Journal of Sustainability Perspectives 4 (1), 2024, 109-119

Journal of Sustainability Perspectives

journal homepage: https://ejournal2.undip.ac.id/index.php/jsp/

Research on the Constructed-Wetland/Regulation-Tank System at Pontificia Universidad Javeriana's Bogotá Campus

Andrés Torres[*1], *Sandra Galarza-Molina*[2], *Jaime Lara-Borrero*[3], *Javier Forero*[4]

[1]*Instituto Javeriano del Agua, Pontificia Universidad Javeriana, Bogotá, Colombia*
[2]*Departamento Ingeniería Civil e Industrial, Facultad de Ingeniería y Ciencias, Pontificia Universidad Javeriana, Cali, Colombia*
[3]*Departamento Ingeniería Civil, Facultad de Ingeniería, Pontificia Universidad Javeriana, Bogotá, Colombia*
[4]*Dirección de Recursos Físicos, Pontificia Universidad Javeriana, Bogotá, Colombia*
[*]corresponding author: andres.torres@javeriana.edu.co

Article Info

Received:
06 June 2024
Accepted:
20 June 2024
Published:
28 June 2024

DOI:
10.14710/jsp.2024.24796

Presented in the 10th International Workshop on UI GreenMetric World University Rankings (IWGM 2024)

Abstract. The stormwater harvesting (SWH) project at Pontificia Universidad Javeriana (Bogotá) began in 2007, initiated by the Water and Environmental Engineering research group (Ciencia e Ingeniería del Agua y el Ambiente), as part of PUJB's Environmental Management Plan and in collaboration with the University's Office of Physical Resources. This process included assessments of water supply and demand, rainwater quality, and financial and construction considerations. The system—a constructed wetland/regulation tank (CWRT)—collects rainwater runoff from the university's parking building (3,776 m²), the soccer field, and surrounding areas (14,816 m²). Beyond its hydrological performance, especially during periods of water scarcity, the system also functions as a full-scale laboratory to study biodiversity and ecological impacts in hydrological and hydraulic processes. The monitoring program, focused on changes in rainwater quantity and quality, has inspired several master's and doctoral research projects. These studies explore critical topics in urban hydrology, including stormwater harvesting, urban sediment management, real-time decision-making systems, and environmental and human health. This paper outlines the development of the stormwater harvesting system, shares the main findings from research projects, and discusses ongoing projects.

Keyword:

Stormwater harvesting, multi-criteria decision analysis (MCDA), rainwater quality, constructed wetland, sustainable infrastructure, water quality improvement, hydraulic performance, rainwater collection, runoff retention, ultrasonic level sensor, Sustainable Urban Drainage Systems (SUDS), sedimentation tanks, regulating tank, non-potable uses.

1. Introduction

In recent years, stormwater harvesting (SWH) has emerged as a pivotal solution in the global quest for sustainable water management strategies. SWH involves the collection and utilization of rainwater runoff from urban areas for non-potable applications such as landscape irrigation, toilet flushing, and surface cleaning [1], [2], [3]. The growing interest in SWH is driven by its multifaceted benefits and its potential to address pressing water-related challenges in urban environments.

One of the primary advantages of SWH is its contribution to urban flood control [4]-[6]. By capturing and redirecting stormwater runoff, SWH systems help mitigate the risk of flooding in urban areas, enhancing community resilience to extreme weather events. Additionally, SWH reduces the reliance on conventional potable water sources [7]-[10], thereby alleviating pressure on municipal water supplies and promoting more sustainable water consumption practices.

Moreover, SWH systems play a crucial role in reducing the load on urban drainage infrastructure during heavy rainfall [11]. By capturing stormwater runoff for later use, these systems decrease the volume of water entering storm drains and sewers, thereby minimizing the risk of overflow and urban flooding. SWH also helps mitigate pollution of urban waterways by intercepting and treating runoff before it reaches natural water bodies [4]-[6], preserving water quality and protecting ecosystems.

