

W A T E F C O N 2 0 2 2

# Water Resources Resilience for Small Island Developing States (SIDS)

CONFERENCE PROCEEDINGS



Thematic sessions:

- Water Security Challenges & Strategies in the 21st Century
- Flooding and Resilience against Climate Change

**7th Water Efficiency Conference**

14-16 December 2022

Hybrid Conference  
The University of the West Indies,  
Trinidad and Tobago

**wat<sub>ef</sub>**

Conference of the Water Efficiency Network



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All enquiries to:

**Dr Kemi Adeyeye**

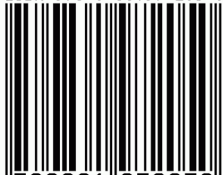
Lead, WATEF Network

Department of Architecture and Civil Engineering

University of Bath

Email: [k.adeyeye@bath.ac.uk](mailto:k.adeyeye@bath.ac.uk)

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## PREFACE

The Water Efficiency Conference 2022 will, for the first time, be held outside Europe in the Caribbean. This is because, true to the network's enduring ethos, we continue to advocate for collaborative solutions to the water and resilience challenges faced globally and experienced more intensely by Small Island Developing States (SIDS). These challenges reflect the changing climate, increasingly unpredictable weather, and the efforts towards sustainable development necessary for social equity and economic growth. Governments across the Caribbean are juggling timely response to disasters and other environmental shocks, with effective service and infrastructure programmes that sustains the health, social, economic, anthropological, and ecological wellbeing of their societies. Proactive partnerships and collaborations across civil society is necessary to succeed in this effort.

I am often asked questions such as: if water on earth is finite and has been the case for millions of years, why is it abundant in some parts, and scarce in others? Why is safe, affordable, accessible water still a challenge for many? Why is there an increased risk of adverse hydrological events globally? If we know of climate change, why are the many people exposed to such risks still without the capacity to mitigate and adapt to these risks in and for their own circumstances and context? These questions manifest daily in our own lived experiences: what we see, hear, breathe, eat and do. These are valid, yet complex questions to answer, but the world needs answers.

A conference on water efficiency and resilience is justified in the face of these challenges and during an energy, cost-of-living, food, and other crises. In an increasingly uncertain world, water is constant and central to most things that matter to us all: the economy, energy, transport, agriculture, health, leisure, wellbeing, social and cultural life. A more equitable world needs adjustments to our water activities as well as our approach to managing our water in nature. It is therefore our privilege as academics, practitioners, and policy makers, to be able to contribute, in our own unique ways, solutions to these fundamental questions. It is with this hope and encouragement that I am grateful for the participation of all the delegates at this conference, whether attending in person or online. Our presentations, deliberations, ideas, and proposals at this year's Water Efficiency Conference move us closer to our goal for a better water world.

I would like to use this opportunity to thank my friend and colleague, Dr Kiran Tota-Maharaj, for an interesting and engaging conference programme. I acknowledge and appreciate our hosts at The University of the West Indies, Trinidad, especially Prof Edwin Ekwue and Dr Vincent Cooper, and the Engineering Institute. Special thanks to Engr Anthony Chadee and our sponsors including the Water and Sewerage Authority of Trinidad and Tobago. Thank you to our keynote speakers: Profs. Maya Trotz, Michelle Mycoo, and Sarah Hainsworth; and our august and exceptional special guest speakers from across the stakeholder spectrum. The British High Commissioner Harriet Cross and her staff for hosting the welcome reception, and the Minister of Public Utilities, the Hon. Marvin Gonzales, MP. Minister of Public Utilities, Trinidad and Tobago.

Together, we have, and will continue to inspire current and future generations to the levels of creativity and innovation needed to collectively, and positively, transition in our changing world.

Dr Kemi Adeyeye  
Water Efficiency Network Lead  
University of Bath, UK.

## EDITORIAL

A very warm Caribbean welcome to all of you at the Water Efficiency Conference 2022 (WATEF 2022), Faculty of Engineering, The University of the West Indies, Saint Augustine Campus, Trinidad. This Water Engineering, Scientific and Technical conference is intended to provide a forum for practitioners, academics, engineers, scientists and researchers across various universities, research centres and industry to present their works, share their knowledge and experiences on water and the environment. Professionals across the Water, Wastewater and Environmental industries and various sectors need to stay on the cutting edge to face the challenges of the future.

