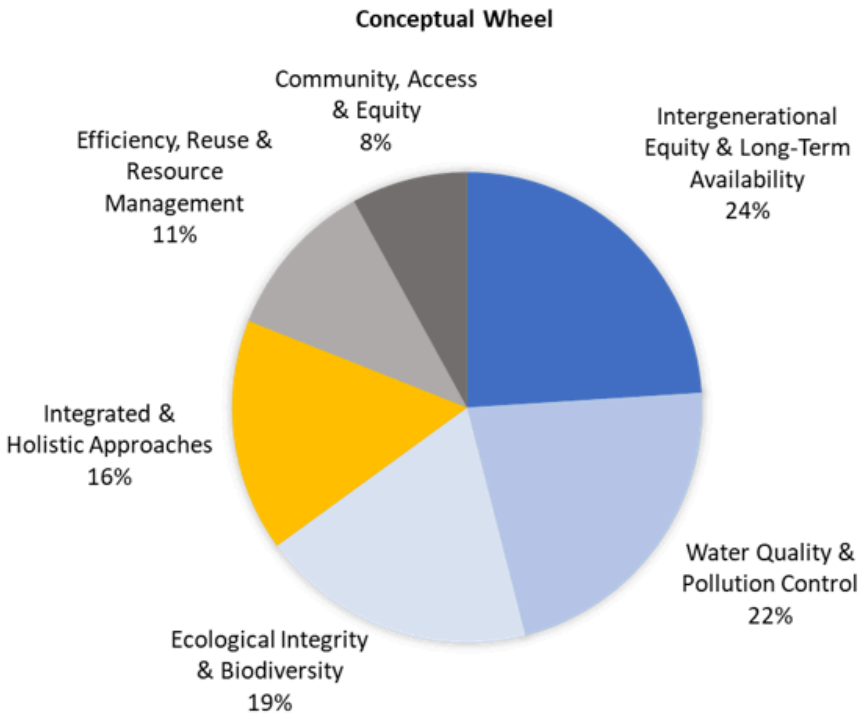


Figure 2

Conceptual themes describing water sustainability based on key informant perspectives

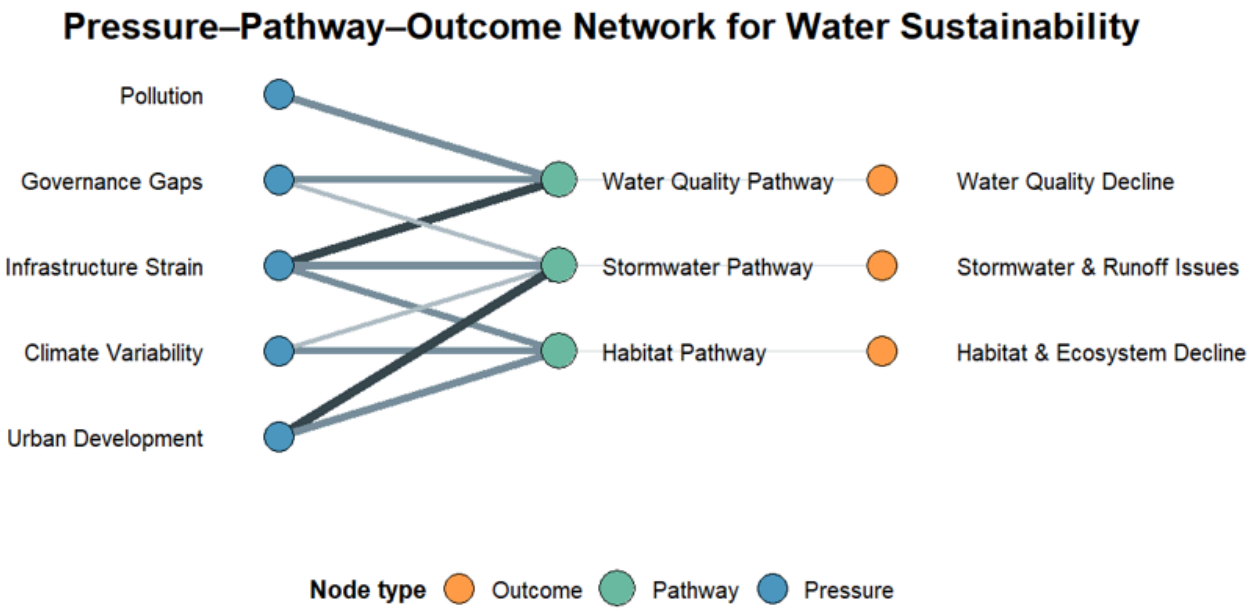


Figure 3

Pressure–pathway–outcome network illustrating drivers affecting water sustainability in Parramatta

