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The dynamic challenges of mainstreaming water sensitive cities in our built environment: Lessons from Australia

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ABSTRACT

Stormwater has been acknowledged as a major concern in cities because of mismanagement of this resource. It has also been underestimated as a resource in climate change actions and policies. Water sensitive urban design (WSUD) is considered as an effective adaptation measure to address these issues while providing many co-benefits. This paper reports the challenges of implementing WSUD in the Australian context. Semi-structured interviews were conducted with 57 experts in Australia. The experts are involved in design, research, engineering, and planning policy in both public and private sectors. The qualitative analysis of the interviews involved thematic and content analysis through NVivo12. Analysis of the responses indicated six main challenges including financial, innovation and evaluation tools, capacity, institutional arrangements, and policy. The experts believe that a lack of standardized design and implementation can be addressed through collaborative design processes. They suggest a robust structure of approval process and establishing clarity of roles and responsibilities in all sectors. All respondents confirm the critical role of monitoring and maintenance in these projects. It is suggested that allocating recurrent funding for these ongoing activities from the beginning and setting incentives to engage communities and local councils in maintaining the projects can be helpful.

1. Introduction

Climate change has exacerbated critical concerns in urban water systems such as flooding, droughts and water resource degradation (Han & Kuhlicke, 2021). According to the IPCC 2022 report (IPCC, 2022), extreme weather events due to anthropogenic climate change have increased, leading to droughts and also floods, such as followed heavy rainfall events in western Europe, China, Japan, the USA, Peru, Brazil and Australia. The report indicated that there is evidence of negative impacts of changes in the hydrological cycle on people and ecosystems. Climate change, land use development and water pollution are the main reasons for water resources degradation (Akhtar et al., 2021; Bossio et al., 2010; Hawken, Avazpour, et al., 2021). Identifying the significance of stormwater management, in the context of climate change, is a critical step in developing sustainable interventions that mitigate the impact of these issues.

Traditional engineering solutions, such as levees, canals, and pipe-based infrastructure have been the typical approaches to urban stormwater management. The measures implemented to accelerate the downstream movement of water have resulted in detrimental consequences such as geomorphic and hydrological changes in channel morphology and behaviour, riverbank erosion, and consequently water degradation and an increased risk of flooding (Avazpour et al., 2018; Mondal & Patel, 2018). Over the past two decades, there has been a change of emphasis from engineered approaches to integrated methods which mainly feature nature-based solutions (Oral et al., 2020). This shift has happened as there are numerous social, environmental and economic benefits to be gained by using nature-based solutions (Coutts et al., 2012), which also facilitate resource recovery through source separation and source control (Nika et al., 2020). The concept of water sensitive cities (WSCs) and Water sensitive urban design (WSUD) emerged in Australia in the 1990s; it reflects the techniques, approaches, and principles employed to manage stormwater (Ashley et al., 2013). Fig. 1 shows the various sources of urban water, the importance of stormwater management and WSUD to achieving WSCs. In this study, a critical role in the success of WSCs is ascribed to stormwater management. Stormwater is considered here to be a major urban water resource to be managed using WSUD measures. Recognizing the related domains of urban water governance, socio-ecological systems, resilience and adaptive management to climate change, this research focused on

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stormwater management within the WSUD and WSC domains.

By its very name, the term WSC positions stormwater management as integral to urban design, not just an engineering strategy and as such, WSUD now engages various design professionals in developing solutions for urban stormwater management. Although the concept of WSUD is known by different terms and acronyms in other countries (Fig. 2), the approaches and techniques applied to urban stormwater management all share the aim of helping cities to reduce urban runoff, minimize the hydrological impacts of urban development on the surrounding environment, enhance water quality and biodiversity through minimizing changes to hydrology and decreasing pollutants (Ashley et al., 2013; Fletcher et al., 2015). However, there are different areas of focus and concern in different countries. In the United States, water scarcity, stormwater reuse and coping with drought are key considerations in cities like Phoenix and Tucson while in cities like Chicago the focus of water management is flood control (Cutts et al., 2015; Dhakal & Chevalier, 2017; Larson et al., 2013). In Australia and in European countries, stormwater quality and quantity have been key concerns, while in developing countries the focus often remains on removal of stormwater from the urban areas in the shortest time (Gogate et al., 2017; Roy et al., 2008).

In Australia, these integrated approaches have received increasing attention from cities that have experienced prolonged droughts between 2001 and 2009 (Furlong, de Silva, & Guthrie, 2016). Many projects have been developed to manage urban water systems, using different terminologies for integrated approaches (Fletcher et al., 2015). However, based on the differences of context and local development, there are some differences in the expression of these principles. The overlap in terms of specificity and breadth of application illustrates the similarity of underpinning ideas, as well as the dynamic and multi-dimensional nature of terms used (Fig. 2) (Fletcher et al., 2015). Table 1 is a summary of named approaches overlapping the concepts of WSCs and WSUD. WSUD and WSC are the terms mainly used in Australia. In this research, WSUD defines the measures used to manage stormwater which can be applied in different urban contexts.

This paper focuses on Australia as one of the main pioneers in stormwater management, with many generations of dealing with the extremes of floods and droughts, now exacerbated by the effects of climate change. There are implications for Australian cities which make them a priority to identify appropriate solutions (Wong, 2015; Wong & Brown, 2008). Australia has achieved significant integration of WSUD principles in new urban developments, particularly in greenfield areas, and the majority of guidelines focus on these new settings. However, there is a lack of guidelines and fact sheets on retrofitting WSUD in existing urban areas. A study by Weber et al. (2009) assessing the Botany Bay catchment in South Eastern Australia indicated that retrofitting WSUD into existing urban areas yields more substantial reductions in pollutant loads compared to implementing it in greenfield settings. These studies emphasize the importance of applying WSUD approaches to both new and existing urban contexts. Australian and international research findings have emphasized that urban water management theories should be linked to design disciplines (Brown et al., 2009). In this regard, using stormwater through the application of WSUD strategies can help practitioners to retrofit urban areas. However, there is still a significant gap between theory and practice (Islam et al., 2021). More research is needed to see if WSUD strategies derived from the theoretical literature, technical frameworks and field experimentation can be combined into an integrated design approach (Furlong, Gan, & de Silva, 2016).

Research has shown that throughout the collaboration between science and design, the link between WSUD, urban landscape design and ecological planning should be better integrated (Ashley et al., 2013; Irvine et al., 2021; Xia et al., 2017). Although WSUD as an approach to manage urban water has been introduced to practice by applying

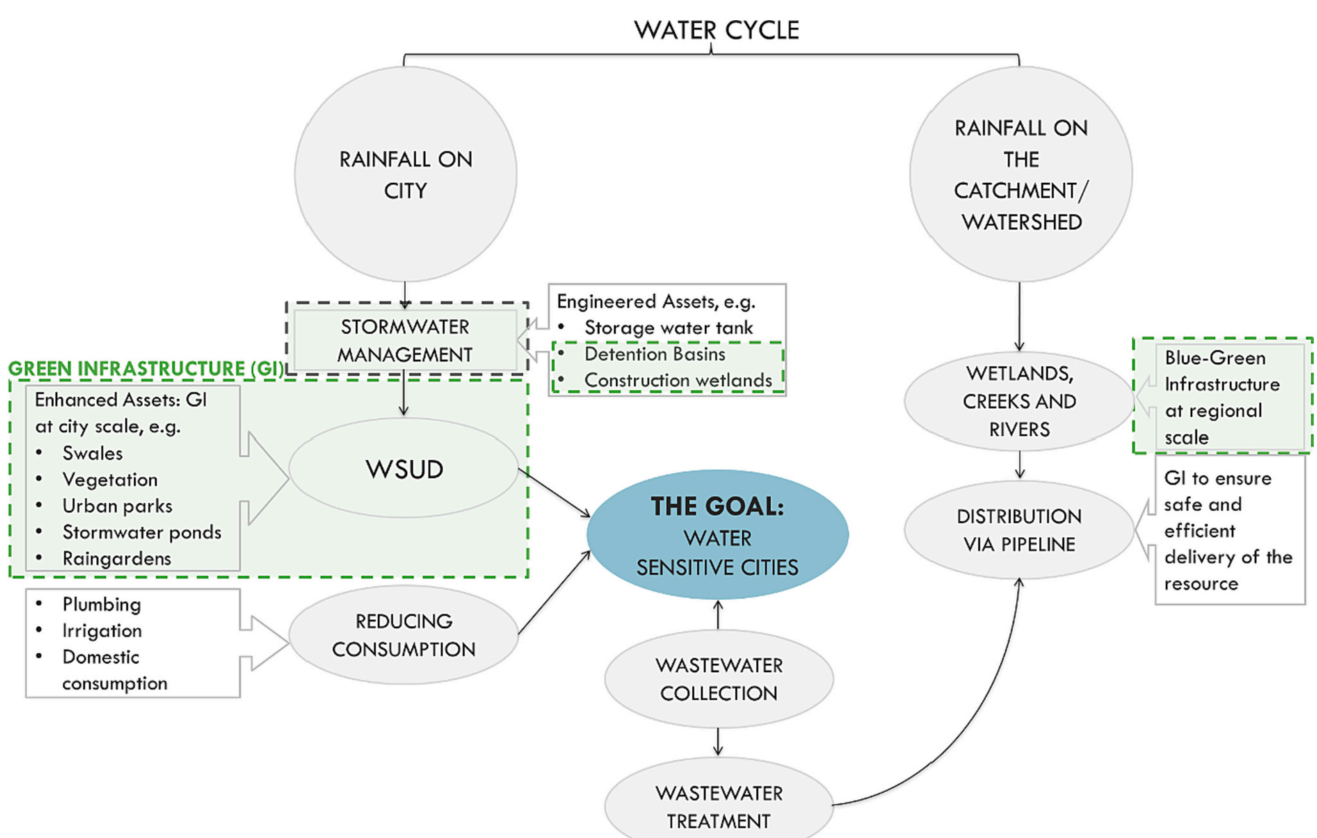

Fig. 1. The relationship between WSUD, WSCs, green infrastructure (GI) and stormwater management in the urban water cycle. (Source: Author).

