ICCAUA Proceedings Journal
Proceedings of the international conference of contemporary affairs in architecture and urbanism-ICCAUA
Volume 9 (December 2026), 2610238

Journal homepage: https://journal.iccaua.com/

DOI: https://doi.org/10.38027/ICCAUA2026EN0238

Understanding the Impact of Water Sensitive Urban Design Principle in Blacktown City Council and the City of Sydney

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Received: 02.05.2026
Revised: 30.06.2026
Accepted: 01.07.2026
Available online: 10.07.2026

This article has been selected and peer-reviewed for publication in this journal as part of the 9th International Conference of Contemporary Affairs in Architecture and Urbanism, held on 7–8 May 2026 in Istanbul, Türkiye.

A b s t r a c t

This study evaluates the effectiveness of Water Sensitive Urban Design (WSUD) in improving urban water quality and environmental outcomes through two Australian case studies: the Sydney Park Water Re-use Project and the Angus Creek Stormwater Harvesting and Re-use Scheme. Using document analysis, geospatial analysis, and MUSIC X hydrological modelling, the research assesses stormwater flow and pollutant removal performance for total suspended solids, total nitrogen, and total phosphorus. Results show that both WSUD treatment trains reduce pollutant loads and improve stormwater quality compared to pre-development conditions. Sydney Park demonstrates increasing efficiency along its wetland sequence, while Angus Creek achieves notable pollutant reduction despite diverting only 10% of runoff. Although performance is limited by pump capacity and diversion constraints, the findings confirm that well-designed WSUD infrastructure enhances environmental health, supports water reuse, and reduces downstream impacts in urban catchments.

Key words: Water Sensitive Urban Design (WSUD); Stormwater Management; Pollutant Removal Efficiency; Urban Water Quality; Hydrological Modelling (MUSIC X).

1. Introduction

The rapid population growth in Australia has driven extensive urban development, resulting in the expansion of impervious surfaces and significant alterations to the natural environment. These changes include modifications to landscapes and streams, shifts in local fauna diversity, and impacts on air quality, all of which influence the hydrological functioning of urban regions (Xiong, Sun, & Ren, 2020). Urbanisation has also introduced challenges such as stormwater management and water quality control. The increase in impervious surfaces reduces natural infiltration, causing stormwater to accumulate and be conveyed rapidly across urban areas. As this runoff travels over hard surfaces, it collects pollutants and contaminants, which are subsequently transported into downstream waterways, contributing to the degradation of aquatic ecosystems. Water Sensitive Urban Design (WSUD) offers a framework for addressing these issues by managing stormwater in ways that integrate ecological sustainability with urban planning needs (Mangangka, 2018).

This principle aims to restore elements of the natural water cycle within urban environments, mitigating the impacts of traditional stormwater systems (Khalaji, Zhang, & Sharma, 2022). To address the challenges associated with traditional stormwater management, the concept of WSUD offers a holistic approach that extends beyond stormwater to include wastewater management, water reuse, and green infrastructure. It aims to restore balance to the urban water cycle, benefiting both built and natural environments. Hence, WSUD not only provides a wide range of solutions but is also flexible in its integration with existing and future infrastructure, serving as a planning and design framework for sustainable water cycle management. This study evaluates the impact of WSUD principles within the two selected local government areas (LGAs) of Blacktown City and the City of Sydney by analysing stormwater quality and assessing how improved stormwater outcomes support both urban and natural environments. By developing MUSIC X models to simulate complete WSUD projects from each LGA and analysing comparable case studies, this research aims to assess how WSUD techniques, such as bioretention systems, constructed wetlands, and permeable pavements are implemented in local government areas. It also evaluates the effectiveness of these techniques in enhancing water quality and biodiversity, reducing flood risk and thus contributing to community wellbeing.

2. Methodology

2.1 Approach

The study adopts a project-specific methodology combining document analysis, geospatial analysis and hydrological performance modelling to evaluate the effectiveness of WSUD in LGAs of the City of Sydney and the City of Blacktown in terms of the case studies of Sydney Park Water Re-use Project and the Angus Creek Stormwater Harvesting and Re-use Scheme, respectively. The extraction of site parameters for catchment characteristics, expected yields in water inflow, operational performance and design objectives were acquired through documentation readily available to the public from government agencies, councils and environmental organisations. Using these parameters assisted in the development of the MUSIC X model to provide a consistent and comparative assessment of pollutant removal efficiency and a hydrological outcome.