SWH is increasingly recognized as a key adaptation measure for addressing climate change [12]-[14]. Climate projections indicate an increase in the frequency and intensity of extreme weather events, and SWH offers a sustainable solution for managing water resources under changing climate conditions. Its decentralized nature and reliance on local rainfall patterns make SWH systems resilient to climate variability, providing communities with a reliable water source, even in drought-prone regions.

Despite its potential benefits, the widespread adoption of SWH faces several challenges, including a lack of comprehensive information regarding its effectiveness [16]. Critical questions remain about the volume of stormwater that can be harvested, the reliability of supply sources, and the necessary storage capacity [25], [26]. Addressing these knowledge gaps is essential for promoting broader implementation of SWH and realizing its full potential as a sustainable water management strategy.

Recent advancements in Water Sensitive Urban Design (WSUD) have further enhanced the feasibility and effectiveness of SWH systems. WSUD integrates principles of sustainable urban water management and offers innovative solutions for rainwater collection and storage [8]. Sustainable Urban Drainage Systems (SUDS), a key component of WSUD, incorporate various elements such as permeable pavements, constructed wetlands, and bioretention gardens to manage stormwater runoff effectively [27]. Initially designed for flood control, SUDS now encompass the collection, storage, and treatment of stormwater, contributing to improved water quality and reduced environmental impacts in urban areas.

In Colombia, while research on SWH [28]-[33] and SUDS [34]-[39] exists, further exploration is needed to integrate SUDS for SWH purposes. Additionally, comprehensive scientific investigations analyzing resource quality, flow rates, and storage options are lacking in the Colombian context. The SWH project at Pontificia Universidad Javeriana Bogotá (PUJB) represents a pioneering initiative aimed at addressing these knowledge gaps. Initiated in 2007 by the research group "Ciencia e Ingeniería del Agua y el Ambiente," this project, embedded within the PUJB Environmental Management Plan, seeks to promote rainwater use for various non-potable purposes across the institutional campus. By implementing low-impact drainage systems and adopting a holistic approach to water management, the project aims to redefine the concept of a sustainable campus and serve as a model for other institutions and communities. This paper provides insights into the development of the stormwater harvesting system at PUJB, shares key findings from ongoing research endeavors, and facilitates discussions on future projects and collaborations.

2. Materials and Methods

A comprehensive study was undertaken to assess the water usage inventory on the campus of Pontificia Universidad Javeriana Bogotá (PUJB). This involved conducting a detailed field survey of the campus, utilizing site record forms and analyzing historical monthly average drinking water consumption data from 2003 to 2010 [40]. Simultaneously, a project was initiated to evaluate water resource availability by analyzing pluviograph records from the surrounding area.

Subsequently, a project was launched to investigate the quality of stormwater on the campus and identify potential water reuse opportunities. Measurement campaigns were conducted from March 2009 to October 2012, during which stormwater quality was assessed for three storm events at various sampling points. A total of 25 analytical tests were performed to quantify the physical properties and chemical constituents of the runoff.

To support the decision-making process for rainwater harvesting (RWH) at the PUJB campus, a Multi-Criteria Decision Analysis (MCDA) tool, CRIDE (multiCRIteria DEcision support tool), was developed. This tool facilitated the determination of the appropriate size for Sustainable Urban Drainage Systems (SUDS) and aided in the design of pumping and treatment systems. Decision-making criteria were collaboratively defined and weighted by the research group and the Physical Resources Office (PRO) of the University. These criteria encompassed technical aspects such as hydraulic and environmental performance, managerial considerations aligned with the University's Development Plan, and financial factors, including the Net Present Value (NPV) of the investments [41].