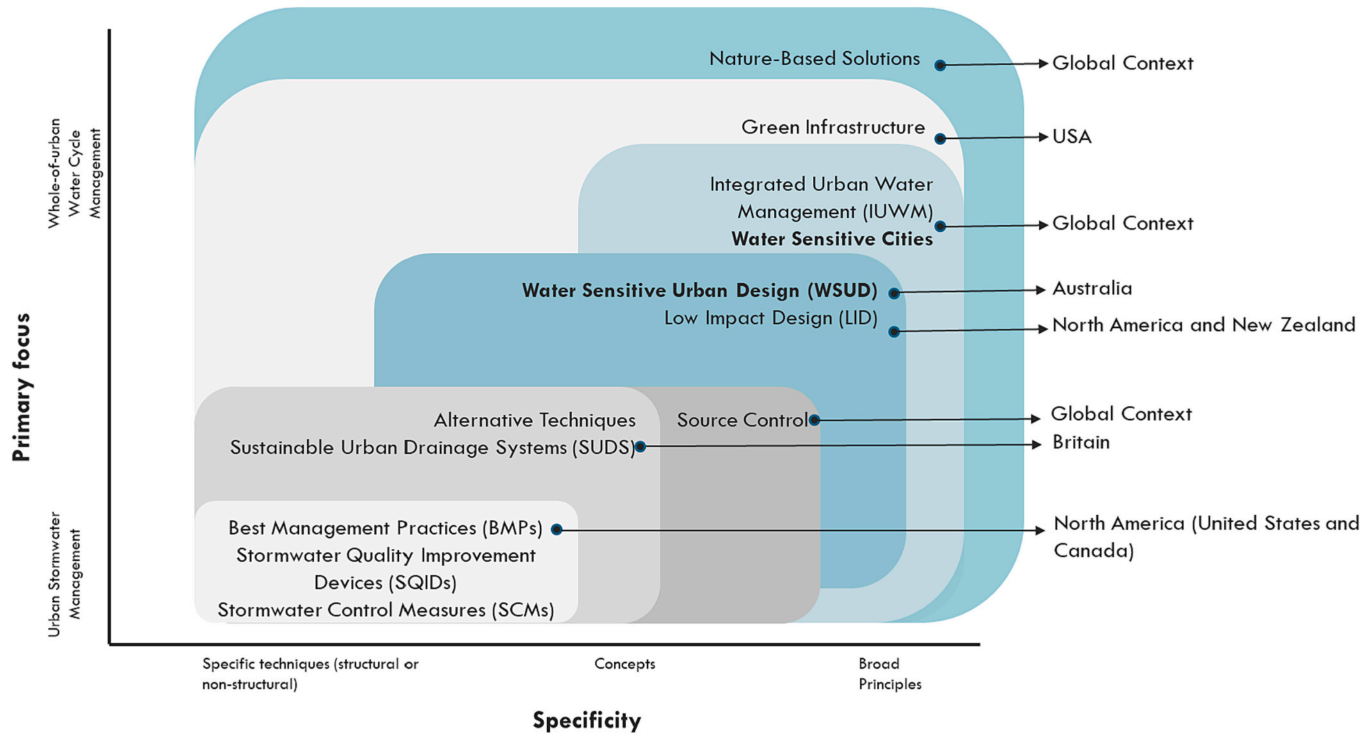

Fig. 2. One possible classification of urban drainage terminology, according to their specificity and the primary geographical area (adapted from (Fletcher et al., 2015; Moosavi et al., 2021).

Table 1
A summary of water management approaches (source: Author).

Key words	Definition	Typical example	Country of origin	Reference
Best Management Practices (BMPs)	Structural measures used to store or treat urban stormwater runoff to reduce flooding, remove pollution, and provide other amenities.	Detention or retention facilities; Infiltration facilities; Wetlands, Vegetative strips, Filters; Water quality inlets	North America, particularly the United States and Canada	Fletcher et al., 2015; Sharma et al., 2016
Low Impact Development (LID)	Strategies with the idea of 'design with nature' using site layout and integrated control measures.	Roof gardens, Rain gardens, Bioswales; Pervious pavements; Wetlands; Green areas and urban natural vegetation corridors	North America, New Zealand	Donofrio et al., 2009; Sharma et al., 2016
Green Infrastructure (GI)	Focuses on increasing green areas and creating ecological nodes and corridors within cities.	Green roofs; Trees; Rain gardens; Permeable pavement that can capture and infiltrate rain	The USA	(Benedict & McMahon, 2006)
Low Impact Urban Design and Development (LIUDD)	Respects the indigenous (Maori) conception of the regional environment while controlling pollution.	Roof gardens, Rain gardens, Bioswales; Pervious pavements; Wetlands; Green areas and urban natural vegetation corridors	New Zealand	Fletcher et al., 2015; He et al., 2019
Sustainable Urban Drainage Systems (SUDS)	Uses the natural features of a site and the pre-development drainage patterns consisting a range of technologies and techniques to drain stormwater/surface water in a sustainable manner.	Green roofs; Permeable surface; Infiltration trenches; Filter drains and filter strips; Swales and shallow drainage channels; Detention basins; ponds and wetlands; Flooding parks	Britain	Qiao et al., 2018
Integrated Urban Water Management (IUWM)	Integrates different sources of urban water through incorporating the roles and interactions of the various institutions involved in management of the urban water cycle.	Water conservation and efficiency; Urban layout and landscaping; Utilisation of nonconventional water sources including roof runoff, stormwater, greywater and wastewater; Application of fit-for-purpose principles; stormwater and wastewater source control and pollution prevention; Stormwater flow and quality management; The use of mixtures of soft (ecological) and hard (infrastructure) technologies	North American	Howe & Mitchell, 2011; Radcliffe, 2019
Water sensitive cities (WSCs) & Water Sensitive Urban Design (WSUD)	Consider all forms of urban water at various scales to support the functions of the natural environment.	Rain gardens, Bioswales; Pervious pavements; Wetlands; Bioretention basins	Australia	Brown et al., 2009; Wong et al., 2020
Sponge Cities	Focuses on recycling stormwater by retention, infiltration and purification techniques to reduces flood risk and increase water availability.	Rain gardens, Bioswales; Pervious pavements; Wetlands; Bioretention basins	China	Hawken, Sepasgozar, et al., 2021; He et al., 2019; Zevenbergen et al., 2018

different techniques such as wetlands and bioswales, the relationship between design in practice and research is not achieved adequately (Hawken, Sepasgozar, et al., 2021).

Although there are studies on the benefits of WSUD, an investigation of the benefits of a WSC approach has not been comprehensively conducted that considers environmental, social, economic and governance aspects (Fogarty et al., 2021). Some tools have been developed to estimate the values of these projects e.g., CIRIA B£ST tool assesses the benefits of blue-green infrastructure while the focus is mainly on natural flood management (Horton et al., 2015), TEEB (The economics of ecosystems and biodiversity) in the Netherlands that focuses on the financial benefits of green spaces (Sukhdev et al., 2014), and the tools developed by Centre for Neighbourhood Technologies (CNT, 2023) in the USA, each has a specific areas of focus. There is a need to identify more assessment tools and indicators in a holistic approach to evaluate the post-implementation performance of WSUD, and that requires exchanging information within a strong technical framework achieved by collaboration between science and professional designers (Xu et al., 2019). However, collaboration between disciplines to achieve a satisfactory output is frequently not considered in the design process. In practice, cooperation between different sectors - such as researchers, government agencies, the private sector and the local community - is not achieved with the process largely conducted by practitioners alone (Ahern et al., 2014). In essence, there is a lack of clarity regarding the role of design in the transdisciplinary process. Just as the role of design professions is not clarified during post-implementation and monitoring, the role of ecologists is typically disregarded in public participation and co-design. The lack of communication between disciplines hinders interdisciplinary learning (Lawrence, 2015).

To link WSUD practice and theory and to enable multidisciplinary collaboration, the challenges of mainstreaming WSUD projects need to be identified. In this research the challenges are considered as dynamic because of the constant changes of the factors that impact them including stakeholders, actors and institutional arrangements. The aim of this paper is to understand how urban water experts in Australia perceive these challenges and how they believe they can be addressed. To begin, a literature review was conducted to identify the challenges of stormwater management in the Australian and international contexts. Second, semi-structured interviews were undertaken with 57 Australian experts across different disciplines in public, private and research sectors. A thematic analysis of the interview transcripts revealed six main challenges to institutionalising WSUD projects in Australia, and the measures necessary to address these challenges, enabling the design of multifunctional and resilient water sensitive projects.

The remainder of this paper is structured as follows. Section 2 reviews the literature around the challenges of implementing WSUD projects. Section 3 presents the applied methodology used to inform the data collection for this research. The result of the thematic analysis of the interviews is elaborated in Section 4, followed by a discussion of the way forward to transition to a WSC. Finally, in Section 5, the research limitations are outlined, followed by Section 6, which concludes the research outcomes, and provides insights for practitioners and academics while outlining future directions for further research.

2. The challenges of implementing WSUD in cities

The literature investigated the challenges of implementing WSUD projects in cities around the world. As revealed by the US National Research Council (NRC, 2009) and studies by the Cooperative Research Centre for Water Sensitive Cities (CRC WSC) (Choi & Mcilrath, 2017; Sharma et al., 2018), the main challenges to implementing green infrastructure and WSUD projects include regulatory constraints across different urban scales, institutional challenges, and technical, financial and socioeconomic challenges. The challenges of WSUD projects in Australia mainly result from governance issues and the complexity of stakeholder environments (Ahammed, 2017; Brodnik & Brown, 2018). Although there are efforts to design multipurpose projects, the main focus is on technology and techniques of implementation rather than the dynamic factors influencing performance of the project (Furlong, de Silva, & Guthrie, 2016). For example, in Elmer Avenue Neighbourhood Retrofit, Los Angeles, while the aim was to control floods and safely capture urban runoff, an attempt was also made to increase the stormwater capacity of the project by utilising the maintenance element of the project, which led to problems in delivering the main aims of the project (Belden & Steele, 2011). The techniques supporting the project were new and, although best practice (around 12 BMPs were adopted), not in common use. This made the maintenance process expensive as each of the elements required a specific maintenance approach. A lesson learned from this project is that more models for critique need to be developed to facilitate the exploration and testing of new techniques (LPS, 2011).

- *Policy and regulations*

Policies and regulations are intended to mediate the relationships between different agencies at different levels including local, precinct and regional scales (Sharma et al., 2016). This enables establishing a link between the theory and practice of WSUD projects in Australia, where the water industry is participated in by different agencies and organizations (Zuniga-Teran et al., 2019). As stated by Schifman et al. (2017), there should be collaboration between professionals through multidisciplinary approaches across all phases of the projects. This leads to establishing common goals and reaching a common perception of the outcome by different disciplines through efficient communication between states, local governments, developers, communities and other stakeholders.

The literature emphasizes the importance of this shift from traditional approaches to innovative, multipurpose techniques and strategies (Madonsela et al., 2019). However, the pace of this shift is slow as policy and regulations have not adopted innovative approaches and it needs to address professional barriers. As stated by Fogarty et al. (2021), although achieving water resilient cities depends on the critical role of regulations and policy, these are mainly underestimated, and the main focus is on the technical performance of a stormwater management system, or on specific elements. Sharma et al. (2016) suggested there was a need to revise regulations and policies to reflect the local context with a focus on multifunctionality. In addition, despite existing policies framing the sustainable management of stormwater, there are institutional complications to implementing WSUD projects (Furlong, de Silva, & Guthrie, 2016). The role of government and water management organizations in the success of WSUD projects is not only about setting up innovative approaches on the ground and building new knowledge but also to establish a culture of engagement and commitment to solutions which support the resilience of our cities (Werbeloff & Brown, 2016). In this regard, there should be more research on enhancing stakeholder engagement, including communities and developers with WSUD projects. A holistic guideline that facilitates sharing and ensures that organizations, developers and stakeholders have sufficient information about the importance of all project stages is essential for fostering effective collaboration, addressing potential challenges, and successfully implementing WSUD initiatives. (Prosser et al., 2015).

According to the Parliament of Australia report (2016) on stormwater management, the submission by CRC for WSCs indicated that the main issue in Australian stormwater management is the uncertainty about legal ownership of stormwater as a resource, and there are also limited resources available to local government. In many cases, local government manages urban water instead of water utilities, leading to some challenges. Australian Water Association submission for the parliamentary inquiry indicated some stakeholders oppose this arrangement, where different water sources are managed by different entities. On the other hand, various stakeholders believe that local governments see stormwater as a threat and act to discharge it as quickly as possible. In addition to the lack of resources that local governments have for stormwater management, even though they manage and own the majority of stormwater infrastructure, they do not own the water.