It is acknowledged that the reliance on secondary data limits the study's ability to validate findings through primary sources such as firsthand fieldwork. Additionally, the quality and comparability of performance data may vary due to differences in monitoring methods across the local government areas, state governments and international contexts, as well as variations in climate conditions and site characteristics among the study areas.

2.2 Data Collection

The collection of data was acquired through government and industry sources that are supported by geospatial measurements and modelling guidelines that fall into the categories below.

1. Local Government Documentation: Blacktown City Council and the City of Sydney Council provide project reports and strategic plans to catchment parameters, land-use classification, volumes for water inflow, treatment objectives and description of infrastructure.
2. Technical Guidelines and WSUD Standards: Blacktown City Council produced WSUD developer handbook MUSIC modelling and design guide (Blacktown City Council, 2020) and the City of Sydney WSUD Technical Guidelines (Evans *et.al*., 2020) provide hydrological and pollutant parameters to ensure a consistent model.
3. Geospatial Data: The area and boundaries of wetlands, ponds and basins associated with the WSUD projects were acquired using SixMaps. The subdivision of catchments was achieved using felt.com which also provided the area of the subdivision.
4. Project Parameters for Modelling: All inputs collected which include area, volume, pollutant loads etc. were inserted into MUSIC X and in accordance with respected technical guidelines.

Further, official government publications including council documents, guideline materials, technical reports and geospatial data sets from SixMaps were included in the data collection criteria. Non-official documents, unverified sources lacking transparency, unrelated material to WSUD and sources not containing specific information or information not relevant to parameters are excluded from the criteria.

2.3 Data Analysis

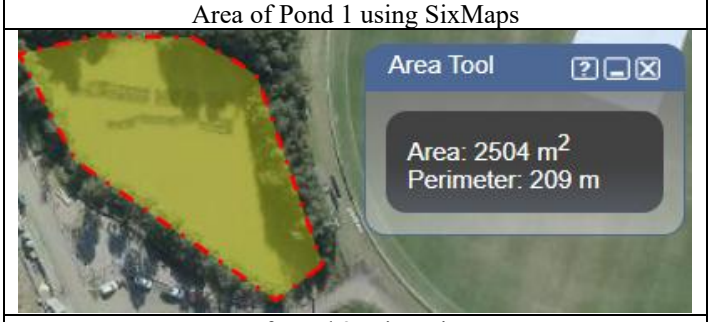
Geospatial analysis was conducted through SixMaps to acquire area of sub-catchments, wetlands and ponds to determine area parameters for MUSIC X model. This model was developed to replicate the functional performance of each WSUD treatment train applied in case studies where catchment nodes were configured according to land-use derived from maps or from online publications reporting on catchment size. Treatment nodes such as wetlands, ponds, bioretention systems and sediment basins and climatic inputs were acquired as input parameters from respected technical guidelines. Pollutant parameters for TSS (total suspended solids), TN (total nitrogen) and TP (total phosphorus) were also acquired through the technical guidelines. The findings from both models were analysed narratively to identify pollutant reduction and the pollutant removal efficiencies in the pre-development and post-development settings to assess the effectiveness of applying WSUD principles. All data including documentations, graphs, spatial parameters, modelling inputs were stored digitally and ordered accordingly by thematics. SixMaps screenshots and MUSIC X model files were archived thematically in folders according to each model.