Additionally, a simplified method for sizing SWH tanks was devised using long-term, high-resolution rainfall time series data and water demand assessments. Following the recommendations of authors such as Campisano et al. [42], this method was tailored for application in developing countries with limited hydrological data resolution. The method accounted for heterogeneous contributing catchments and variable water demand flow rates, incorporating probabilities for meeting water demand and the most probable time steps along with their respective variabilities. Input data included 73 years of daily rainfall records (1936–2010) from the San Luis rain gauge station and the monthly water usage inventory at the university from October 2003 to March 2010. The contributing catchment area covered 22,026.20 m², comprising sports facilities, parking structures, sports fields, green spaces, and roads, with a weighted runoff coefficient of 0.51 [43].

Following the construction of the SWH facility, known as the Constructed Wetland/Regulation Tank (CWRT) system, in 2013, several research projects were initiated, including two PhD theses. These projects focused on developing real-time decision-making systems for rainwater harvesting and on the management and utilization of urban runoff sediments.

In 2024, a research project was launched between the Bogotá and Cali campuses of Pontificia Universidad Javeriana to identify adaptation measures for SUDS to mitigate the effects of climate change on runoff quantity and quality regulation. This project includes the

CWRT system in Bogotá and reflects the university's commitment to sustainability and innovation in water management practices.

The following figure presents a diagram illustrating the timeline of the six phases that comprise the previously presented methodology.