For over 10 years, WATEF has been at the forefront of water conferences with specific focus and engagement on engineering education at the undergraduate, postgraduate, and professional level. WATEF has been and continues to be a platform for educators in this field, exploring challenges, sharing experiences, discussing approaches, and generating new impulses for education and training in the water sector. A special emphasis has always been on the transfer of knowledge and pedagogical paradigms between academia and industry. It is a wonderful opportunity for a Caribbean Small Island Developing State (SIDS) such as Trinidad and Tobago to be centred around such a truly international interaction and event, focusing on sustainability, resilience and climate change impacting on water resources. In the past 15 years, the demands on water infrastructure facing Caribbean SIDS have increased considerably. Little did we know, just how pertinent our chosen conference motto “Water Resources Resilience for Small Island Developing States (SIDS)” were to become for this event with Trinidad and Tobago being best suited for this conference, geographically as well as technically. This dynamic twin-island republic has a relatively high reliable water infrastructure (including desalination plants) for its population but in recent times water resources have been impacted by unforeseen climate change events.

As conference chair, I am blessed with an astute organising team, who worked tirelessly over the past two (2) years to make this conference a successful event. We sincerely thank the Faculty of Engineering at the University of the West Indies, St. Augustine Campus for their support in holding this event in Trinidad and their representatives and academic staff for engaging in this conference.

We trust you will enjoy this conference in the Caribbean as well as your stay in Trinidad and Tobago, West Indies. With your engagement and participation, we believe that WATEF 2022 will become a great milestone in the history of the University of the West Indies and the country of Trinidad and Tobago, West Indies. We do hope you will find this conference stimulating and enjoyable. WATEF 2022 offers opportunities to renew old friendships and to make new collaborations. Have a great and memorable time in the Caribbean.

Dr Kiran Tota-Maharaj  
Conference Chair WATEF 2022

## SCIENTIFIC COMMITTEE

<b>Kiran</b>	<b>Tota-Maharaj</b>	Aston University Birmingham
<b>Sue</b>	<b>Charlesworth</b>	Coventry University
<b>Edwin</b>	<b>Ekwue</b>	The University of the West Indies, Trinidad
<b>Kemi</b>	<b>Adeyeye</b>	University of Bath
<b>Joseph</b>	<b>Akunna</b>	Abertay University
<b>Kourosch</b>	<b>Behzadian</b>	University of West London
<b>Trevor</b>	<b>Bishop</b>	H2Outcomes
<b>Vincent</b>	<b>Cooper</b>	The University of the West Indies, Trinidad
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<b>Ines</b>	<b>Meireles</b>	University of Aveiro
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<b>Luis</b>	<b>Sañudo-Fontaneda</b>	University of Oviedo
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<b>Chad</b>	<b>Staddon</b>	UWE, Bristol
<b>Devi Prasad</b>	<b>Tumula</b>	University of Salford

## Conference Organising Committee

- Dr Vincent Cooper, Lecturer, Civil and Env Engineering, UWI
- Mr Navneet Boodhai, Manager, Engineering Institute, UWI
- Ms Julie Kublasingh, Accounting Assistant, Engineering Institute, UWI
- Engr. Anthony Chadee, Chair IEEE TT, Senior Manager WASA
- Eng. Dr. Tagore Ramlal, Vice Chair IET TT LN, Associate Professor, Utility Engineering, UWI
- Charlotte Bryant, Project Coordinator, WATEF Network

## KEYNOTE SPEAKERS

### **Prof. Michelle Mycoo. The University of the West Indies (UWI), Trinidad and Tobago**



Professor Michelle Mycoo is Professor of Urban and Regional Planning at UWI, St. Augustine, she has conducted extensive research and training on water management, climate change, disaster risk reduction and urban planning. She is currently the Coordinating Lead Author of the Small Islands Chapter of the Intergovernmental Panel on Climate Change Sixth Assessment Report, Working Group II, is a member of the International Science Council, the Scientific Advisory Committee of UNESCO's Management of Social Transformations. She has conducted capacity building workshops for UNDP's Global Water Partnership and holds a PhD (McGill University), MSc in Urban Planning (The University of Hong Kong) and a BA in Geography and Social Sciences (UWI).