2.4 Study Areas

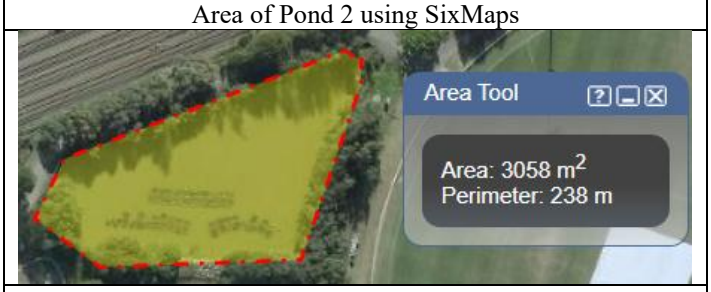
2.4.1 Angus Creek Stormwater Harvesting and Re-use Scheme

The Angus Creek Stormwater Harvesting and Re-use Scheme is a major WSUD project located in the Blacktown LGA in the Blacktown International Sports Park Sydney, Rooty Hill, NSW (Figure 1). The scheme provides irrigation water to mainly the Blacktown Internation Sports Park and surrounding council reserves. The surrounding catchment includes the suburbs of Rooty Hill and Minchinbury and is approximately 655 hectares and is 35% impervious (CRC for Water Sensitive Cities, n.d.). The catchment generates approximately 2 billion litres of run off (CRC for Water Sensitive Cities, n.d.), where the schemes capacity allows 10% of the catchments generated run off to be used for water demands. Storage Ponds have the capacity to store 8 million litres of storm water harvested from Angus Creek. These storage ponds are separated into three segments to segregate the inlet and outlet to aid in the settlement of contaminants from harvested stormwater. Floating wetlands are installed around the storage pond to further improve the water quality by plant uptake and absorption. The wetlands for treatment remove excess nutrients (heavy metals, hydrocarbons) using a high-density variety of plants. Multi-phase Treatment and Storage provide further improvements of water quality are needed; thus, a system of filters and various disinfection methods are needed, which include chlorination and UV disinfection.

Area of Pond 1 using SixMaps



Area of Pond 2 using SixMaps



Area of Pond 3 using SixMaps

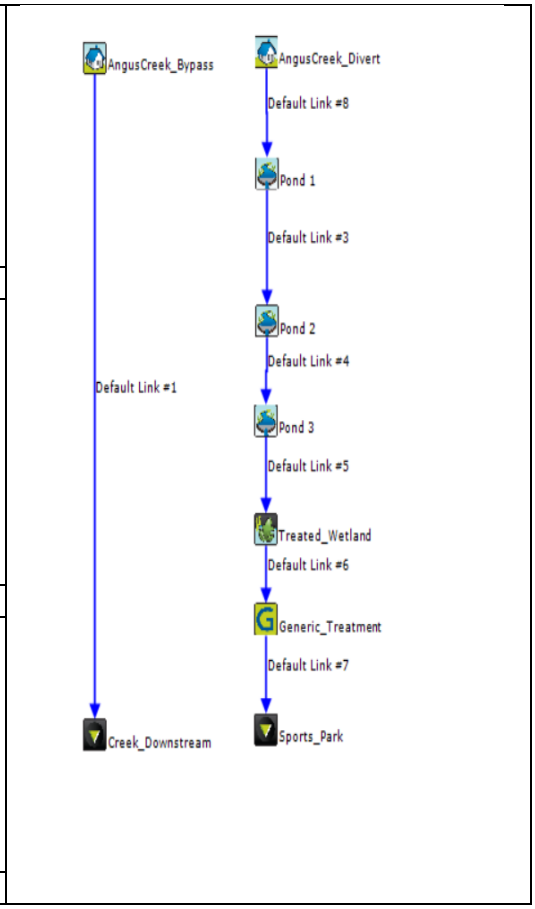
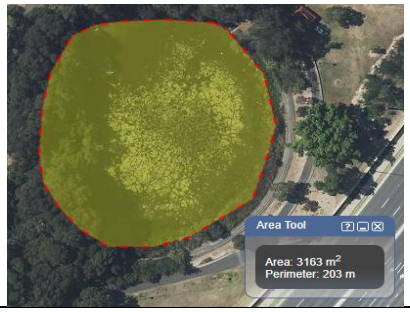


Figure 1. Area of ponds with figures from SixMaps and MUSIC X modelling structure for Angus Creek Stormwater Harvesting and Re-use Scheme.