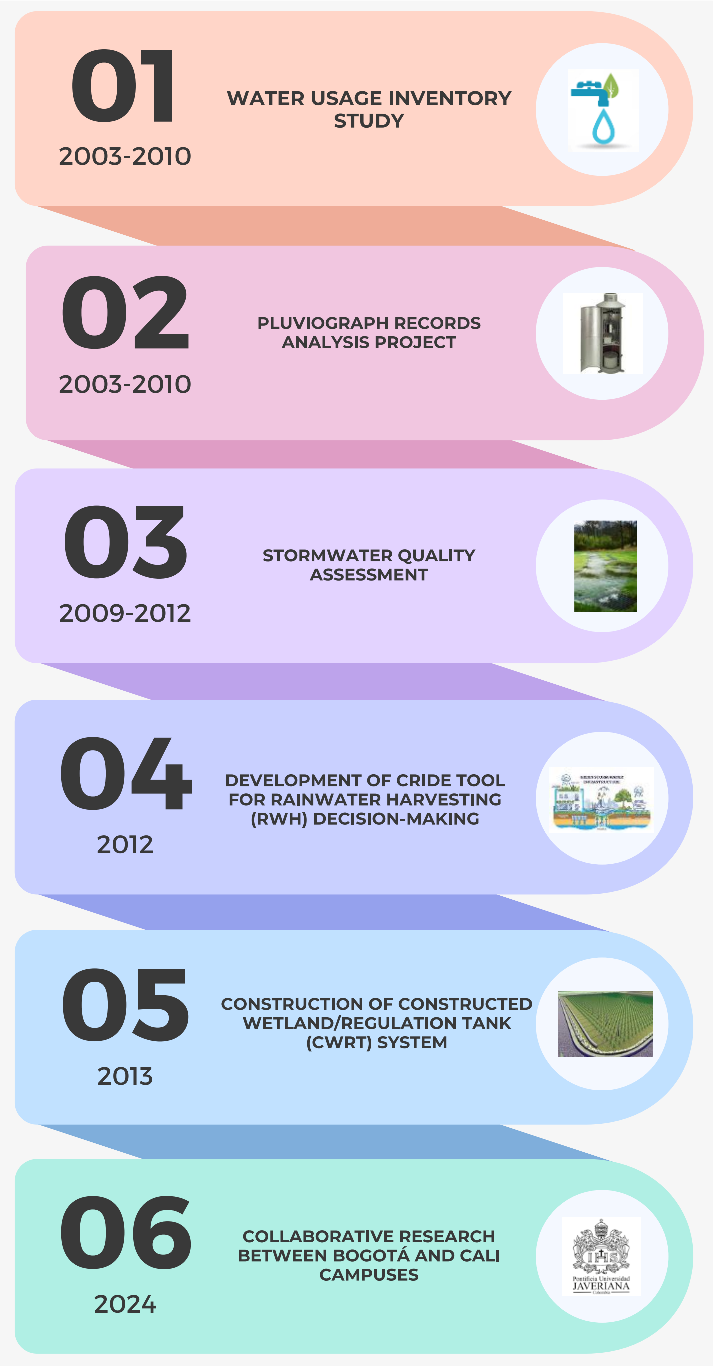

Figure 1. Timeline of the Six Phases of the Presented Methodology

3. Results

The assessment of water usage at PUJB provided valuable insights into the campus's consumption patterns. PUJB consumes approximately 16,651 m^3 of water monthly and 199,807 m^3 annually. Significant variation was observed among buildings, with daily water consumption ranging from 134 L to 111,751 L. Some buildings demonstrated high water usage, ranging from 14,971 L/day to 78,051 L/day, while others had lower demands, between 219 L/day and 1,978 L/day.

The analysis identified activities responsible for the highest water demands, such as floor cleaning, garden irrigation, toilet discharges, and surface cleaning, which collectively accounted for 72% of total water usage. Essential activities relying on potable water, including handwashing, laboratory work, drinking, showers, and dishwashing, made up only 20% of the total usage. These results emphasize the need for optimizing water usage and implementing sustainable management practices to enhance resource efficiency on campus.

The findings from the stormwater quality project at PUJB revealed elevated pollutant levels in runoff. Analysis of 25 stormwater parameters across three storm events showed that pH, turbidity, BOD, and several metals, including Cd, Hg, Mn, and Pb, exceeded regulatory limits set by the EPA, Colombia, and Japan. These levels highlight potential environmental risks, stressing the importance of effective stormwater management practices to mitigate contamination and protect urban water quality. Continued research and monitoring are needed to assess the long-term impacts of stormwater pollution and develop sustainable management strategies at PUJB.

Following the implementation of CRIDE, scenario five emerged as the optimal solution, ranking highest among the evaluated options. This scenario involves collecting runoff from nine designated basins for non-potable uses such as floor cleaning, sanitary discharge, and landscape irrigation. Sustainable Urban Drainage Systems (SUDS), including basins, bioretention gardens, permeable paving, and constructed wetlands, were integrated for rainwater collection and treatment [44], [41]. Upon assessment completion, the results were presented to the Physical Resources Office (PRO) of the University for review and decision-making.

The PRO opted to proceed with scenario five, starting the construction of a stormwater harvesting (SWH) system for one of the nine designated basins. This basin, covering approximately 2.73 hectares, represents 15% of the total campus area and has a contributing catchment of 2.20 hectares with a weighted runoff coefficient of 0.51. The selection of this basin reflects its suitability for rainwater collection and its significant contribution to overall water management on campus.

The decision to prioritize scenario five demonstrates the university's commitment to sustainable water management and the adoption of innovative solutions to address water-related challenges. By leveraging SUDS techniques and targeted interventions, the university aims to enhance water efficiency, reduce dependence on conventional water sources, and promote environmental stewardship. The successful implementation of scenario five will serve as a model for future sustainability initiatives, fostering resilience and positive change on campus.

Following the assessment, the SWH project implementation phase commenced, involving collaboration between the PRO, university researchers, and an expert designer. This participatory approach ensured the development of an effective engineering design for the SWH system, with key criteria including stormwater quality and the location of existing drainage systems guiding the decision-making process.

Ultimately, the project selected a location for the SWH system that collects stormwater runoff from various campus areas, including a parking structure (3,776 m²) and the soccer field and surrounding areas (14,816 m²). By strategically selecting these areas, the project maximized water capture efficiency and minimized environmental impact.

The collaborative effort ensured that critical factors, such as water quality and system integration, were considered during planning. Through multidisciplinary expertise and stakeholder engagement, the SWH project developed a sustainable and resilient water management solution tailored to PUJB's specific needs and conditions.