These problems also result from the lack of economic incentives and private sector engagement. Currently, there is no private sector investment in stormwater management, primarily due to the lack of comprehensive objectives guiding stormwater management, which in turn affects private sector interest. According to the parliamentary inquiry, to ensure consistency in stormwater management and engage the private sector in offering innovative solutions, state governments should establish well-defined policies and leadership roles for improving stormwater management within their jurisdiction. This requires a jurisdictional arrangement within state public sectors and collaboration between state and local governments. In this regard, state governments need to provide better support to local councils (The Parliament of Australia report, 2016).

- *Complexity of stakeholders*

There are different approaches to determine the definition of stakeholders. In this paper, stakeholders are defined as the government professionals, neighbourhood associations, organizations, communities and individuals who are involved in any stage of a WSUD project. This definition aligns with that of the Network of Conservation Educators and Practitioners (NCEP), which points out that these groups often have quite different values and positions which may be difficult to reconcile (Vogler et al., 2017). For example, some want to emphasize ecological issues, others aesthetic aspects. Thus 'stakeholder complexity' refers to the number of parties and perspectives involved in a project that, in practice, can lead to difficult collaboration processes.

One of the main issues in stakeholder management is convincing them about the benefits of WSUD projects and balancing their requirements and project outcomes (Brodnik & Brown, 2018). Scholars believe that appropriate implementation of WSUD projects and providing the right case studies for the stakeholders can justify the approach and convince them about the benefits of grounding sustainable water management solutions (Cook et al., 2019). In this regard, lack of shared knowledge and skills between government professionals and academics in design, implementation, monitoring and maintenance of WSUD projects can lead to uncertainty about the benefits of the projects and hinder the successful engagement of stakeholders. Prosser et al. (2015) and Furlong et al. (2019) argued that despite the existence of new green infrastructure techniques and principles, certain organizations and experts have access to them but most of the time they do not work together. Although knowledge sharing between actors is necessary to transfer techniques and enhance capacity, it is not achievable if the transfer processes and technologies are not adapted to the culture of the organizations. To transfer knowledge and share technology, some scholars suggest using publications and reports (Leonard et al., 2019). The challenges and solutions of knowledge sharing, and stakeholder engagement are: 1) developing a holistic guideline by local governments to provide enough information for all involved stakeholders; 2) increasing the capacity to absorb new techniques and innovations; 3) increasing the stakeholders' awareness to appreciate the situation; 4) developing publications and reports through workshops to engage all disciplines in early stages of the projects; and 5) encouraging mutual exploration of the potential benefits of WSUD projects through engagement workshops. In this way the relevant dominant benefits can be identified which may vary between location specific contexts (Hawken, Sepasgozar, et al., 2021; Johnson et al., 2019).

- *Innovation and technology*

The idea of applying new technology and innovations in water management projects has become highlighted since awareness of the consequences of relying on grey infrastructure has been raised (Dhakal & Chevalier, 2017). In addition, the cost of maintenance and construction of grey infrastructure has led to emerging innovative ideas to control urban water through nature-based solutions (Alves et al., 2019). Climate change and water issues have encouraged cities to build up capacity to accept and absorb changes - such as extreme weather condition, governance structure - in ways not possible with grey infrastructure. However, evolving to green infrastructure requires new policies and regulations for managing water resources (Brears, 2018). To date, policy and regulation have not facilitated successful translation of fresh ideas into the design and implementation of WSUD. This can produce a mismatch between the goals and the outcomes of projects. A process for transferring innovative ideas from policy to implemented outcomes – based on what stakeholders need – should be available during project development (Zevenbergen et al., 2018). Providing a situation in which organizations can create changes that stakeholders can accept, will facilitate the transformation to WSCs (Ruangpan et al., 2020; Sharma et al., 2018).

- *Standardization and technical guidelines*

Implementing technologies on the ground is another challenging task in WSUD projects as there is no specific technical guideline to facilitate it (Collins et al., 2020). Enhancing communication between disciplines through technical guidelines can be an area for future research to investigate how to share knowledge and techniques between organizations. It has benefits in cost and resource management of the projects (Hawken, Sepasgozar, et al., 2021). In Australia, this is one of the challenges that is linked to confidentiality matters (Brodnik & Brown, 2018). Local governments in Australian cities have tried to facilitate communication by running workshops, site visits, and courses but there also needs to be research on how to develop guidelines from these (Hawken, Sepasgozar, et al., 2021). Technical guidelines can be effective on the standardization of WSUD projects to assess the projects in design, implementation, and maintenance stages (Madsen et al., 2017). However, lack of experienced personnel who have adequate knowledge to set and document project standards is still a big challenge for organizations (Zuniga-Teran et al., 2019).

- *Financing WSUD*

Because of the costs of site evaluation and design, it is difficult to convince stakeholders about implementing WSUD (Xu et al., 2019). To reduce the costs, Fogarty et al. (2021) conducted a comprehensive study on regulatory frameworks and funding mechanisms to manage water resourcing. They suggested a comprehensive development study with site-specific scenarios for discussion among stakeholders and actors. A cost assessment ahead of the projects in conjunction with modelling of the economic benefits of their environmental and social outcomes can facilitate comparison between solutions (Chan et al., 2018; Whiteoak, 2019; Whiteoak, 2019). The other aspect of the economic challenge relates to the perception of the environmental, social, cultural and economic benefits of these projects. In this regard, He et al. (2019) argued that providing an opportunity for communities and other stakeholders to be involved in the process of design and research through workshops and meetings, and also documenting case studies can facilitate fundraising and increase public awareness about the benefits of these projects.

In this section, the literature was reviewed to map the challenges of mainstreaming WSUD projects in the context of Australia. These challenges are categorized in policy and regulations, innovation and technology, stakeholders' complexity, standardization, and financing of WSUD projects. Although these challenges are investigated in the Australian context, there are common aspects with other jurisdictions. In the following sections, the methodology of comparing findings from the literature with those gathered through semi-structured interviews with Australian water management experts, is discussed. Through thematic analysis, the challenges are discussed in accordance with the outcome of the literature review.

3. Methodology

Australia was considered an ideal case for this study as it has a significant background in design and implementation of WSUD and it has also coped with water management challenges despite a complex governance structure for stormwater management. 57 semi-structured interviews were undertaken with government professionals, academics, and practitioners in Australia. The experts were selected based on their involvement in different scales and phases of water management projects including design, implementation, and maintenance. The interviewees also represent different disciplines: environmental science, biology and ecology, civil and environmental engineering, urban design and landscape architecture, urban policy and planning, and infrastructure management. Interviewees were targeted on the basis of their understanding and expertise in water management and WSC issues, and their interest in the performance of stormwater management projects. They also needed to have been involved in at least one water management project, academically or practically. The respondents were selected from different states and territories to enable geographical analysis (Fig. 3).

For the purpose of this research, the focus is to indicate the challenges of stormwater management in Australia and compare these with other countries. To gain a balance between government professionals, academics, and practitioners, 11 experts had been completely involved in academic research projects, 26 were involved in practice and 20 were engaged with both research and practice. This study mainly focused on the experts with more than six to ten years' experience in senior positions including project managers, directors and project team leaders. They were selected through a review of LinkedIn profiles, the academic and 'grey' literature and university websites. The total number of interviewees (57) is regarded as an appropriate sample size in qualitative research projects (Vasileiou et al., 2018) and allowed comprehensive coding of the interview transcripts. The data collection was approved by the UNSW Panel for the Ethical Conduct of Research. To maintain the anonymity of participants, each was given a code that indicates their profession, area of expertise, and the stage and scale of the projects they discussed during the interview (Table 2).

The interviews were conducted between September 2020 and January 2021; each took around one hour and was recorded. The interviews were carried out online (Teams or Zoom) and/or by telephone as face-to-face interviews were not possible because of COVID-19 restrictions. One of the advantages of semi-structured interviews is that it

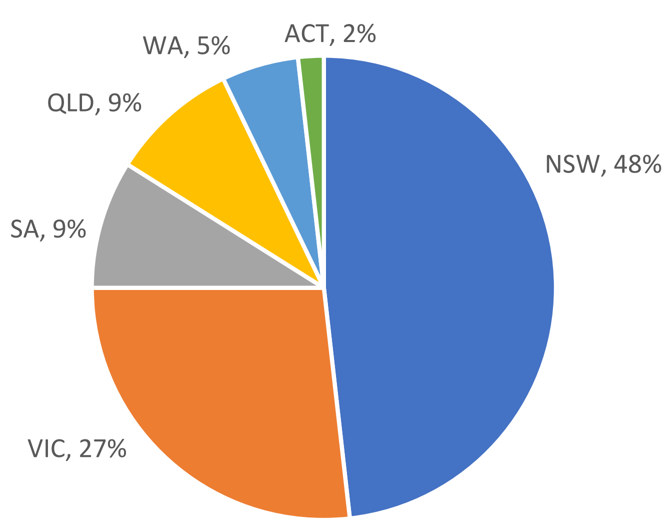

Fig. 3. Percentage of the interviewees based on geographical location in Australia.

gives an opportunity to discuss different aspects of the interviewees' responses in more depth (Horton et al., 2004). To analyse the data, each interview's audio-record was transcribed and coded, using NVivo12 (Richards, 1999). Matters discussed during the interviews were categorized into three main areas: 1) the perception of the experts about WSUD projects; 2) the regulations, climate change adaptation strategies and potential they see in the specific city in which they were involved; 3) the experience of implementing WSUD strategies in a specific project they worked on.

After transcribing the interviews, initial coding was done through reading the transcripts using thematic analysis. Following the initial coding, the codes were categorized into related themes based on evaluation coding. Evaluation coding is a process which involves applying non-quantitative codes to qualitative data to assess the merit, worth, performance or significance of a policy or program. Evaluation coding describes, compares and predicts the data (Saldaña, 2021). The final stage involved analysis of the themes and writing the key concepts through elaborating codes justified by the relevant quotes.

Statistical analysis of the codes was not applied in this paper, and the codes were adopted through an iterative methodology (Morse et al., 2016).

4. Results and discussion

In the following sections, the core concepts and key challenges of implementing WSUD projects to mainstream WSCs based on the above analysis, are discussed.

4.1. Core ideas and concepts

When the interviewees were asked about the barriers and opportunities of stormwater management through WSUD projects, the main challenges they mentioned fell into six major themes: institutional arrangements, innovations and technical challenges, jurisdiction, sociocultural context, maintenance, and project finance. Fig. 4 summarizes the key features of the challenges and enablers of WSUD.

4.1.1. Institutional arrangements and standards

- *Design and implementation standards*

The majority of interviewees said that it is necessary to develop a clear standardized design process that aligned with the regulations in designing and maintaining the infrastructure, with one respondent stating that: *"… It's really about setting things at that top level and getting them right there and then making sure that it's clear in terms of standards and regulations for the people who are expected to sort of implement them on their side-by-side basis what it actually means for them"* (PD1).

As stated by some interviewees, having standardized processes enables projects to be systematically evaluated within a framework of design and implementation. This evaluative framework also enables the designers and agencies to convince developers and stakeholders about the benefits of the projects. In addition, the experts indicated the importance of the alignment of planning controls and engineering standards in WSUD projects.