Area of Wetland 1 using SIXMAPS

Area of Wetland 2 using SIXMAPS

Area of Wetland 4 using SIXMAPS



Area of Wetland 5 using SIXMAPS

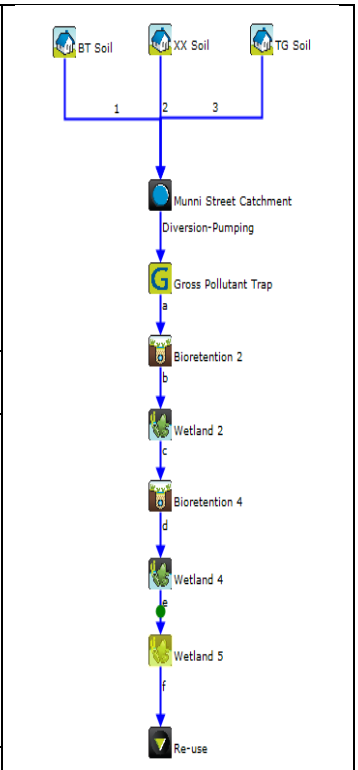


Figure 2. Area of wetlands with figures from SixMaps with MUSIC X modelling structure for Sydney Park Water Re-use Project.

2.4.2 Sydney Park Water Re-use Project

Located in the suburb of St Peters within the City of Sydney council, the Sydney Park Water Re-use Project is an integration of water infrastructure into an urban parkland (Figure 2). The project captures and treats approximately 850 million litres of water per year where the water is supplied from the 213.6-hectare Munni Channel catchment area (NSW Government, n.d.). Low storm water flows pumped onto the surface from underground pipes, which are to be treated by vegetated swales. The treated water is then diverted to small wetlands where sedimentation and adsorption take place for further water treatment. The water is then discharged into the larger system of wetlands throughout Sydney Park. The water treatment for larger storm flows is initiated from a gross pollutant trap followed by a system of wetlands (Wetlands 2 and 4) where the storm water goes through filtration, sedimentation, and adsorption. From Wetland 5, the treated stormwater is reused throughout the park, and any overflow is diverted into the urban stormwater system. Wetlands 1, 2 and 4 are paired with bioretention systems to assist in capturing sediments. Sydney Park utilises a reuse system where the water is further treated prior to re-use through filtration and UV filtration. The water treated is used for irrigation and other non-potable purposes. The remaining water flows back into Wetland 2 followed by the other system of wetlands and any excess water is discharged downstream into nearby Alexandria Canal.

3. Results

3.1 Angus Creek Stormwater Harvesting and Re-use Scheme using MUSIC X Model

The scheme provides treated water for amenities (toilet flushing) and irrigation of sports grounds. Table 1 shows values of reductions in all three pollutant parameters, which demonstrate the success of the WSUD program to provide the level of water for activities of the sports park.

Table 1: Treatment train effectiveness for Angus Creek pre-development and post-development conditions using MUSIC X model.

	Bypassed Flow Downstream			Diverted Flow: Sports Park		
	Inflow	Outflow	% Reduction	Inflow	Outflow	% Reduction
Flow (ML/yr)	15490	15490	0	1720	1566	8.955
Total Suspended Solids (kg/yr)	2787000	2787000	0	309400	227800	26.37
Total Phosphorous (kg/yr)	4646	4646	0	515.9	411.7	20.19
Total Nitrogen (kg/yr)	30980	30980	0	3440	3159	8.163
Gross Pollutants (kg/yr)	136100	136100	0	15120	37.49	99.75
	Catchment Prior to Scheme					
	Inflow	Outflow	% Reduction			
Flow (ML/yr)	17200	17200	0			
Total Suspended Solids (kg/yr)	2881000	2881000	0			
Total Phosphorous (kg/yr)	5159	5159	0			
Total Nitrogen (kg/yr)	34400	34400	0			
Gross Pollutants (kg/yr)	151200	151200	0			

The WSUD program also diverts 10% of stormwater flow from Angus Creek. Table 1 provides the residual load of pollutants prior to the scheme and the residual loads of the water being bypassed downstream of Angus Creek during the scheme. The residual load in the bypassed water shows a lower value of residual load, thus water downstream is cleaner from residual loads compared to prior the scheme. The scheme is limited by its 10% diversion where results will improve if diversion intake increases where these results will include a drastically lower pollutant load and flow rate downstream. However, this will also require an upgrade of infrastructure to accommodate large quantities of water. Despite the limitation of the 10% diversion, the results in Table 1 have provided a positive outcome as there is a reasonable percentage of reduced pollutants loads, which ultimately reduces pollutant load downstream and provides water for the Angus Park facilities, making the park self-sustainable and the scheme is leaving a positive impact to the downstream ecosystem.