The CWRT system, constructed between 2012 and 2013, includes two settling tanks, a horizontal subsurface flow (HSSF) wetland, and a reservoir tank with a 211 m^3 capacity for storing stormwater. The system's design allows for a 15-day storage time, with a 75% probability of meeting water demand. Continuous monitoring of the system's hydraulic performance, using triangular sharp-crested weirs at the wetland's inlet and outlet, facilitates ongoing assessment of its efficiency.

Preliminary results indicate the constructed wetland delays runoff hydrographs by 11 to 53 minutes and attenuates peak outflow to 37%–78% of inflow peaks, retaining up to 46% of total rainfall volume. These outcomes highlight the wetland's effectiveness in reducing peak flows and retaining stormwater, contributing to sustainable stormwater management on the PUJB campus. Continued monitoring will provide further insights into its long-term performance.

Rainwater characterization during three storm events revealed high turbidity and Total Suspended Solids (TSS) in the effluent, making it unsuitable for uses like showers and toilets but viable for irrigation and landscaping. Microbiological analysis detected 15 MPN/100 mL, further limiting the use of this water for certain applications. Chloride and Total Dissolved Solids (TDS) remained stable at the constructed wetland outlet but increased at the CWRT system outlet during all three events. Continued research is required to improve treatment processes and ensure rainwater quality for various uses.

An online water quality monitoring system, utilizing UV-Vis spectrometers, was implemented for real-time analysis, supported by Arima-based predictions. The system demonstrated robust forecasting accuracy, with prediction errors remaining under 15% across all datasets. This monitoring approach enables stakeholders to proactively manage water quality and optimize treatment processes, enhancing decision-making and supporting sustainable water resource management.

4. Conclusions

This paper outlines the methodologies employed and data used during the planning and design phases of the PUJB SWH system, which consists of a constructed wetland/reservoir tank. It also provides an overview of the entire pre-construction process.

The water use inventory at PUJB revealed that the majority of demand is for non-potable purposes, leading to the proposal of several SWH scenarios. The optimal scenario was selected using a custom Multi-Criteria Decision Analysis (MCDA) tool. This scenario integrates non-potable uses across nine basins, utilizing Sustainable Urban Drainage Systems (SUDS) for water collection, storage, and treatment. The sizing of the constructed wetland/reservoir tank in this scenario was determined using a simplified method specific to the reservoir tank.

Preliminary findings suggest that the constructed wetland effectively reduces peak runoff and overall runoff volume, while also serving as a research platform to study biodiversity and ecological impacts on hydrological and hydraulic processes.

The developed methodologies have the potential for integration into real-time control systems, such as those used for managing sewer systems and stormwater basins. These approaches could reduce the need for extensive monitoring equipment, thereby lowering the requirements for specialized training and reducing operational costs.

Sediments collected from the CWRT system's sand traps are deemed suitable for soil remediation and revegetation on non-agricultural land, provided that the receiving soil has inferior characteristics compared to the sediments. However, due to the high concentrations of Total Organic Carbon (TOC), the use of these sediments should be limited to filling material for concrete structures and culverts in core or foundation areas. Additionally, the elevated levels of heavy metals (HM) found in the sediments make them unsuitable for agricultural use.

References

1. B.E. Hatt, A. Deletic, and T.D. Fletcher, "A review of integrated storm water treatment and re-use in Australia", Journal of Environmental Management, vol. 79, no. 1, pp. 102-113, , 2006, doi: 10.1016/j.jenvman.2005.06.003

2. W.D. Shuster, D. Lye, A. de La Cruz, L.K. Rhea, K. O'connell, and A. Kelty, "Assessment of residential rain barrel water quality and use in Cincinnati, Ohio", Journal of the American Water Resources Association (JAWRA), pp. 1-13, 2013, doi: 10.1111/jawr.12036

3. S. Ghimire, D. Watkins, and K. Li, "Life cycle cost assessment of a rain water harvesting system for toilet flushing", Water Science & Technology: Water Supply Journal, vol. 12, no. 3, pp. 309-320, 2012.