Despite the views above about the critical role of standardizing the design and implementation process, the interviewees pointed out that there is still a long way to go to develop a unified framework. As pointed out by one interviewee, in England, there is a standardized approach in water management and flood control (Chan et al., 2018) but in Australia, there are different responses from different councils and agencies. For example, in UK, there are reports such as the Planning Policy Statement 25 (PPS25) (DCLG, 2007); and the National Planning Policy Framework (NPPF) (DCLG, 2012) that are guidelines for planning process within flood-risk appraisal and assessment practices and Code for Sustainable Homes (DCLG, 2011) has the greatest influence on

Table 2
Summary of interviewees with codes indicating profession and discipline (Source: Author).

	Area of experience					Total
	Science 'S'	Engineering 'E'	Design 'D'	Policy and planning 'P'	Management 'M'	
Academia 'A'	2 interviewees (AS1, AS2)	2 interviewees (AE1, AE2)	1 interviewee (AD1)	4 interviewees (AP1 to AP4)	2 interviewees (AM1, AM2)	11
Practice 'P'	4 interviewees (PS1 to PS4)	4interviewees (PE1 to PE4)	5 interviewees (PD1 to PD5)	5 interviewees (PP1 to PP5)	8 interviewees (PM1 to PM8)	26
Both practice and academia 'B'	3 interviewees (BS1, BS2, BS3)	4 interviewees (BE1 to BE4)	5 interviewees (BD1 to BD5)	3 interviewees (BP1 to BP3)	5 interviewees (BM1 to BM5)	20
Total	9	10	11	12	15	57

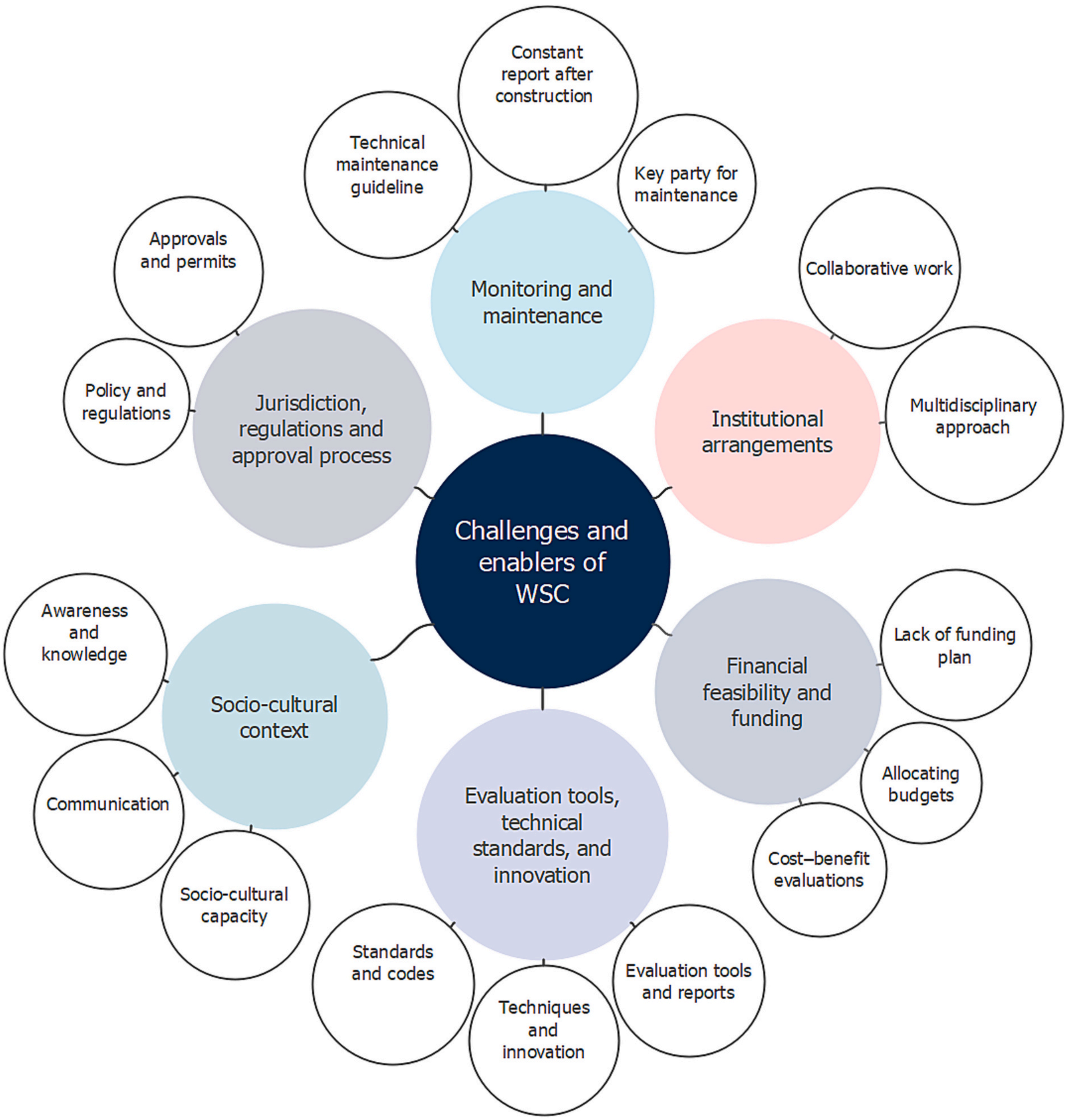

Fig. 4. Challenges and enablers of mainstreaming WSCs (Source: Author).

property developments.

To reach a standardized design, one of the interviewees indicated the importance of a multifunctional design by incorporating the social, ecological, and economic aspects of WSUD projects: *"… in the UK, standardized design is resolved by developing a certification approach"* (PD4). Flood and Water Management Act 2010 (Legislation, 2010) and the Code (Water, 2021) are among the programs to standardize stormwater management in UK. The approach provides an integration between disciplines and water agencies and develops learning opportunities. It highlights the benefits of the standards and the necessity for governments to develop them if they are lacking.

- *Collaborative design and delivery of WSUD projects*

One of the main issues in design and implementing the water management projects according to the interviewees relates to cross-agency projects and the solutions to be developed by different agencies (Malekpour et al., 2021). It is emphasized that these solutions come from different agencies with different areas of focus, and it is hard to develop a solution while there are no specific criteria for the deliverables. As one of the interviewees highlighted: "… *they're both speaking to the same fundamental issues, and you need sort of shared solutions to make sure that those things are deliverables*" (BE3). Similarly, some interviewees echoed the effect of cross-agency decision making in water management projects.

Most interviewees emphasized that a successful water management project should consider a collaborative approach between different disciplines. They mentioned the critical role of urban designers and landscape architects in implementation and post-implementation of the projects which is mainly disregarded:

> *"In our project, there was a hierarchy of who should be involved in what stage. We clarified the roles at the beginning of planning and research of the project and as we were aware of the effect of different disciplines, we tried to make a balance and involve designers in engineering and technical as well as maintenance discussions and also ask our engineers to work with designers from the beginning. That was the key to the success of this project"* (PM3).

However, some interviewees highlighted that in some projects, it is not easy to ask engineers to work with designers and ecologists, partly/mainly because of a lack of a common language and therefore difficulties in communication. Most interviewees pointed out that the challenges of managing WSUD projects are grounded in lack of communication between different disciplines and agencies and most of the experts emphasized the advantages of collaborative design through cross-agency and cross-disciplinary cooperation. However, it should be considered that this challenge could be attributed to the differing goals among various agencies. For example, across Asia and in the UK, the drivers formulating climate change adaptation policies in water management are directed by central governments like the National Planning Policy Guidance (NPPG) in the UK, also mentioned by Young and Essex (2019). This shows that robust top-down governance could be very beneficial in developing climate change and water management policies. Strategic guidance from central government can be beneficial in prioritizing stormwater management actions to be implemented locally. Support from higher levels of government can result in confidence in implementing adaptation strategies.

According to this research, however, the integration of top-down and bottom-up approaches could be more effective in achieving WSC goals. Application of top-down or bottom-up approaches depends on the context. Top-down governance works for certain contexts such as UK and China where roles and responsibilities are clarified at high levels. However, in other areas such as Australia, the USA and Europe, the bottom-up approach helps by integrating stakeholders across scales. A combination of a top-down structure at high levels and bottom-up local governance provides a holistic urban water management approach in which the roles and responsibilities are clear, and all stakeholders are collaborating. This concept is supported by the literature (Aina et al., 2019; Gabe et al., 2009; Girard et al., 2015).

Thus, the process of stormwater management starts with defining strategies, indicating methods and developing objectives at a high governance level, while design specifications, engineering and construction matters are detailed at lower levels. This hierarchical and centralized approach can set evaluation criteria for more local policies. A smooth transition from strategy to design, without any conflict, requires clear communication between stakeholders and separation of responsibilities between scales.

4.1.2. Evaluation tools, technical standards and innovation

According to the interviewees, in Australia, engineers, construction teams and maintenance experts have adequate knowledge of how to implement a specific WSUD technique on a site *"They are all familiar with the techniques. However, when it comes to the communication, the challenge arises"* (AE2). However, our interviewees emphasized how innovation in communicating water management strategies can be beneficial for cities:

> *"…it is more important to be innovative, because by innovation, knowledge can be transferred to other cities and projects and we as experts can learn from each other to control and manage urban water and adapt to extreme weather events"* (PS2).

The importance of innovations and use of technology was stressed by interviewees, with one respondent highlighting the role of technology in their project *"the project was a success to control stormwater quality by in-situ technology working with some sensors to monitor and control algae"* (PM8). In addition to the use of technology, most interviewees stated that innovation in WSUD projects must be achieved through multifunctionality:

> *"… in our project, the innovation was not about technology, it was about how the design could work for different purposes such as social, environmental, and economic. WSUD projects are multifunctional and have social, economic, and environmental benefits"* (BD3).

Following the above statements, some interviewees pointed out the other aspects of innovation in WSUD projects including improved communication between teams and with the government; Interviewee PM5 mentioned they had designed a new tool to strengthen the relationship between stakeholders, researchers, and government which:

> *"…facilitated communication between all sectors and helped to allocate the responsibilities of each party"*.

Interviewees pointed to other aspects of innovation, for example by integrating blue, green and grey infrastructure (PP5) (Alves et al., 2019). This was echoed by another interviewee who then pointed out that multifunctionality leads to urban resilience: *"…the innovation in water management projects comes with multifunctionality that leads to city resilience. This is the main goal of these projects and achieving this goal necessitates considering the urban water system and infrastructure as a whole spectrum"*. (PP1) While interviewees highlighted the importance of taking a comprehensive approach to the functional development of cities in introducing urban water projects, most stated that to achieve a multifunctional project, is a big challenge as there are a multitude of stakeholders and agencies involved.

Based on the interviews, it became evident that achieving success in WSCs depends on innovative approaches in multifunctionality which thus leads to resilient infrastructure. It should be emphasized that such innovation is within the consistent fundamental principles of WSUD and WSC approach. However, the majority of respondents stated that the difficulty of achieving this aim is to prioritize the goals. They mentioned that the solution to prioritizing the challenges is through learning from pilot projects. Interviewees also indicated that pilot projects are the best way in which to introduce WSC goals to communities "… *if you need public support in a WSC, there must be pilot projects to show them the benefits of WSCs and to justify the project"* (BM3). For example, the SWITCH project was an extensive study that focused on addressing significant sustainability challenges in urban water management over an extended period. Across several cities worldwide, it aimed to investigate the requirements for transitioning to a more sustainable urban water management. This included conducting research based on identified needs, demonstrating activities, facilitating multi-stakeholder learning, and providing training and capacity building opportunities (Butterworth et al., 2011). While projects such as SWITCH project serve as an appropriate demonstration of such studies, according to the interviewees, there is still a need for more projects in various contexts to provide greater opportunities for learning.