### **Prof. Maya Trotz. University of South Florida, USA**



Prof. Maya Trotz is a Guyanese born professor of Civil and Environmental Engineering at the University of South Florida. She directs STRONG Coasts, a National Research Traineeship program to foster food, energy, and water solutions with coastal communities, and leads the knowledge management component of a Green Climate Fund project, "Water Sector Resilience Nexus for Sustainability in Barbados." She is a past President of the Association of Environmental Engineering & Science Professors and a board member of Fragments of Hope Corp, a coral restoration NGO in Belize. She holds a BS in Chemical Engineering from MIT, and MS and Ph.D. degrees in Environmental Engineering from Stanford University.

### **Prof. Sarah Hainsworth. The University of Bath, UK**



Professor Sarah Hainsworth OBE CEng FIMMM FREng CSci is Pro-Vice-Chancellor (Research) at the University of Bath, UK and is a Professor of Materials and Forensic Engineering. Sarah is a Fellow of the Royal Academy of Engineering, a Fellow of the Institute of Materials, Minerals, and Mining, and a Fellow of the Women's Engineering Society. She was awarded an OBE in 2019 for her services to engineering and forensic sciences. Sarah is strongly committed to research and teaching in sustainability and the circular economy throughout several research institutes. Sarah holds a BEng (Hons) in Science of Engineering Materials and a PhD (both University of Newcastle upon Tyne).

## SPONSORS

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## SPECIAL SESSIONS



### Special session 1: Flooding and resilience to climate change

Flooding in Trinidad and Tobago, and indeed across the Caribbean, is occurring more frequently, with greater magnitudes, and with increasing scale of damage. Flood risk management approaches based solely on flood defence works would prove to be inadequate unless they are complemented with other strategies such as flood prevention, property floodproofing, preparation and recovery. Such a diverse set of strategies would strengthen resilience even from the short term when flood defence works are still being planned. The presentation by the Director of Drainage describes the plans by the government to improve flood defence measures, and the time frame for their completion. In the intervening time, several sectors of the society would remain vulnerable to flooding and so it is important to develop these other strategies that would achieve an acceptable flood risk level. The presentation by the ODPM is on the status of the governance system for flood risk management, involving flood hazard mapping for land zoning, early flood warning systems for reducing losses and for evacuation and the requirement for floodproofing at the household level. The presentation by Pat Shako, the UK FCDO (Caribbean region) will highlight the role and activities of development partnerships to support resilience efforts. The presentation by Col Dave Williams is on the growing awareness of households to take charge to protect their property using some of the products that are fast becoming available in the country. The discussion will be guided by a panel of experts who will be able to respond to the entire range of strategies to be employed in a healthy flood risk management system.


#### Speakers:

<b>Katherine Badloo-Doerga</b>	<b>Director, Drainage Division, Ministry of Works and Transport, Trinidad</b>	<b>Topic:</b> The national drainage plan
	<p>Mrs. Doerga has worked with the Ministry for the past eighteen (18) years, in three (3) major Divisions, ten (10) years in the Construction Division, seven (7) years as Chief Planning Engineer in the Highways Division, and currently as the aforementioned. Mrs. Badloo Doerga graduated from the University of the West Indies, Trinidad with a B.Sc. (Hons) in Civil Engineering and holds a master's degree in construction engineering and Management. Katherine is a registered Engineer with the Board of Engineering as well as a Member of the Association of Professional Engineers of Trinidad and Tobago (APETT). The Director has served on multiple committees ranging from Disaster Prevention and Preparedness to Structural Assessments and Retrofitting, as well as the Community Flood Early Warning System on behalf of the Ministry.</p>	
<b>Anwar Baksh</b>	<b>Planning and Developing Office, Office of Disaster preparedness and Management, Trinidad and Tobago</b>	<b>Topic:</b> Flood risk management governance
	<p>Anwar Baksh presently serves as the Planning and Development Officer and lead of the Mitigation, Planning and Research Unit at the Office of Disaster Preparedness and Management Trinidad and Tobago. Anwar's role has presented him with great opportunities to utilize his full cadre of skills to promote disaster risk reduction and management with Trinidad and Tobago and by extension the Caribbean Region. His expertise lies in communications and networking where technical capacity meets human interaction. Critical to his function is the focus on the advancement of the</p>	