4. T.D. Fletcher, A. Deletic, V.G. Mitchell, and B.E. Hatt, "Reuse of urban runoff in Australia: a review of recent advances and remaining challenges", Journal of Environmental Quality, vol. 37, pp. S116-27, 2008.

5. M. Van Roon, "Water localization and reclamation: steps towards low impact urban design and development", Journal of Environmental Management, vol. 83, pp. 437-447, 2007.

6. K. Zhu, L. Zhang, W. Hart, M. Liu, and H. Chen, "Quality issues in harvested rainwater in arid and semi-arid Loess Plateau of northern China", Journal of Arid Environments, vol. 57, pp. 487-505, 2004.

7. E. Ghisi, D. Fonseca Tavares, and V. Rocha, "Rainwater harvesting in petrol stations in Brasília: Potential for potable water savings and investment feasibility analysis", Journal of Resources, Conservation and Recycling, vol. 54, pp. 79-85, 2009, doi:10.1016/j.resconrec.2009.06.010

8. T.H.F. Wong, "Water sensitive urban design - the journey thus far", Australian Journal of Water Resources, vol. 10, no. 3, pp. 213-222, 2006.

9. P. Coombes, G. Mitchell, and P. Breen, "Roof-water, stormwater and wastewater reuse", in Australian run-off quality, T.H.E. Wong, Ed. Sydney: Engineers Australia, 2003, pp. 5.1-5.22.

10. P. Coombes, J. Argue, and G. Kuczera, “Figtree Place: A case study in water sensitive urban development (WSUD)”, Urban Water, vol. 1, no. 4, pp. 335-343, 2000.

11. European Environment Agency (EEA), “Towards efficient use of water resources in Europe”, Report No1/2012, Copenhagen, 2012.

12. E. Boelee et al., “Options for water storage and rainwater harvesting to improve health and resilience against climate change in Africa”, Regional Environmental Change, vol. 13, no. 3, pp. 509-519, 2012, doi: 10.1007/s10113-012-0287-4

13. O.O. Aladenola and O.B. Adeboye, “Assessing the potential for rainwater harvesting”, Water Resources Management, vol. 24, pp. 2129-2137, 2010.

14. E. Rozos, C. Makropoulos, and D. Butler, “Design robustness of local waterrecycling schemes”, Journal of Water Resources Planning and Management, vol. 136, no. 5, pp. 531-538, 2010.

15. R.R. Brown and P. Davies, “Understanding community receptivity to water re-use: Kuring-gai Council case study”, Water Science and Technology, vol. 55, no. 4, pp. 283-290, 2007, doi: 10.2166/wst.2007.119

16. M.A. Imteaz, A. Shanableh, A. Rahman, and A. Ahsan, “Optimisation of rainwater tank design from large roofs: a case study in Melbourne, Australia”, Resources, Conservation and Recycling, vol. 55, pp. 1022-1029, 2011.

17. A. Assayed et al., “On-site rainwater harvesting to achieve household water security among rural and peri-urban communities in Jordan”, Resources, Conservation and Recycling, vol. 73, pp. 72-77, 2013.

18. K.M. Debusk, J.D. Wright, and W.F. Hunt, “Demonstration and monitoring of rainwater harvesting technology in North Carolina”, in Low Impact Development International Conference (LID), San Francisco, California, Estados Unidos, 11-14 de abril 2010, pp. 1-10, doi: 10.1061/41099(367)1

19. M.S. Lariyah, M.D Mohd Nor, Z.A. Mohamed Roseli, M. Zulkefli, and M.P. Amirah Hanim, “Application of water sensitive urban design at local scale in Kuala Lumpur”, in The 12nd International Conference on Urban Drainage, Porto Alegre, 10-15 September 2011, pp. 1-14.

20. R. Farreny, T. Morales-Pinzón, A. Guisasola, C. Taya, J. Rieradevall, and X. Gabarrell, “Roof selection for rainwater harvesting: quantity and quality assessments in Spain”, Water Research, vol. 45, pp. 3245-3254, 2011.