Some interviewees also mentioned the necessity of a technical guideline to demonstrate the best WSUD projects: "*it is very important to know about the techniques and approaches of water management in other cities or even other parts of the world and it happens through sharing case studies*" (PD4). This assists not only the practitioners and designers to update their knowledge and use others' experience, but also is helpful to present the benefits of WSUD projects to the public and clients: "*… most of the time, it is difficult to convince a client especially about the cost-effectiveness of WSUD projects. They need a clear economic perspective, and the case studies could be helpful*" (BD1). According to the interviewees, case studies also provide an opportunity to clarify the techniques and to eradicate the ambiguity of the technical aspects.

Thus, regarding innovations and technological challenges of WSUD projects, a common thread in the responses highlights the necessity of innovative approaches in managing stormwater and implementing WSUD projects (Faivre et al., 2017).

4.1.3. Jurisdiction and approval process

In spite of rapid urban development for more than a hundred years, stormwater management has been considered relatively recently, compared to other types of urban water resources (Zuniga-Teran et al., 2019). According to most interviewees, the effectiveness of the current system of stormwater management and regulations should be monitored to ensure they are effective.

When interviewees were asked to provide their point of view on stormwater management regulation in cities, the majority indicated that the awareness of the importance of this resource and the need to regulate it is increasing. Some interviewees emphasized the benefits of regulating stormwater: "*… because of climate change, in cities with less water scarcity problem, the concern of managing water is growing as they may experience extreme weather condition and we can see some approaches to prioritize stormwater as one of the main urban water resources*" (BS1). This contrasts with conventional practice:

> "*… Most of the focus of managing stormwater has been to dispose it in the fastest way from cities and this has been a big challenge in Australia to convince the states to set stormwater as one of the main resources in water management projects*" (AE1).

The complexity/variety of stakeholders is one of the big challenges in managing WSUD projects. In Australia, the complexity of water management relates to the relationship between planning departments and water agencies (Furlong, de Silva, & Guthrie, 2016): "*… there are different sides of government. The water side and the planning side are quite separate and it's hard to have them talk to each other consistently in a sort of meaningful way where everything kind of comes together*" (PS2).

The views of the interviewees about the regulatory system and approval process confirms the important role of local agencies in these projects. This can have an impact on allocating budget and resources to implement the regulations, and as a result, affects the efficiency of the regulations in practice. As one interviewee stated, this challenge has an impact on distinguishing issues at the source: "*… as the result of lack of budget, when it comes to water quality at source, there is not enough staff and resource to determine the problem*" (PM3).

Another aspect of implementing WSUD projects relates to the impact of developers' perspectives (Cook et al., 2019). This highlights the important benefit of case studies and examples for communities and developers so they can observe the changes and be aware of the amenities WSUD projects can bring to their neighbourhoods which could result in an increase in property values: "*Providing financial capacity, introducing projects and the outcomes of the cases to the stakeholders, and creating engagement programs can convince the developers and property owners to allocate a part of their land to these types of projects*" (PP4). Cooks River Naturalization project is one of the best known WSUD projects in Australia and is used as a reference when implementing WSUD in the local council area (Canterbury-Bankstown) according to the lead organization (Sydney Water). The channelization of Sydney waterways with concrete began in the late 19th century with the aim of flood control supporting urban development (Cunningham, 2017). The concrete lining of waterways had seriously impacted the ecological health of Sydney's waterways. The WSUD concept for the Cooks River was an opportunity to reintroduce 1.1 km of natural waterway with native plants and amenities such as seating areas, pathways, picnic areas and outdoor classrooms (Cunningham, 2017).

In line with interviewees' perspectives and the literature, we suggest that cities develop policies to consider stormwater as a major resource in water management and which provides a holistic approach across scales of water governance (Kuller et al., 2018).

4.1.4. Socio-cultural context

One of the main challenges in implementing WSUD projects is that it is not clear to what extent communities accept the physical and visible changes: "*… if we are not able to showcase the projects and their benefits to the communities, it is difficult to have their support*" (BD2).

The capacity building by public participation was mentioned by most of the interviewees as the main factor in the success of WSUD projects and also the main challenge to manage, especially when the community believe they are presented with a *fait accompli*. One of the aspects of public participation relates to awareness of climate change and presenting the public with information that shows the effectiveness of WSUD projects in mitigating climate change can be very effective:

> "*… in our project, we did a survey to estimate the support of the community. The survey showed that as they were not aware of the effects of climate change on water resources, they could not understand the benefits of the project*" (PS1).

In recent years, in all WSUD projects there is a section about community engagement: "*It is essential to raise the public knowledge and to gain their approval in projects. Nowadays, in Australia, there is a partnership between local governments and communities*" (PP2).

According to the interviews, paying attention to socio-cultural matters plays a critical role in the success of WSUD projects, necessitating consideration of community engagement and cultural aspects in all stages.

4.1.5. Monitoring and maintenance

It was notable that for all interviewees, monitoring and maintenance is the key factor leading to high performance in WSUD projects. The majority believed that there should be ongoing reporting about the performance of the projects: "*… the monitoring is very critical, and it can be ongoing monthly or annual depends on the project*" (PM4). However, interviewees mentioned it is problematic to have a constant report: "*… reporting can be an issue because of the resources allocated to a project, and the cost of monitoring*" (AS1). On the other hand, the other problem is about resources and budget: "*… monitoring mainly needs analysts and experts familiar with the technology and tools and we cannot find them in all projects because of the cost or lack of these experts*" (BM3).

The first maintenance challenge is lack of knowledge. Some interviewees suggested a technical guideline for project maintenance based on project type, scale, and climate zone. The other main challenge of maintaining WSUD projects relates to project size and the number of experts involved (Furlong et al., 2019). Compared to large infrastructure projects, WSUD projects are not convincing for engineers in terms of financial benefits:

"*… there's a certain lack of acceptance of green infrastructure from our water management agencies, just because they tend to be super engineers and they also tend to be used to doing enormous projects and it's a bit challenging having them do smaller projects because the level of administration is the same as for say a billion-dollar sewage treatment plant. And so that is a problem because it's not worth it for anybody*" (PD1). The example of the

London Thames Tideway Tunnel serves as a strong demonstration of this concept, with arguments against implementing a large-scale infrastructure solution instead of supporting the implementation of decentralized local Sustainable Urban Drainage Systems (SUDS) schemes (Loftus & March, 2019).

Others stated that one of the key factors in maintenance of WSUD projects is clarifying the roles and responsibilities of each party including the public sector or local government, the private sector and the local communities. However, there is a conflict among different levels of governance in maintenance activities: *"… local governments are responsible for WSUD maintenance while controlling water quality at the source relates to the government, and it is problematic to put all under the same umbrella in terms of maintenance"* (BM5). Thus, considering maintenance at the planning stage by clarifying the roles of each party is essential.

4.1.6. Financial feasibility and funding

Grey infrastructure has been constructed for many years and maintenance is costly (Brears, 2018). This can be a convincing reason to implement WSUD projects and nature-based solutions that are less expensive. However, there are challenges of how to convince the community, indicate who is responsible for financing, and how to quantify the costs and the benefits.

Although the need to improve green areas is becoming more pressing, these systems must be resilient and adaptable to climate change, and there are still costs to design and maintain WSUD systems. In addition, while there are some tools available to evaluate the benefits and costs of such systems, estimating the costs and developing more tools remains a challenge (Xu et al., 2019), and the balance between costs and benefits remains unclear: *"we know about the benefits of WSUD projects, but when it comes to the costs, clients are not sure if it is worth or not. It is difficult to convince them while it is not clear how much we can rely on calculations and how to compare them with the other benefits"* (PE3).

A financial plan that compares the long-term benefits of these projects with the costs of implementation and maintenance was suggested by the interviewees. As indicated by one interviewee, the ecosystem services provided by WSUD projects are extensive. However, quantifying them poses a challenge, whether due to a lack of evaluations or inefficiency in knowledge sharing regarding evaluation approaches to raise awareness about the existence of such tools: *"it is important to include the benefits of WSUD projects while analysing the costs because the costs of implementing these projects can hinder the benefits, however there is still no specific party or market to quantify the benefits in the economic evaluation"* (PP5). Thus, an analysis of ecosystem benefits, installation and monitoring and maintenance costs is required though it means more investment is also needed to conduct these activities.

In spite of the benefits of WSUD projects and the lower cost compared to grey infrastructure, there are complications in funding and indicating who is responsible for project finance (Fogarty et al., 2021). Like the other challenges, putting all of the parties on one page is problematic. Most interviewees pointed out that considering different financial supporters in WSUD projects can lead to a better result. Most interviewees also mention that the financial aspects of maintenance and capacity building, that is enhancing the knowledge and understanding of all stakeholders are among the main challenges: *"Capacity building in WSUD projects can play a critical role in the sustainability of these projects and the source of costs for capacity building must be clarified. This area is always challenging and needs collaboration between all stakeholders"* (PM6). Some interviewees stated that offering incentives can be helpful to implement and maintain WSUD projects. However, it is also challenging to indicate who is responsible for financial incentives and subsides.

Communities must be aware of the costs of the implementing a WSUD feature especially on private properties. However, the interviewees mentioned that it is difficult to ask people to pay for implementing intangible green infrastructures: "*… there's sort of more complex things like getting networking infrastructure. So, there's certain things that people can do simply and there's other things which are difficult to believe before it is built. And, in this case, it is difficult to ask the community to pay for it"* (PM5).

5. The way forward: transitioning to water sensitive cities

According to Mguni et al. (2022), WSUD has been extensively integrated into stormwater management and water supply systems in various cities, including Australia, Sweden, and the UK. However, the progress of its application in large-scale retrofitting has been relatively slow (Brown et al., 2013; Mukhtarov et al., 2019; Radcliffe, 2019; Trapp et al., 2017). Despite the potential for achieving a significant change in water quality and WSC through the implementation of WSUD in existing urban areas, the majority of studies, guidelines, and fact sheets focus primarily on the importance of integrating WSUD in new development contexts. This emphasis on new developments indicates that there are several challenges in implementing WSUD in cities, specifically in urban contexts. Therefore, this study aims to investigate these challenges to achieve the highest level of success in transitioning to WSC in both existing and new settlements through managing resources, regulations, policy, and stakeholders. The interviewed experts identified six main challenges involved in mainstreaming WSUD projects and stormwater management (Fig. 4, Table 3).

The role of policy and regulations was the first main factor that affects the performance of WSUD projects. It includes changes in regulations about the approval process, financial support, and applying new standards to manage these projects (Furlong, de Silva, & Guthrie, 2016). The literature mainly covered the optimization of policies. However, there is a need to revise policies and consider innovative standards and regulations in water management (Sharma et al., 2012). Policies should also enable governments to balance financial mechanisms with WSUD benefits (Chan et al., 2018; Whiteoak, 2019).