Governance framework for Disaster Risk Reduction and Management in Trinidad and Tobago in support to the implementation of the Sendai Framework for Disaster Risk Reduction (2015-2030). To this end, Anwar has worked in several areas of programmatic areas: Early Warning Systems, Recovery Planning, strategic planning, partnership and resilience building and several other areas to support the national DRRM agenda of Trinidad and Tobago. Through his work, Anwar has been able to strengthen and forge partnerships across the regional and global landscape with the aim of strengthening the resilience our country and the region. With the support of those around him, he is determined and committed to disaster management and loss prevention in the face of climate change for the small island developing state of Trinidad and Tobago.

<b>Fazir Khan</b>	<b>Managing Director, Alpha Engineering &amp; Design (2012) Ltd.</b>	<b>Topic:</b> Flooding resilience
	<p>Fazir Khan has over 30 years' experience as a practicing professional Civil Engineer and Project Manager, working locally and within the Caribbean Basin. He graduated from the University of the West Indies, Trinidad with a B.Sc. (Hons) in Civil Engineering. He has obtained a diploma in Management for the Henley University and certificates in Project Risk Management, Project Cost and Schedule Management, and Contracting and Negotiation Skills from the Arthur Lok Jack Graduate School. Fazir is a certified A+ modeler for Detention Pond Systems; Urban Storm Water Management; and Hydrological Modeling for sustainable solutions on large sites. He has a certificate in Integrated Coastal Zone Management from IHE Delft University. Apart from the Association of Professional Engineers of Trinidad and Tobago (APETT) where he was a Past President (2016/2017), he is also a registered member of the Board of Engineering of Trinidad and Tobago and the British Hydrological Society, England. During his 21 years with Alpha, Fazir has worked extensively on large integrated developments, infrastructure designs, water and wastewater projects and construction activities for various public sector and private Clients. Previous to his employment with Alpha, he worked at Trinidad Contractors Limited for 5 years as a Project Engineer, assigned to several engineering and construction projects within the Caribbean region.</p>	
<b>Pat Shako</b>	<b>Climate &amp; Disaster Resilience Adviser, UK Foreign, Commonwealth &amp; Development Office (Caribbean)</b>	<b>Topic:</b> Development and resilience
	<p>Pat Shako joined the Department for International Development (DFID) Caribbean - now UK FCDO in 2018 as the Climate and Disaster Resilience Adviser. She currently helps to conceptualise and oversee the implementation of a portfolio of projects involved in building resilience and disaster risk reduction support for 7 ODA eligible countries across the Caribbean. Pat also provides technical support to the UK on policy and political climate change issues for an extra 5 Caribbean countries. Work areas focus on climate change adaptation across multiple sectors including incorporating resilience systems into public financial management and disaster management systems (including social protection systems); ecosystem-based solutions for resilience; renewable energy; as well as blue economy</p>	

and disaster risk finance instruments for small island developing states. Prior to this role, Pat has worked as staff with the World Bank, the Inter-American Development Bank (IDB), the Caribbean Development Bank (CDB), and has provided leadership on conservation and regional water issues during her positions with Global Water Partnership – Caribbean, and The Nature Conservancy. Pat holds a M.Sc. in Natural Resource Economics, and a MBA Finance and has worked across the Caribbean for over 25 years.