3.2 Sydney Park Water Re-use Project using MUSIC X Model

The Munni Catchment is represented in the MUSIC X model as three sources, differentiated according to three soil types within the catchment. Soils Vary in seepage, infiltration and capacity, thus separate source provides an accurate representation of the catchment. The junction node represents the combined sources that form the Munni Street Channel. As presented in Table 2, the results at the junction show 0% pollutant removal, which also reflect pre-project conditions. The treatment sequence in Sydney Park begins at Wetland 2, flows into Wetland 4 and then to Wetland 5, with pollutant removal efficiency increasing along the treatment train. Table 2 demonstrates reduced annual flow in Wetland 2 by 3.2%, total suspended solids by 11.7%, total phosphorus by 12.3%, total nitrogen by 9.9% and gross pollutants by 34.2%. To conclude, wetland 5 showed flow reduction by 6.7%, total suspended solids by 17.6%, total phosphorus by 18.1%, total nitrogen by 15.1% and gross pollutants by 43.9%. The results indicate positive effects of the WSUD treatment train, comprising of bioretention and wetland systems. This delivers water for irrigation; wetland top up and broader amenities.

Excess treated water is dispensed downstream into the Alexandria Canal, improving environmental outcomes by discharging cleaner water compared to pre-project conditions. Reduced flows from the Munni Catchment also help minimise erosion in the downstream ecosystem. The project is limited to 850 million litres per year with pump capacity restricted to 1000 litre per second. This means that only a portion of stormwater can be diverted during high-flow events, making the system non-efficient during heavy storms due to pump limitations. Most of the storm water from the Munni channel will convey downstream straight into the Alexandria Canal. However, the effectiveness of the treatment has been proven through the results in Table 2, thus allowing the treated water to be reused for irrigation or non-potable uses. The treated water also provides cleaner water downstream when discharged in excess is made from Sydney Park, ultimately lowering the pollutant load in downstream ecosystems.

Table 2: Treatment train effectiveness for Sydney Park pre-development and post-development conditions using MUSIC X model.

	Junction: Munni St Catchment			Wetland 2		
	Inflow	Outflow	% Reduction	Inflow	Outflow	% Reduction
Flow (ML/yr)	9943	9943	0	9943	9620	3.247
Total Suspended Solids (kg/yr)	1730000	1730000	0	1730000	1527000	11.73
Total Phosphorous (kg/yr)	2843	2843	0	2843	2493	12.27
Total Nitrogen (kg/yr)	21240	21240	0	21240	19100	9.938
Gross Pollutants (kg/yr)	53430	53430	0	53430	35140	34.24
	Wetland 4			Wetland 5 and Junction		
	Inflow	Outflow	% Reduction	Inflow	Outflow	% Reduction
Flow (ML/yr)	9943	9357	5.887	9943	9280	6.669
Total Suspended Solids (kg/yr)	1730000	1433000	17.18	1730000	1426000	17.58
Total Phosphorous (kg/yr)	2843	2339	17.67	2843	2327	18.1
Total Nitrogen (kg/yr)	21240	18130	14.63	21240	18020	15.12
Gross Pollutants (kg/yr)	53430	30290	43.32	53430	29970	43.91

