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Editorial

Advances in Urban Hydrology and Stormwater Management

Shirley Gato-Trinidad [1,*], Upaka Rathnayake [2] and Kuok King Kuok [3]

[1] Department of Civil and Construction Engineering, School of Engineering, Swinburne University of Technology, Hawthorn 3122, VIC, Australia
[2] Department of Civil Engineering and Construction, Faculty of Engineering and Design, Atlantic Technological University, F91 YW50 Sligo, Ireland; upaka.rathnayake@atu.ie
[3] Department of Civil Engineering, Faculty of Engineering, Computing & Science, School of Engineering and Science, Swinburne University of Technology Sarawak Campus, Kuching 93350, Sarawak, Malaysia
* Correspondence: sgatotrinidad@swin.edu.au

1. Overview of Recent Developments in the Field

Rapid global population growth and accelerating urbanisation continue to reshape hydrological processes and intensify stormwater management challenges. As of 28 September 2026, the world population has reached 8.3 billion [1], with cities now home to 45% of the global population—more than double the proportion recorded in 1950 [2]. Urban expansion has increased impervious surfaces, altered natural drainage pathways, and amplified flood risk, making traditional "end-of-pipe" stormwater systems increasingly inadequate for contemporary conditions. As cities expand and climate patterns shift, the science and practice of urban hydrology and stormwater management become ever more central to sustainable urban development worldwide [3].

Decentralised stormwater systems have emerged as alternatives, yet they are often designed for historical or simplified storm conditions and may fail under extreme rainfall events. Climate change further complicates design and modelling by altering rainfall intensity, storm duration, and hydrological response. These shifts raise critical questions:

- Are current modelling approaches valid under changing climatic regimes?
- Can default parameters derived from historical records reliably represent future conditions?
- How can hydrology and water quality modelling be better integrated?
- Do existing flood maps adequately reflect evolving urban form and rainfall patterns?
- Can design guidelines adapt quickly enough to incorporate climate-driven change?
- What role should blue–green infrastructure play in increasingly dense cities?

Contemporary stormwater management increasingly combines engineered systems with nature-based solutions (NbS). Green infrastructure such as rain gardens, green roofs, bioswales, and permeable pavements enhances infiltration, evapotranspiration, and pollutant removal while reducing peak flows. Blue–green networks provide multifunctional benefits, including flood mitigation, improved water quality, biodiversity enhancement, urban cooling, and climate resilience. Advances in monitoring, modelling, and data analytics now enable finer prediction of urban flow regimes and more effective optimisation of integrated stormwater portfolios.

Against this backdrop, this Special Issue aims to showcase innovative research and emerging developments in urban hydrology and stormwater management in the context of rapid population growth, climate change, evolving urban landscapes, and increasing global pressures on water security. It brings together contributions from diverse geographical, socio-economic, and climatic settings, including Australia, Austria, China, India, Spain, and

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the United States, highlighting the breadth of contemporary challenges and the variety of context-specific solutions being explored worldwide.

2. Knowledge Gaps Addressed by This Special Issue

Urban hydrology and stormwater management are undergoing rapid transformation as cities confront intensifying climatic extremes, expanding urbanisation, ageing infrastructure, and rising expectations for resilient, sustainable water systems. Despite significant advances, persistent gaps remain in modelling stormwater quality across diverse land uses, integrating governance and planning frameworks, improving real-time flood monitoring, strengthening infrastructure under compound hazards, and deploying nature-based solutions at scale. Key challenges include:

- The long-standing difficulty of modelling runoff quality in ways that capture contributions from diverse land-use types;
- Limitations in widely used tools such as MUSIC and SWMM ranging from the inability to simulate heavy metals to subjective, parameter-heavy calibration processes and the need for more accurate, real-time methods to estimate urban floodwater depth;
- Governance and institutional barriers further constrain system-scale effectiveness, with fragmented planning, rigid capital programmes and weak stakeholder alignment preventing stormwater systems from functioning as integrated urban infrastructure;
- Insufficient understanding of roof typology impacts on urban hydrology;
- Limited frameworks for assessing the seismic vulnerability of gravity dams under compound climate stresses;
- Lack of city-scale prioritisation tools for blue–green infrastructure placement;
- The need for more systematic approaches for analysing seasonal flood dynamics and to identify the most sustainable Nature-based Solutions for mitigating extreme events and restoring ecosystem services.