21. M. Jones and W. Hunt, “Performance of rainwater harvesting systems in the southeastern United States Resources”, Conservation and Recycling, vol. 54, pp. 623-629, 2010.

22. M. Han and J. Park, “Innovative rainwater harvesting and management in the republic of Korea”, in Rainwater and Urban Design 2007 [online]. [Barton, A.C.T.]: Engineers Australia, 2007, pp. 329-339.Available:http://search.informit.com.au/documentSummary;dn=889583555548333;res=IELENG

23. C.H.W. Lim and N.S. Lim, “Urban stormwater collection for potable use”, in The 11th IWSA-ASPAC Regional Conference, Sydney, 1-5 November 1998, pp. 571-577.

24. V.G. Mitchell, D.T. Mccarthy, A. Deletic, and T.D. Fletcher, “Urban stormwater harvesting - sensitivity of a storage behaviour model”, Environmental Modelling & Software, vol. 23, pp. 782-793, 2008, doi: 10.1016/j.envsoft.2007.09.006

25. R. Farreny, X. Gabarrella, and J. Rieradevalla, “Cost-efficiency of rainwater harvesting strategies in dense Mediterranean neighbourhoods”, Resources, Conservation and Recycling, vol. 55, pp. 686-694, 2011.

26. A. Campisano, I. Gnecco, C. Modica, and A. Palla, “Designing domestic rainwater harvesting systems under different climatic regimes in Italy”, Water Science & Technology, vol. 67, no. 11, pp. 2511-2518, 2013.

27. J. Mentens, D. Raes, and M. Hermy, “Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century?”, Landsc. Urban Plann., vol. 77, pp. 217-226, 2006.

28. A. Torres, S. Méndez-Fajardo, A. Gutiérrez, and S. Sandoval, “The quality of rainwater runoff on roofs and its relation to uses and rain characteristics in the Villa Alexandra and Acacias Neighborhoods of Kennedy, Bogota, Colombia”, Journal of Environmental Engineering-Asce, vol. 139, no. 10, pp. 1273-1278, 2013.

29. N. Castañeda, “Propuesta de un sistema de aprovechamiento de agua lluvia como alternativa para el ahorro de agua potable”, Revista Gestión y Ambiente, vol. 13, no. 2, pp. 25-40, 2010.

30. J. Ramírez, “Construcción verde en concreto”, Noticreto. Revista de la Técnica y la Construcción, vol. 2, pp. 20-27, 2009.

31. J.A. Lara-Borrero, A. Torres, M.C. Campos-Pinilla, L. Duarte-Castro, J.I. EcheverriRobayo, and P.A. Villegas-González, “Aprovechamiento del agua lluvia para riego y para el lavado de zonas duras y fachadas en el campus de la Pontificia Universidad Javeriana (Bogotá)”,

Ing. Unv., vol. 11, no. 2, pp. 193-202, 2007.

32. J.A. Ballén, M.A. Galarza, and R.O. Ortiz, “Sistemas de aprovechamiento de agua lluvia para vivienda urbana”, in VI SEREA. Seminario Iberoamericano sobre Sistemas de Abastecimiento Urbano de Agua, João Pessoa, 5-7 de junio 2006, pp. 1-12.

33. L. S. Sánchez and E. Caicedo, “Uso del agua lluvia en la Bocana-Buenaventura”, in AGUA 2003 Internacional: Usos Múltiples del Agua para la Vida y el Desarrollo Sostenible, Cartagena, Colombia, 2003, pp. 1-9.

34. A. Torres, A. L. Santa, and J.A. Quintero, “Desempeño hidráulico de un modelo de trinchera de retención utilizada como componente del drenaje urbano”, Revista Acodal, vol. 229, no. 1, pp. 19-27, 2012.

35. C. Devia, A. Puentes, N. Oviedo, A. Torres, and H. Angarita, “Cubiertas verdes y dinámica hídrica en la ciudad”, in XXV Congreso Latinoamericano de Hidráulica, San José, Costa Rica, 9 al 12 de septiembre 2012.