The other main factor that has an enormous influence on the outcome of WSUD projects is developing a collaborative approach through clear communication (Furlong, Gan, & de Silva, 2016). There should be research to provide a link between all aspects of collaborative design between experts, researchers and also practice firms. The interviewees echoed the importance of communication and collaborative design in monitoring and maintenance. It is important to clarify roles and responsibilities of each sector and expert, and to recognize their differing aims and purposes, and also conduct engagement with communities to gain their consistent support that leads to implementation of these projects. In addition, the interviewed water management experts emphasized documenting WSUD projects and sharing knowledge to enable them to communicate the results within institutions. It is also beneficial to popularize new technology through sharing to raise community awareness and consequently target community support in implementing WSUD.

Although each of these above challenges has a direct impact on the performance of WSUD projects, it is necessary to identify interconnections between them as well. Institutional arrangements and standards should be reviewed in accordance with local and state regulations. However, it is important to consider the cultural and social context of WSUD projects to manage financial aspects. Each geographical area has its own challenges, and it is important to analyse the context, determine the origin of the challenges, and evaluate the site-specific benefits. In this regard, providing an evaluative model that analyses the environmental, social, economic, and political benefits of WSUD projects against financial assessment can be helpful to make a balance between the costs and cities' liveability, resilience, and sustainability (Whiteoak, 2019). By comparing the state of stormwater management in Australia with other countries through the interviews and literature, the similarities and differences can be identified as illustrated in Table 3. These challenges are presented based on their priority in the relevant context. If a challenge is not indicated for a

Table 3
The state of stormwater management challenges in Australia and other parts of the world.

Challenges and enablers of mainstreaming WSCs	The details of challenges	AU	US	EU	Asia (CHN, SEA, ME)	AF
Institutional arrangements	Lack of cooperation between government sectors at urban scales	×	×			
	Lack of clarity in roles and responsibilities, especially after completion of projects	×	×			
	Lack of communication and collaboration strategies between disciplines	×	×			
	Lack of interest in change among developers			×		
	Lack of innovation and integration of professionals because of the top-down governance structure				×	
Jurisdiction, regulations and approval process	Impact of politics on climate change actions		×			
	Complexity of jurisdiction and bureaucracy/ governance structure	×	×	×		
	Power of private ownership		×			
	Lack a systematic approach at the city scale	×	×			
	Lack of system thinking to find the reason of problems				×	×
	Lack of regulations for stormwater management				×	×
	Conflicts over priorities identified to address the challenges	×	×	×	×	×
	Old culture of managing stormwater in local governments that prevents action for change	×				
Evaluation tools, technical standards, and innovation	Lack of familiarity of municipalities with the new techniques	×	×			
	Lack of contextualized standards	×	×			×
	Lack of monitoring and measurement and evaluation plans and tools		×			
	Old infrastructure and low capacity of existing infrastructure to adapt to change		×	×	×	
	Lack of cost – benefit evaluation tools/ models	×	×	×	×	×
Socio-cultural context	Lack of awareness about climate change actions				×	
	Social equity issues		×		×	×
	Lack of community engagement		×		×	×
	Inhabit areas at higher risk of climate adverse impact					×
Monitoring and maintenance	Lack of knowledge about maintenance	×	×	×		
	Cutting maintenance costs	×	×	×		×
Financial feasibility and funding	Lack of funding plans for all scales of WSUD projects		×		×	
	Lack of human resources	×	×	×	×	×
	Lack of evidence on the financial viability of projects in the long-term	×	×	×		
	Lack of incentive programs	×	×			
	Pressure from developers about costs and implementation of WSUD	×				

The crosses indicate the countries to which the detailed challenges apply and require prioritization.
CHN: China, SEA: Southeast Asia, ME: Middle East.

particular context, it does not imply the absence of challenges but rather indicates that there are other priorities to be considered first.

In addition, given the unpredictability of climate change, ongoing investigation should seek in-depth details of specific stormwater management projects. A review of projects in different contexts, and exposed to unpredictable changes of climate, would offer valuable opportunities for scenarios development and identification of emerging challenges.

The interviewees stated that the majority of challenges in planning, design, and implementation of WSUD projects can be resolved through amendments in the policy framework. They emphasized the necessity of providing a collaborative framework across all agencies, experts, and stakeholders (Fig. 5) as supported by Malekpour et al. (2021). This framework should provide clear guidelines for all stages of WSUD, outlining the roles and responsibilities of all stakeholders, ensuring that each party, including communities, government bodies, professionals from various disciplines, and developers, understands their specific contributions and obligations throughout the entire WSUD process. It should also include the development of an integrated financial mechanism, budget allocation, and comprehensive consideration of all benefits in the evaluation criteria for all stakeholders. It would ensure that adequate funding is allocated to various aspects of the projects, from planning and design to implementation and maintenance.

In this paper, the interviews with experts from different disciplines demonstrate that required measures to transform to a WSC and to provide amenity, water security, social health and well-being and economic benefits is through managing and addressing the six nominated dynamic challenges of the projects. The experts emphasized the need to clarify roles and responsibilities and facilitate communication between stakeholders, practitioners, researchers and governments through regulations and collaboration while the way that this collaboration should be achieved is not fully covered in the literature.

6. Limitations and implications for further research

The focus of this research is Australia as one of the pioneers of WSUD. However, it lacks reflections from government professionals, academics, and practitioners in other countries to compare or contrast their experiences to see if they are consistent with what is experienced in

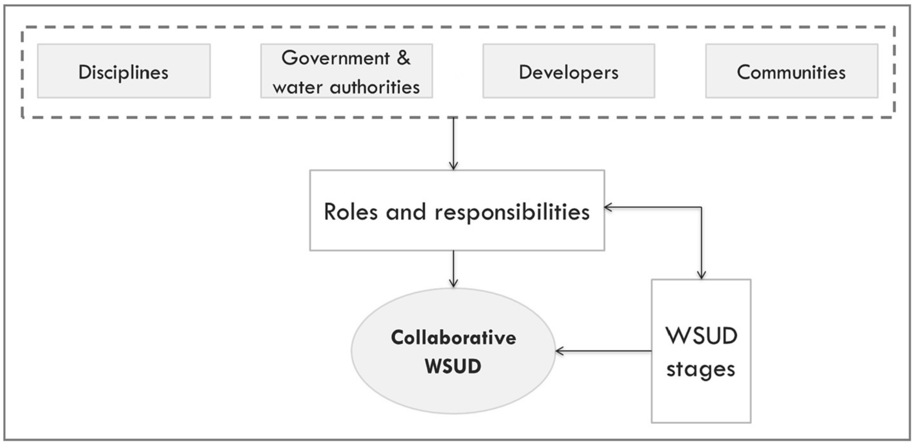

Fig. 5. Collaborative framework indicating the relationship between stakeholders, roles and responsibilities and WSUD stages.

Australia. We suggest the structure of this research can be applied in different countries to investigate drivers and challenges of implementing stormwater management projects and to compare the governance structures, policies, and the socio-cultural context. This also facilitates knowledge sharing and would allow comparative case studies to be created with the existing one such as SWITCH project. While the SWITCH projects are comprehensive cases that emphasize conducting research through demand, showcasing initiatives, enabling collaborative learning among multiple stakeholders, and providing training and capacity-building opportunities, there is still a demand for analysing more case studies and sharing their outcomes. The lessons can provide guidance to researchers, practitioners, and stakeholders and provide a platform to share the experience of other countries.

Australia, being a prominent pioneer in stormwater management, is currently experiencing the impacts of climate change. There are governance challenges in achieving WSCs across the country. While this paper primarily concentrates on Australia, it is important to note the similarities and differences between countries, as explained in comparing Australia with other contexts (Table 3). Therefore, it is recommended for future research to explore how the lessons learned can be effectively translated into specific contexts. More research is needed to understand the socio-cultural aspects of water governance in both developed and developing countries, identify optimum water governance structures and to compare policies at local, city, and regional scales.

In addition, communities play an important role in the approval, progress, and performance of WSUD projects. However, different criteria apply in different social and cultural contexts. There is, therefore, an opportunity for further research on the integration of communities, across different socio-cultural contexts, with stormwater management projects.

7. Conclusion

We have investigated the perception of water management professionals about the challenges in planning and design, implementation, management and maintenance of WSUD projects. We interviewed researchers, engineers, landscape architects and designers, urban planners and government officials in different Australian cities to understand how they perceive barriers and drivers of WSUD projects. We examined efforts that have been made to address WSUD challenges and to inform the next water management steps. The key contribution of this research is a novel WSUD evaluation assessment methodology based on the viewpoint of a broad range of built environment disciplines. The data analysis facilitates evaluation of WSUD through comparative insight of challenges and enablers beyond simple overlaying of results.

The results indicate that there are challenges in six main areas of research and practice of WSUD including institutional arrangements and standards, technical challenges and innovative approaches, the approval process, socio-cultural context, monitoring and maintenance, and finance. Based on the perspectives of water professionals, nature based WSUD projects are critical for managing stormwater in Australian cities that are facing extreme climate change events. The results are not just limited to Australia as there are many challenges in stormwater management that are common to other parts of the world. The results demonstrate that there should be clearer regulations and standards for managing stormwater. All the respondents to the survey believe that stormwater has not been prioritized in Australia although it can play a critical role in urban areas. The results also revealed that there is limited integration and collaboration between disciplines which would otherwise raise awareness and enhance climate-change adaptation knowledge and capacity. However, there are differences between countries in governance structures, stakeholders and community engagement policies, priorities, socio-cultural contexts and the broad subject of social equity. Thus, climate change adaptation, in combination with innovative technologies, should be considered as a context-specific.

All the respondents believed that WSUD projects involve complex organization, departments, and governance structure, and it is important to consider a regulation and approval process to engage with them. Lack of a robust structure of regulations and standards can also result in financial conflicts in some of these projects, for example a consensus indicating who is responsible to pay for the project. In all WSUD projects, the main challenge is to maintain the projects after completion.

This paper contributes towards mainstreaming WSUD projects through indicating barriers exploring potentials and providing recommendations to enhance their functions in Australia and internationally. In a global context, Australian water management is a case study example for other countries, demonstrating how to provide green areas through WSUD projects to develop resilient and liveable urban areas. If WSUD is designed and implemented considering all six challenges in advance, such projects seem to work for cities with different geographical and social backgrounds.

Some of our findings align with previously researched barriers and drivers of WSUD in the literature, while some challenges align only with the Australian context and may not be applicable to other countries. The main challenge in Australia is not about techniques of WSUD construction, it is about regulations, standards, and local and state collaboration on these projects. However, in countries like China and in the Middle East, the main challenge is the top-down governance structure of these projects and in some cases, the techniques applied to implement WSUD. The complex structure of urban water management in different political, cultural and social contexts confirms the necessity of building a contextual understanding of WSUD projects to investigate the challenges. This can influence the specific strategies and approaches required to improve the sustainability of these projects in the future.

This paper conducted interviews with professionals discussing WSUD projects in both new and existing urban settings. However, further research is required to assess the extent of WSUD integration with urban areas and new developments and its impact on urban resilience.