This Special Issue, "Advances in Urban Hydrology and Stormwater Management", brings together ten papers that collectively address these challenges through methodological innovation, applied research, and interdisciplinary perspectives.

3. How This Special Issue Addresses These Gaps

A central theme emerging from the contributions is the need for more robust and integrated modelling approaches. Teang et al. (2026) [Contribution 1] demonstrate how coupling exponential buildup–washoff functions with MUSLE within PCSWMM improves characterisation of runoff quality in mixed urban–rural catchments in Geelong, Australia. As noted, "*The results show the need for spatially targeted management strategies to improve stormwater runoff quality*…" Their findings highlight the potential of cascading wetlands as key elements of nature-based stormwater systems. Complementing this, Yang et al. (2025) [Contribution 4] extend MUSIC's capabilities to simulate heavy metals in constructed wetlands across Greater Melbourne, Australia, addressing a long-standing limitation in preliminary planning, and Ahmadi et al. (2025) [Contribution 7] automate SWMM calibration using PySWMM and Pymoo in a sewershed in Virginia, US, reducing subjectivity and improving reliability.

Beyond modelling, several papers interrogate the institutional and infrastructural dimensions of urban water management. Grigg (2025) [Contribution 2] identifies fragmented planning processes, rigid capital programmes, and uneven stakeholder influence as barriers to system-scale transformation, calling for a coordinated road map that integrates engineering, planning, and public administration. Lin et al. (2025) [Contribution 3] advance real-time flood resilience by developing an AI-enabled multimodal framework that

uses social media images and text to rapidly estimate flood depths without costly training or additional hardware. As described, "*an automated web crawler collects flood images and their textual descriptions… eliminating the need for additional hardware investments*." Kim and Xu (2025) [Contribution 5] address infrastructure vulnerability by introducing a scaled boundary finite element method for assessing gravity dam performance in South Asia (India) under concurrent seismic and hydrological loading, offering improved accuracy and computational efficiency.

The Special Issue also expands understanding of urban hydrological processes and their interaction with built form. Chen et al. (2025) [Contribution 6] show that roof typology in Hangzhou, China significantly influences water retention, drainage behaviour, and flood risk, providing actionable insights for urban design and flood mitigation. Reinstaller et al. (2025) [Contribution 8] present a city-scale prioritisation workflow for blue–green infrastructure in Feldbach, Austria, demonstrating that strategic placement informed by flood hazard and heat island mapping yields substantially higher hydrological benefits.

Finally, contributions from Song and Wang (2025) [Contribution 9] and Sánchez-García et al. (2024) [Contribution 10] address seasonal flood dynamics in the Yellow River, Ningxia, China, and nature-based solutions for extreme events in the Llobregat River, Catalonia, Spain. Their studies offer scientific foundations for flood-season staging, water environment management, and targeted NbS interventions that enhance resilience in riverine and urban systems.

Together, the papers in this Special Issue advance the scientific, technical, and governance foundations of urban hydrology and stormwater management. They offer new tools, frameworks, and evidence to support cities in designing more adaptive, integrated, and resilient stormwater systems capable of meeting the escalating challenges of climate change, urban growth, and environmental protection.

4. Future Research Directions and Emerging Opportunities

Future research should focus on:

- Integrating climate-adaptive parameters into hydrological and water quality models;
- Developing real-time, AI-enabled monitoring systems that leverage multimodal data streams;
- Advancing compound hazard modelling for critical infrastructure;
- Establishing economic and multi-criteria frameworks for BGI prioritisation;
- Strengthening interdisciplinary governance models that align planning, engineering, and community engagement;
- Expanding NbS evaluation methods to incorporate long-term ecosystem performance and climate resilience;
- Enhancing seasonal flood-regime analysis to support adaptive basin management.

5. Conclusions

This Special Issue highlights significant advances in urban hydrology and stormwater management, addressing long-standing modelling limitations, governance barriers, infrastructure vulnerabilities, and the need for scalable nature-based solutions. The contributions collectively strengthen the scientific and practical foundations required to design more adaptive, integrated, and resilient stormwater systems capable of meeting the escalating challenges posed by climate change, urban growth, and environmental protection across the globe.

Building on this success, a second edition of this Special Issue has been launched (web link: https://www.mdpi.com/journal/hydrology/special_issues/GZ73DL9AQC (accessed on 3 October 2026)) to continue advancing knowledge, foster interdisciplinary collaboration, and address emerging challenges in urban hydrology and stormwater management.

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