<b>Dave Williams</b>	<b>President, Emergency Management Agency of Trinidad and Tobago</b>	<b>Topic:</b> Property-level floodproofing
	<p>Colonel Williams served as a commissioned officer in the Trinidad and Tobago Defense Force for thirty-four years, retiring in April 2009. With respect to disaster risk reduction, he has been in the business for just over twenty years to date, amassing experience in directing response operations, leading rapid needs assessment teams, and adapting, developing and teaching disaster management subjects. He spent seven years as Director of the now-defunct National Emergency Management Agency (now re-incarnated as the ODPM) and two years (August 2010 –August 2012) as the Chief Disaster Management Coordinator at the Ministry of Local Government. Most recently, he held the appointment of Deputy CEO at the ODPM for a brief period of 10 ten months.</p>	

#### Discussion/ Q&A

##### Panelists:

**Dr Vincent Cooper**

**Ms Stacey-Ann Pi Osoria**

University of West Indies, Trinidad and Tobago

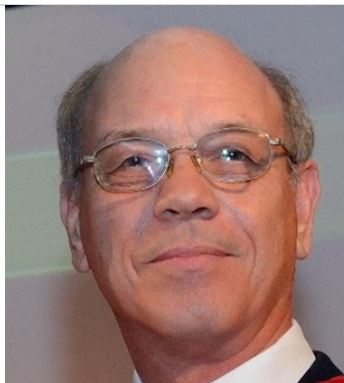

PODS - Emergency management consultancy and solutions

## Special Session 2 (Industry Day): Water security challenges and strategies in the 21st century

Chair: *Engr Anthony Chadee*


According to climate model predictions, the Caribbean is facing a very uncertain future on providing the water for its development. In the first session of this special session Dr. Cashman explores the predicted changes in water availability and what this might mean for Caribbean development. In the meantime, expectations for growing the economy may increase water demands in various sectors. The presentation by WASA, Mr Lord and Dr Sammy explores the technical innovations and projections for the future, focusing specifically on solutions for effective water demand management including for major water consumers in Trinidad and Tobago. In the final paper, Mr. Meade from the Water Resources Agency considers these supply and demand predictions and discusses strategies that need to be fully developed for achieving water security. The talks are followed by a discussion with a panel of experts.

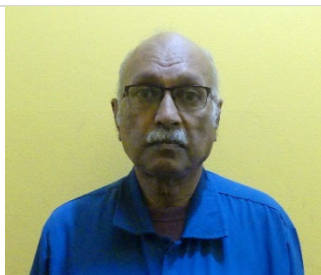
### Speakers:

<b>Adrian Cashman</b>	<b>Consultant, AKWATIX Water Resources Management</b>	<b>Topic:</b> Water bombs and the future of water
	Dr Adrian Cashman has over 40 years of experience in the water sector. He has been working in the Caribbean, based in Barbados for the past 15 years, first with the University of the West Indies and now as an international water resources management consultant. He has worked on numerous research and consultancy projects across the Caribbean. Prior to 2018, he spent 12 years with the University of the West Indies and served as the Director of the Centre for Resource Management and Environmental Studies (CERMES), training and mentoring many postgraduate students who have gone on to play important roles in the water sector across the Region. Dr Cashman's published works cover a diverse range of fields including critical accounting, geography, water and climate change, water policy, resource management and future studies. He has worked with a wide range of international and regional organisations on water and climate related matters. Up until 2022 he was a member of Global Water Partnerships Technical Advisory Committee and continues to serve the Caribbean as Deputy Chair of the Global Water Partnership Caribbean's Technical Committee. In 2020, he received the Caribbean Water and Wastewater Associations Gold Award for services to the Caribbean water sector.	
<b>Kennedy Lord</b>	<b>Manager, Seven Seas Water Group, Trinidad</b>	<b>Topic:</b> Desalination, the impact to Trinidad and Tobago Water Sector
	Kennedy Lord is the Plant Manager at Seven Seas Water Group Point Fortin Trinidad. He holds a BSc Mechanical Engineering Technology specializing in Manufacturing from the University of Houston and a MBA Management from Florida Institute of Technology. He along with his Team has guided the operations of the 6.7 million gallons per day Desalination Plant at Point Fortin Trinidad to achieve all Operations Performance KPI over the last 36 months. Mr. Lord worked in heavy Manufacturing as the Production Superintendent and Manufacturing System Specialist before joining Seven Seas Water. He has published articles for the International Cement Review and the Florida Tech Magazine. He is Married and father of two adult children,	



when he is not engaged in assisting to improve his community, he is either involved in Fishing, Hiking or Golfing.