CRediT authorship contribution statement

Behnaz Avazpour: Conceptualization, Methodology, Formal analysis, Investigation, Writing Original draft preparation, Writing Review and Editing, Data Curation, Visualization, Project administration, Validation. **Paul Osmond:** Conceptualization, Methodology, Writing Review and Editing, Project administration. **Linda Corkery:** Conceptualization, Methodology, Writing Review and Editing, Project administration. All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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References

Ahammed, F. (2017). A review of water-sensitive urban design technologies and practices for sustainable stormwater management. *Sustainable Water Resources Management, 3*(3), 269–282. https://doi.org/10.1007/S40899-017-0093-8

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning, 125*, 254–259. https://doi.org/10.1016/J.LANDURBPLAN.2014.01.020

Aina, Y. A., Wafer, A., Ahmed, F., & Alshuwaikhat, H. M. (2019). Top-down sustainable urban development? Urban governance transformation in Saudi Arabia. *Cities, 90*, 272–281. https://doi.org/10.1016/j.cities.2019.03.003

Akhtar, N., Syakir Ishak, M. I., Bhawani, S. A., & Umar, K. (2021). Various natural and anthropogenic factors responsible for water quality degradation: A review. *Water, 13* (19), 2660. https://doi.org/10.1007/s11269-009-9571-6

Alves, A., Gersonius, B., Kapelan, Z., Vojinovic, Z., & Sanchez, A. (2019). Assessing the co-benefits of green-blue-grey infrastructure for sustainable urban flood risk management. *Journal of Environmental Management, 239*, 244–254. https://doi.org/10.1016/J.JENVMAN.2019.03.036

Ashley, R., Lundy, L., Ward, S., Shaffer, P., Walker, L., Morgan, C., Saul, A., Wong, T., & Moore, S. (2013). Water-sensitive urban design: Opportunities for the UK. *Proceedings of the Institution of Civil Engineers: Municipal Engineer, 166*(2), 65–76. https://doi.org/10.1680/MUEN.12.00046/ASSET/IMAGES/SMALL/MUEN166-065-F6.GIF

Avazpour, B., Osmond, P., & Corkery, L. (2018). Rehabilitating dryland river systems in arid and semi-arid environments focusing on water sensitive urban design approaches. *OIDA International Journal of Sustainable Development, 11*(12), 11–20.

Belden, E., & Steele, N. L. (2011). Green infrastructure and sustainable design for streets: The Elmer avenue neighborhood retrofit demonstration. In *World environmental and Water resources congress 2011: Bearing knowledge for sustainability* (pp. 3166–3173).

Benedict, M., & McMahon, E. (2006). *Green Infrastructure - Linking Landscapes and Communities*. Washington, DC: Island Press.

Bossio, D., Geheb, K., & Critchley, W. (2010). Managing water by managing land: Addressing land degradation to improve water productivity and rural livelihoods. *Agricultural Water Management, 97*(4), 536–542.

Brears, R. C. (2018). From traditional grey infrastructure to blue-green infrastructure. *Blue and Green Cities, 1–41*. https://doi.org/10.1057/978-1-137-59258-3_1

Brodnik, C., & Brown, R. (2018). Strategies for developing transformative capacity in urban water management sectors: The case of Melbourne, Australia. *Technological Forecasting and Social Change, 137*, 147–159. https://doi.org/10.1016/J.TECHFORE.2018.07.037

Brown, R. R., Farrelly, M. A., & Loorbach, D. A. (2013). Actors working the institutions in sustainability transitions: The case of Melbourne's stormwater management. *Global Environmental Change, 23*(4), 701–718.

Brown, R. R., Keath, N., & Wong, T. H. F. (2009). Urban water management in cities: Historical, current and future regimes. *Water Science and Technology, 59*(5), 847–855. https://doi.org/10.2166/WST.2009.029

Butterworth, J., McIntyre, P., & da Silva Wells, C. (2011). *SWITCH in the city: Putting urban water management to the test*. The Hague: The Netherlands, IRC International Water and Sanitation Centre.

Chan, F. K. S., Griffiths, J. A., Higgitt, D., Xu, S., Zhu, F., Tang, Y. T., … Thorne, C. R. (2018). "Sponge City" in China—A breakthrough of planning and flood risk management in the urban context. *Land Use Policy, 76*, 772–778.

Choi, L., & Mcilrath, B. (2017). *Policy frameworks for water sensitive urban design in 5 Australian cities*.

CNT. (2023). Center for Neighborhood Technology, water. https://cnt.org/water.

Collins, R., Johnson, D., Crilly, D., Rickard, A., Neal, L., Morse, A., Walker, M., Lear, R., Deasy, C., Paling, N., Anderton, S., Ryder, C., Bide, P., & Holt, A. (2020). Collaborative water management across England – An overview of the Catchment Based Approach. *Environmental Science & Policy, 112*, 117–125. https://doi.org/10.1016/J.ENVSCI.2020.06.001

Cook, S., van Roon, M., Ehrenfried, L., LaGro, J., & Yu, Q. (2019). WSUD "best in class"—Case studies from Australia, New Zealand, United States, Europe, and Asia. Approaches to water sensitive urban design: Potential, design, ecological health, urban greening. *Economics, Policies, and Community Perceptions, 561–585*. https://doi.org/10.1016/B978-0-12-812843-5.00027-7

Coutts, A. M., Tapper, N. J., Beringer, J., Loughnan, M., & Demuzere, M. (2012). Watering our cities: The capacity for Water Sensitive Urban Design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography, 37*(1), 2–28. https://doi.org/10.1177/0309133312461032

Cunningham, D. (2017). *Cooks River naturalisation*. Sydney Water. Retrieved from https://cooksriver.org.au.

Cutts, B. B., Muñoz-Erickson, T. A., & Shutters, S. T. (2015). Public representation in water management—A network analysis of organization and public perceptions in Phoenix, Arizona. *Society & Natural Resources, 28*(12), 1340–1357. https://doi.org/10.1080/08941920.2015.1020581

DCLG. (2007). *Department for Communities and Local Government. Development and flood risk: A practice guide companion to PPS25 'LivingDraft'*. London: CrownPrint.

DCLG. (2011). *Code for sustainable homes – technical guide*. London, UK: DCLG.

DCLG. (2012). *Department for Communities and Local Government*. Crown copyright, London: National Planning Policy Framework.

Dhakal, K. P., & Chevalier, L. R. (2017). Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. *Journal of Environmental Management, 203*, 171–181. https://doi.org/10.1016/J.JENVMAN.2017.07.065

Donofrio, J., Kuhn, Y., McWalter, K., & Winsor, M. (2009). Research article: Water-sensitive urban design: An emerging model in sustainable design and comprehensive water-cycle management. *Environmental Practice, 11*(3), 179–189. https://doi.org/10.1017/S1466046609990263

Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., & Vandewoestijne, S. (2017). Nature-based solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environmental Research, 159*, 509–518. https://doi.org/10.1016/J.ENVRES.2017.08.032

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., … Mikkelsen, P. S. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal, 12*(7), 525–542. https://doi.org/10.1080/1573062X.2014.916314

Fogarty, J., van Bueren, M., & Iftekhar, M. S. (2021). Making waves: Creating water sensitive cities in Australia. *Water Research, 202*, Article 117456. https://doi.org/10.1016/J.WATRES.2021.117456

Furlong, C., de Silva, S., & Guthrie, L. (2016). Planning scales and approval processes for IUWM projects; lessons from Melbourne, Australia. *Water Policy, 18*(3), 783–802. https://doi.org/10.2166/WP.2015.118

Furlong, C., Dobbie, M., Morison, P., Dodson, J., & Pendergast, M. (2019). Infrastructure and urban planning context for achieving the visions of integrated urban water management and water sensitive urban design: The case of Melbourne. In *Approaches to water sensitive urban design: Potential, design, ecological health, urban greening, economics, policies, and community perceptions* (pp. 329–350). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-812843-5.00016-2.

Furlong, C., Gan, K., & de Silva, S. (2016). Governance of integrated urban water management in Melbourne, Australia. *Utilities Policy, 43*, 48–58. https://doi.org/10.1016/J.JUP.2016.04.008

Gabe, J., Trowsdale, S., & Vale, R. (2009). Achieving integrated urban water management: Planning top-down or bottom-up? *Water Science and Technology, 59* (10), 1999–2008. https://doi.org/10.2166/wst.2009.196

Girard, C., Pulido-Velazquez, M., Rinaudo, J. D., Pagé, C., & Caballero, Y. (2015). Integrating top–down and bottom–up approaches to design global change adaptation at the river basin scale. *Global Environmental Change, 34*, 132–146. https://doi.org/10.1016/j.gloenvcha.2015.07.002

Gogate, N. G., Kalbar, P. P., & Raval, P. M. (2017). Assessment of stormwater management options in urban contexts using multiple attribute decision-making. *Journal of Cleaner Production, 142*, 2046–2059. https://doi.org/10.1016/J.JCLEPRO.2016.11.079