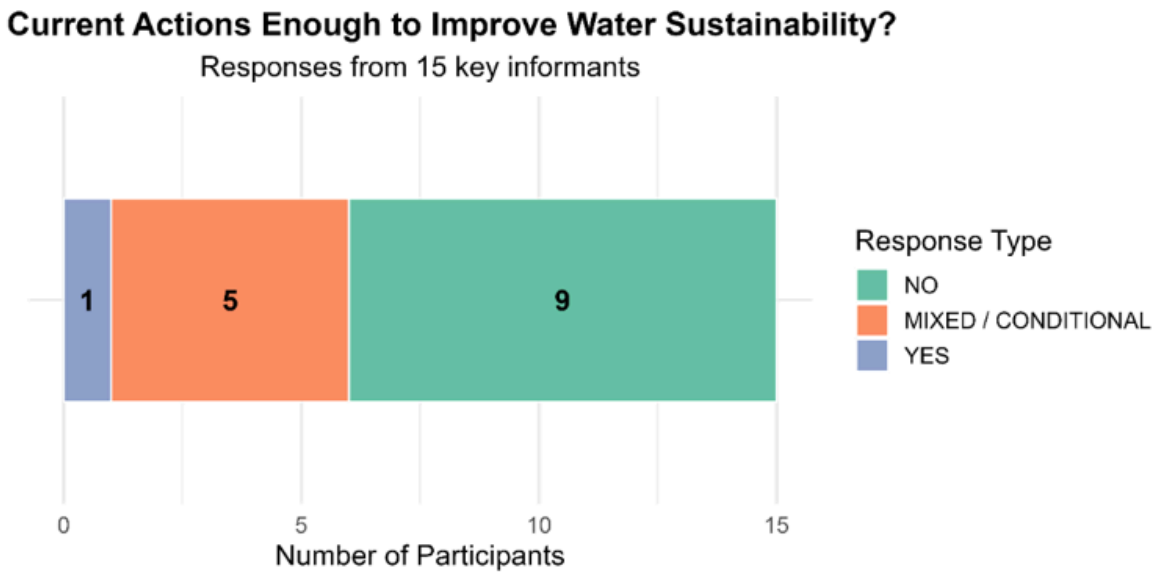


Figure 4

Key informants' assessment of the sufficiency of current actions for water sustainability

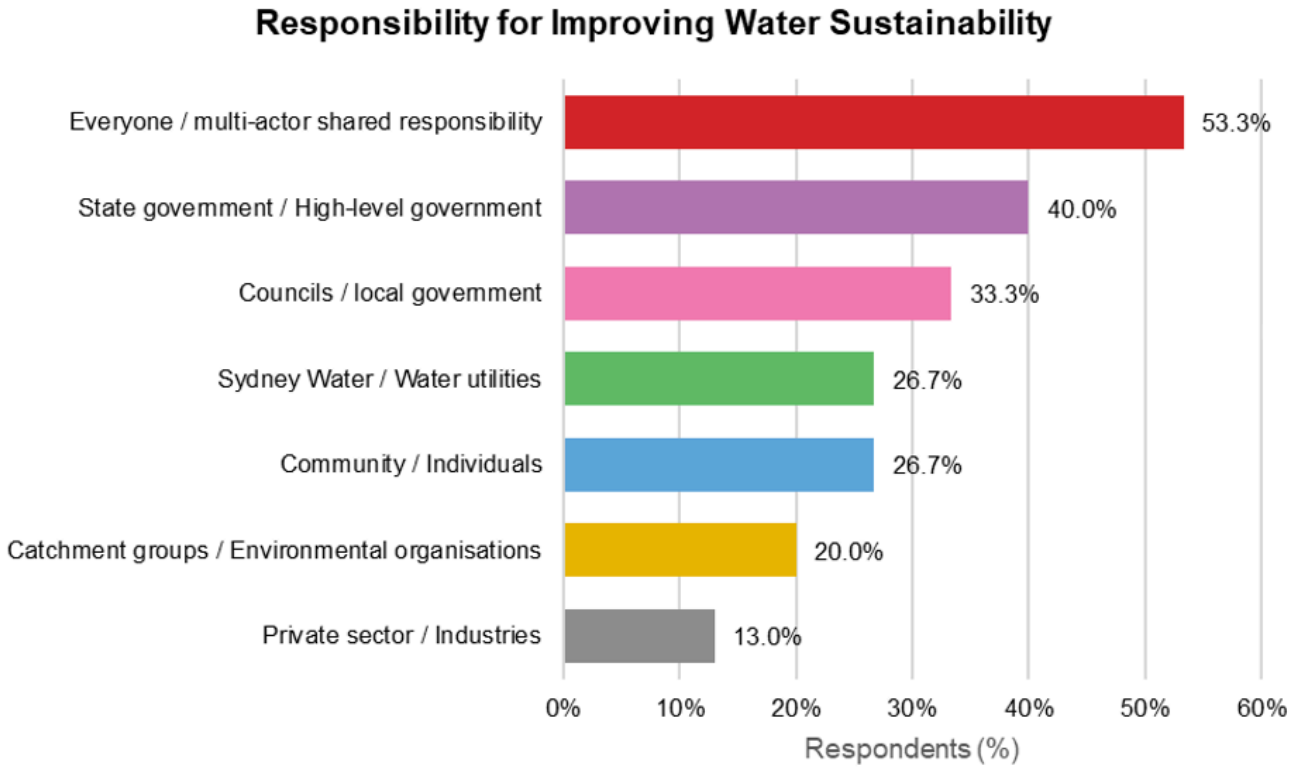


Figure 5

Stakeholder responsibility for improving water sustainability as identified by key informants

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ParramattaSupplementaryFile.docx