36. D. Álvarez and J. Celedón, “Evaluación de las capacidades hidráulicas y de retención de contaminantes de un modelo de trinchera de retención construida con una canastilla en PVC (Aquacell) acoplada con capa filtrante en geotextil, arena y grava utilizada como componente del drenaje urbano”, MSc. Thesis, Pontificia Universidad Javeriana, 2012.

37. A. Torres, D.H.M. Ortega Suescún, and E. Herrera Daza, “Propiedades filtrantes de los pavimentos porosos rígidos”, in Gestión integrada del recurso hídrico frente al cambio climático, L.D. Sánchez, A. Galvis, I. Restrepo, and M.R. Peña, Eds. Cali: Editorial Universidad del Valle, 2011, pp. 39-48.

38. G.A. Gómez González, A.F. Rodríguez Benavides, and A. Torres, “Durabilidad de las capacidades filtrantes de la capa de rodadura de un pavimento poroso rígido”, in XXIV Congreso Latinoamericano de Hidráulica, Punta del Este, noviembre 2010, pp. 1-11.

39. S. Galarza and. F. Garzón, “Estudio de viabilidad técnica de los sistemas urbanos de drenaje sostenible para las condiciones tropicales de Colombia”, Epiciclos, vol. 4, no. 1, pp. 59-70, 2005.

40. A. Torres, J. Estupiñán, and H. Zapata, “Proposal and assessment of rainwater haversting scenarios on the Javeriana University campus, Bogota”, in The 12nd International Conference on Urban Drainage, Porto Alegre, 10-15 September 2011, pp. 1-8.

41. S. Galarza-Molina, A. Torres, J. Lara-Borrero, and P. Moura, “CRIDE - Multi-Criteria Analysis Tool for decision making support in rainwater harvesting in the campus of the Pontificia Universidad Javeriana”, in International Journal of Information Technology & Decision Making, 2014, doi: 10.1142/S0219622014500862

42. A. Campisano, P. Cutore, and. C. Modica, “Performance of domestic rainwater harvesting systems at regional scale”, in World Environmental and Water Resources Congress 2013: Showcasing the Future © ASCE, Cincinnati, Ohio, May 19-23, 2013, pp. 280-289.

43. S. Galarza-Molina, and A. Torres, “Simplified method for rainwater harvesting tank sizing using long day-resolution rainfall time series”, in NOVATECH 2013-8th International Conference, Lyon, 23-27 de junio 2013, pp. 1-10.

44. CIRIA, The SUDS manual. Dundee, 2007.

45. C. Ardila, R. León, S. Galarza, A. Torres, "USOS POTENCIALES DEL EFLUENTE DEL HUMEDALCONSTRUIDO EN LA PONTIFICIA UNIVERSIDAD JAVERIANA BOGOTÁ", in Rev. U.D.C.A Act. & Div. Cient., enero-junio 2016, pp. 237-242

46. N. Hernández, J. Camargo, F. Moreno, L. Plazas, A. Torres, "Arima as a forecasting tool for water quality time series measured w ith UV-Vis spectrometers in a constructed wetland", in Tecnología y Ciencias del Agua, vol. VIII, núm. 5 septiembre-octubre de 2017, pp. 127-139

47. M. Pimiento, J. Lara, A. Torres, "Potential Uses of Stormwater Runoff Sedimentgs Retained in a ConstructedWetland/Storage-Tank", in INGENIERÍA Y UNIVERSIDAD: ENGINEERING FOR DEVELOPMENT, 17 June 2021, pp. 16

48. J. Sanabria, L. Rivera, A. Cabra, C. Jiménez, J. Torres, M. Pimiento, V. Duque, A. Torres, "Risk assessment of runoff sediments in an experimental catchment in Bogotá related to hydrological and granulometric characteristics", in REVISTA PRODUCCIÓN + LIMPIA-VOL 15, 23 Noviembre 2020