Han, S., & Kuhlicke, C. (2021). Barriers and drivers for mainstreaming nature-based solutions for flood risks: The case of South Korea. *International Journal of Disaster Risk Science, 12*(5), 661–672. https://doi.org/10.1007/S13753-021-00372-4/TABLES/4
Hawken, S., Avazpour, B., Harris, M. S., Marzban, A., & Munro, P. G. (2021). Urban megaprojects and water justice in Southeast Asia: Between global economies and community transitions. *Cities, 113*, Article 103068. https://doi.org/10.1016/J.CITIES.2020.103068
Hawken, S., Sepasgozar, S. M. E., Prodanovic, V., Jing, J., Bakelmun, A., Avazpour, B., … Zhang, K. (2021). What makes a successful Sponge City project? Expert perceptions of critical factors in integrated urban water management in the Asia-Pacific. *Sustainable Cities and Society, 75*, Article 103317. https://doi.org/10.1016/J.SCS.2021.103317
He, B. J., Zhu, J., Zhao, D. X., Gou, Z. H., Qi, J.d., & Wang, J. (2019). Co-benefits approach: Opportunities for implementing sponge city and urban heat island mitigation. *Land Use Policy, 86*, 147–157. https://doi.org/10.1016/J.LANDUSEPOL.2019.05.003
Horton, B., Digman, C. J., Ashley, R. M., & Gill, E. (2015). *BeST (Benefits of SuDS Tool) Technical Guidance*. London, UK: CIRIA.
Horton, J., Macve, R., & Struyven, G. (2004). Qualitative research: Experiences in using semi-structured interviews. *The Real Life Guide to Accounting Research, 339–357*. https://doi.org/10.1016/B978-008043972-3/50022-0
Howe, C., & Mitchell, C. (2011). *Water sensitive cities. Cities of the future series*. London: IWA Publishing. ISBN: 9781780400921.
IPCC. (2022). In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, … B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (p. 3056). Cambridge, UK and New York, NY, USA: Cambridge University Press. https://doi.org/10.1017/9781009325844.
Irvine, K., Loc, H. H., Sovann, C., Suwanarit, A., Likitswat, F., Jindal, R., Koottatep, T., Gaut, J., Chua, L., Qi, L. W., & De Wandeler, K. (2021). Bridging the form and function gap in urban green space design. *The Journal of Water Management Modeling (JWMM), 29*, 1–19. https://doi.org/10.14796/JWMM.C476
Islam, A., Hassini, S., & El-Dakhakhni, W. (2021). A systematic bibliometric review of optimization and resilience within low impact development stormwater management practices. *JHyd, 599*, Article 126457. https://doi.org/10.1016/J.JHYDROL.2021.126457
Johnson, C., Tilt, J. H., Ries, P. D., & Shindler, B. (2019). Continuing professional education for green infrastructure: Fostering collaboration through interdisciplinary trainings. *Urban Forestry & Urban Greening, 41*, 283–291. https://doi.org/10.1016/J.UFUG.2019.04.021
Kuller, M., Farrelly, M., Deletic, A., & Bach, P. M. (2018). Building effective planning support systems for green urban water infrastructure—Practitioners' perceptions. *Environmental Science & Policy, 89*, 153–162. https://doi.org/10.1016/J.ENVSCI.2018.06.011
Larson, K. L., Polsky, C., Gober, P., Chang, H., & Shandas, V. (2013). Vulnerability of water systems to the effects of climate change and urbanization: A comparison of Phoenix, Arizona and Portland, Oregon (USA). *Environmental Management, 52*(1), 179–195. https://doi.org/10.1007/s00267-013-0072-2
Lawrence, R. J. (2015). Advances in transdisciplinarity: Epistemologies, methodologies and processes. *Futures, 65*, 1–9. https://doi.org/10.1016/J.FUTURES.2014.11.007
Legislation, U. K. (2010). Flood and Water Management Act. https://www.legislation.gov.uk.
Leonard, R., Iftekhar, S., Green, M., & Walton, A. (2019). Community perceptions of the implementation and adoption of WSUD approaches for stormwater management. In *Approaches to water sensitive urban design: Potential, design, ecological health, urban greening, economics, policies, and community perceptions* (pp. 499–522). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-812843-5.00024-1.
Loftus, A., & March, H. (2019). Integrating what and for whom? Financialisation and the Thames Tideway Tunnel. *Urban Studies, 56*(11), 2280–2296.
LPS. (2011). Elmer Avenue Neighborhood Retrofit. Retrieved May 10, 2022, from https://www.landscapeperformance.org/case-study-briefs/elmer-avenue-neighborhood-retrofit.
Madonsela, B., Koop, S., van Leeuwen, K., & Carden, K. (2019). Evaluation of water governance processes required to transition towards water sensitive urban design—An indicator assessment approach for the City of Cape Town. *Water, 11*(2), 292. https://doi.org/10.3390/W11020292
Madsen, H. M., Brown, R., Elle, M., & Mikkelsen, P. S. (2017). Social construction of stormwater control measures in Melbourne and Copenhagen: A discourse analysis of technological change, embedded meanings and potential mainstreaming. *Technological Forecasting and Social Change, 115*, 198–209. https://doi.org/10.1016/J.TECHFORE.2016.10.003
Malekpour, S., Tawfik, S., & Chesterfield, C. (2021). Designing collaborative governance for nature-based solutions. *Urban Forestry & Urban Greening, 62*, Article 127177. https://doi.org/10.1016/J.UFUG.2021.127177
Mguni, P., Abrams, A., Herslund, L. B., Carden, K., Fell, J., & Armitage, N. (2022). Towards water resilience through nature-based solutions in the global south? Scoping the prevailing conditions for water sensitive design in Cape Town and Johannesburg. *Environmental Science & Policy, 136*, 147–156. https://doi.org/10.1016/j.envsci.2022.05.020
Mondal, S., & Patel, P. P. (2018). Examining the utility of river restoration approaches for flood mitigation and channel stability enhancement: A recent review. *Environmental Earth Sciences, 77*, 1–25.
Moosavi, S., Browne, G. R., & Bush, J. (2021). Perceptions of nature-based solutions for urban water challenges: Insights from Australian researchers and practitioners. *Urban Forestry & Urban Greening, 57*, Article 126937. https://doi.org/10.1016/J.UFUG.2020.126937
Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2016). Verification strategies for establishing reliability and validity in qualitative research. *International Journal of Qualitative Methods, 1*(2), 13–22. https://doi.org/10.1177/160940690200100202
Mukhtarov, F., Dieperink, C., Driessen, P., & Riley, J. (2019). Collaborative learning for policy innovations: Sustainable urban drainage systems in Leicester, England. *Journal of Environmental Policy & Planning, 21*(3), 288–301.
Nika, C. E., Gusmaroli, L., Ghafourian, M., Atanasova, N., Buttiglieri, G., & Katsou, E. (2020). Nature-based solutions as enablers of circularity in water systems: A review on assessment methodologies, tools and indicators. *Water Research, 183*, Article 115988.
NRC. (2009). *Urban stormwater management in the United States* (pp. 1–598). National Research Council Council. https://doi.org/10.17226/12465
Oral, H. V., Carvalho, P., Gajewska, M., Ursino, N., Masi, F., Hullebusch, E. D. V., Kazak, J. K., Exposito, A., Cipolletta, G., Andersen, T. R., & Finger, D. C. (2020). A review of nature-based solutions for urban water management in European circular cities: A critical assessment based on case studies and literature. *Blue-Green Systems, 2*(1), 112–136. https://doi.org/10.2166/bgs.2020.932
Prosser, T., Morison, P. J., & Coleman, R. A. (2015). Integrating stormwater management to restore a stream: Perspectives from a waterway management authority. *Freshwater Science, 34*(3), 1186–1194. https://doi.org/10.1086/682566/SUPPL_FILE/APPENDIXS2.PDF
Qiao, X.-J., Kristoffersson, A., & Randrup, T. B. (2018). Challenges to implementing urban sustainable stormwater management from a governance perspective: A literature review. *Journal of Cleaner Production, 196*, 943–952. https://doi.org/10.1016/j.jclepro.2018.06.049
Radcliffe, J. C. (2019). History of water sensitive urban design/low impact development adoption in Australia and internationally. In *Approaches to water sensitive urban design* (pp. 1–24). Woodhead Publishing.
Richards, L. (1999). *Using NVIVO in qualitative research*. Sage.
Roy, A. H., Wenger, S. J., Fletcher, T. D., Walsh, C. J., Ladson, A. R., Shuster, W. D., … Brown, R. (2008). Impediments and solutions to sustainable, watershed-scale urban stormwater management: Lessons from Australia and the United States. *Environmental Management, 42*(2), 344–359. https://doi.org/10.1007/s00267-008-9119-1
Ruangpan, L., Vojinovic, Z., di Sabatino, S., Leo, L. S., Capobianco, V., Oen, A. M. P., … Lopez-Gunn, E. (2020). Nature-based solutions for hydro-meteorological risk reduction: A state-of-the-art review of the research area. *Natural Hazards and Earth System Sciences, 20*(1), 243–270. https://doi.org/10.5194/NHESS-20-243-2020
Saldaña, J. (2021). *The coding manual for qualitative researchers*. Sage.
Schifman, L. A., Herrmann, D. L., Shuster, W. D., Ossola, A., Garmestani, A., & Hopton, M. E. (2017). Situating Green infrastructure in context: A framework for adaptive socio-hydrology in cities. *Water Resources Research, 53*(12), 10139–10154. https://doi.org/10.1002/2017WR020926
Sharma, A., Gardner, T., & Begbie, D. (2018). *Approaches to water sensitive urban design: Potential, design, ecological health, urban greening, economics, policies, and community perceptions*. Woodhead Publishing.
Sharma, A. K., Cook, S., Tjandraatmadja, G., & Gregory, A. (2012). Impediments and constraints in the uptake of water sensitive urban design measures in greenfield and infill developments. *Water Science and Technology, 65*(2), 340–352. https://doi.org/10.2166/WST.2012.858
Sharma, A. K., Pezzaniti, D., Myers, B., Cook, S., Tjandraatmadja, G., Chacko, P., … Walton, A. (2016). Water sensitive urban design: An investigation of current systems, implementation drivers, community perceptions and potential to supplement urban water services. *Water, 8*(7), 272. https://doi.org/10.3390/W8070272
Sukhdev, P., Wittmer, H., & Miller, D. (2014). The economics of ecosystems and biodiversity (TEEB): Challenges and responses. In *Nature in the balance: The economics of biodiversity* (pp. 135–152). Oxford University Press.
The Parliament of Australia report. (2016). *Stormwater management in Australia. Environment and Communications: References Committee*. Parliament House, Canberra: The Senate Printing Unit. © Commonwealth of Australia 2015 ISBN 978-1-76010-338-5.
Trapp, J. H., Kerber, H., & Schramm, E. (2017). Implementation and diffusion of innovative water infrastructures: Obstacles, stakeholder networks and strategic opportunities for utilities. *Environmental Earth Sciences, 76*, 1–14.
Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over a 15-year period. *BMC Medical Research Methodology, 18*(1), 1–18. https://doi.org/10.1186/S12874-018-0594-7/TABLES/3
Vogler, D., Macey, S., & Sigouin, A. (2017). Stakeholder analysis in environmental and conservation planning. *Lessons in conservation, 7*(7), 5–16.
Water, U. K. (2021). *Design and construction guidance for the sewage sector (the code)*.
Weber, T., Stewart, J., & Dahlenburg, J. (2009). The importance of retrofitting WSUD in restoring urbanised catchments. In *, Vol. 7. 6th International Conference on Water Sensitive Urban Design, Perth, WA* (pp. 11–18).
Werbeloff, L., & Brown, R. R. (2016). Using policy and regulatory frameworks to facilitate water transitions. *Water Resources Management, 30*(11), 3653–3669. https://doi.org/10.1007/S11269-016-1379-6/FIGURES/3
Whiteoak, K. (2019). Approaches to water sensitive urban design: Potential, design, ecological health, urban greening. In *Economics, policies, and community perceptions* (pp. 287–302). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-812843-5.00014-9.

Wong, T. (2015). Water sensitive urban design - the journey thus far. *Australasian Journal of Water Resources, 10*(3), 213–222. https://doi.org/10.1080/13241583.2006.11465296

Wong, T., & Brown, R. R. (2008). *Transitioning to water sensitive cities: Ensuring resilience through a new hydro-social contract (p. CD Rom-CD Rom)*. Iwa Publishing. https://research.monash.edu/en/publications/transitioning-to-water-sensitive-cities-ensuring-resilience-throu.

Wong, T., Rogers, B. C., & Brown, R. (2020). Transforming cities through water-sensitive principles and practices. *One Earth, 3*(4), 436–447. https://doi.org/10.1016/j.oneear.2020.09.012

Xia, J., Zhang, Y., Xiong, L., He, S., Wang, L., & Yu, Z. (2017). Opportunities and challenges of the Sponge City construction related to urban water issues in China. *Science China Earth Sciences, 60*(4).

Xu, C., Tang, T., Jia, H., Xu, M., Xu, T., Liu, Z., Long, Y., & Zhang, R. (2019). Benefits of coupled green and grey infrastructure systems: Evidence based on analytic hierarchy process and life cycle costing. *Resources, Conservation and Recycling, 151*, Article 104478. https://doi.org/10.1016/J.RESCONREC.2019.104478

Young, D., & Essex, S. (2019). Climate change adaptation in the planning of England's coastal urban areas: Priorities, barriers and future prospects. *Journal of Environmental Planning and Management, 63*(5), 912–934. https://doi.org/10.1080/09640568.2019.1617680

Zevenbergen, C., Fu, D., & Pathirana, A. (2018). Transitioning to sponge cities: Challenges and opportunities to address urban water problems in China. *Water, 10*(9), 1230. https://doi.org/10.3390/W10091230

Zuniga-Teran, A. A., Staddon, C., de Vito, L., Gerlak, A. K., Ward, S., Schoeman, Y., Hart, A., & Booth, G. (2019). Challenges of mainstreaming green infrastructure in built environment professions. *Journal of Environmental Planning and Management, 63*(4), 710–732. https://doi.org/10.1080/09640568.2019.1605890