4. Conclusion

The modelling of the Sydney Park and Angus Creek WSUD projects demonstrates clear benefits of integrated stormwater treatment systems in improving urban water quality and supporting sustainable water management. The representation of three soil-based sources for the Munni Catchment, the MUSIC X model accurately reflects pre-development and post-development conditions. The Sydney Park treatment train, pollutant removal efficiency increased progressively from Wetlands 2 to 5, with notable reduction in total suspended solids, total phosphorus, total nitrogen and gross pollutants. These improvements highlight the effectiveness of the wetland and bioretention systems when delivering cleaner water, supporting irrigation, wetland top up and reducing downstream erosion. However, the system is constrained to diversion limits and pump capacity, the system still provides treatment for meaningful portion of stormwater during moderate flows. Similarly, the Angus Creek Stormwater Harvesting and Reuse Scheme also demonstrates positive outcomes. The diversion of 10% of stormwater from Angus Creek showed reduction in residual pollutants loads in bypass flows, thus downstream water quality is improved compared to pre-scheme conditions. The diverted flow has also been demonstrated to effectively improve water quality where its uses can be provided for irrigation and amenities. Although limited by diversion limits or pump capacities, these WSUD projects stand ideal as a model for future WSUD projects for other LGA's where more projects along one main water channel can drastically improve water quality as altogether. Ultimately, the results confirm that well designed WSUD programs significantly enhance water quality, environmental health and sustainable water use in urban settings.

Acknowledgements

The authors acknowledge the City of Sydney and Blacktown City Council for providing access to project documentation and supporting information used in this study. The authors also appreciate the availability of the MUSIC X modelling tool, which supported the hydrological and water quality analysis. The authors also thank reviewers for their constructive feedback, which helped improve the clarity and quality of this work.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflicts of Interest

The authors report no conflicts of interest.

Data Availability Statement
The data supporting the findings of this study are derived from publicly available reports, project documentation, and model outputs generated using the MUSIC X software. Due to the use of project-specific datasets and council-based documentation (City of Sydney and Blacktown City Council), some data may be subject to access restrictions. Processed data and modelling outputs used in this study are available from the corresponding author upon reasonable request.

Institutional Review Board Statement
This study does not involve any humans or animals, as such ethics approval was not applicable for this research.

CRediT Author Statement
Eng. Hons. Candidate Andrew Fernando Djamaan: Investigation, Data curation, Formal analysis, Software, Visualization, Writing – original draft.
Dr. M. Ashiqur Rahman: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing, Project administration.
All authors have read and approved the final manuscript.

References
Blacktown City Council. (2020). *Water sensitive urban design (WSUD) developer handbook: MUSIC modelling and design guide*. https://www.blacktown.nsw.gov.au/files/assets/public/v/1/wsud/wsud-developer-handbook-2020/blacktown_council_wsud_developer_handbook_2020_uploaded-12122025.pdf

CRC for Water Sensitive Cities. (n.d.). *Angus Creek stormwater harvesting and reuse scheme*. https://watersensitivecities.org.au/solutions/case-studies/angus-creek-stormwater-harvesting-and-reuse-scheme/

Evans, C., Linda, C., Sara, P. K., & Lei, Z. (2020). Sydney Park water re-use project methods. *Landscape performance series*. Landscape Architecture Foundation. https://doi.org/10.31353/cs167

Khalaji, F., Zhang, J., & Sharma, A. K. (2025). Social and economic impacts of water sensitive urban design: A review. Water, 17(1), 16. https://doi.org/10.3390/w17010016

Mangangka, I. R. (2018). Understanding water sensitive urban design (WSUD) concept. Jurnal Sipil Statik, 6(1), 21–34.

Amen, M. A., & Ali, F. A. (2025). Analyzing the impact of spatial centrality and courtyard diversity on tourist attractions in the walled city of Lefkoşa. PLOS One, 20(8), e0330956. https://doi.org/10.1371/journal.pone.0330956

Amen, M. A., Afara, A., & Nia, H. A. (2023). Exploring the Link between Street Layout Centrality and Walkability for Sustainable Tourism in Historical Urban Areas. Urban Science, 7(2), 67. https://doi.org/10.3390/urbansci7020067

NSW Government. (n.d.). Sydney Park water re-use project. https://www.planning.nsw.gov.au/government-architect-nsw/research-and-case-studies/public-projects/sydney-park-water-re-use-project

Xiong, H., Sun, Y., & Ren, X. (2020). Comprehensive assessment of water sensitive urban design practices based on multi-criteria decision analysis via a case study of the University of Melbourne, Australia. *Water, 12*(10), 2885. https://doi.org/10.3390/w12102885