<b>Keith Meade</b>	<b>Director, Water Resources Agency</b>	<b>Topic:</b> Strategies for water security in the future
	<p>Keith Meade is a water resources management professional with over 20 years' experience in the water sector. He has practical experience in hydrology, water resources assessments and planning, strategic business management, disaster management, environmental management and forest management. At present, Keith Meade is a Senior Manager at the Water and Sewerage Authority in Trinidad and Tobago and heads its Water Resources Agency. Keith possesses a MSc. In Water Resources Management and a BSc. Forestry from the University of Michigan, USA. Keith has conducted independent research on the impact of climate change on the water resources of the Great Lakes, and runoff patterns under various land-use practices in the Northern Range of Trinidad. He is presently involved in an Inter-Agency partnership which is establishing a Community Flood Early Warning System, and in the expansion and modernization of the hydrological monitoring network of Trinidad and Tobago. Mr. Meade spends time in fitness and faith-based activities.</p>	

<b>George Sammy</b>	<b>CEO, EcoEngineering Consultants Limited, Trinidad</b>	<b>Topic:</b> Water engineering
	<p>Dr. George Sammy is an Environmental Engineer based in Trinidad and Tobago and offering environmental consultancy services throughout the West Indies. He earned a doctorate in Engineering from the University of Oklahoma in 1983, and his expertise in Environmental Impact Assessment is internationally recognized. In July 2021, Dr Sammy was lead author of "A Handbook for Environmental Impact Assessment Practitioners in the Organization of Eastern Caribbean States". He has also developed and presented a large number of EIA training courses as part of university degrees and as stand-alone courses. Dr. Sammy's experience with water supply projects has spanned many decades. He has worked on projects such as the Arena Dam and Tumpuna Weir, the Northern Range Valleys Projects and the intake for the original North Oropouche River Project. He was initially the Assistant Resident Engineer and subsequently Resident Engineer on the construction of the Arena Dam and Tumpuna Weir. In 1983, he was assigned the Construction Manager of the entire Caroni-Arena Water Supply Project. Between 1985 and 1986, Dr. Sammy was the Project Manager on the design of the Point Fortin Water Supply Project. George's Environmental Engineering experience covers a wide range of project types including water supply pipelines in Trinidad and Water Supply Projects in St. Lucia, Tobago and Dominica.</p>	

#### Discussion/ Q&A Panelists:

<b>Mr Frankie Balkissoon</b>	Director, Engineering Division, Ministry of Agriculture
<b>Ms Candice Santana</b>	Caribbean Water and Wastewater Association

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# #1. Flooding and resilience





# Optimal Design Storm Frequency for Flood Mitigation

**Vishwanath Maraj<sup>1\*</sup>, Vincent Cooper<sup>2</sup>, Matthew Wilson<sup>3</sup>**

<sup>1</sup>CIVENT Limited, No. 28 Union Park East, Gopaul Lands, Marabella, Trinidad, W.I. <sup>2</sup>Civil Engineering Department, University of the West Indies, St. Augustine, Trinidad, W.I. <sup>3</sup> Geospatial Research Institute, University of Canterbury, New Zealand

## ABSTRACT

Determining the right amount of money or budget to be spent on flood mitigation works has always been a challenge in developing countries. Recent work has identified a recommended budget based on the value accepted for flood mitigation works in developed countries, measured as the Cost per Inhabitant. In addition to this approach, the industry also utilizes the hydroeconomic analysis (HEA) to determine an optimal design storm frequency that yields the most economical budget and design approach to flood mitigation works. This study investigates both economic approaches to determine the level of protection or the optimal design storm frequency for flood mitigation works. These economic approaches were executed for flood mitigation works within the North Valsayn community of Trinidad. To facilitate these economic assessments in determining the optimal design storm frequency, flood hazards were identified using a calibrated 2D hydraulic model done in LIS-FLOODFP. A Flood Damage Curve was used as a measure of the community's vulnerability using data collected from social surveys. Flood mitigation works were identified for the various design storm frequencies and the associated life cycle costs were determined. Upon execution of both economic approaches, the HEA indicated that it is most economical to maintain the existing flood condition as the annual cost of mitigation works far outweighs the annual damage cost. On the contrary, when implementing the Cost per Inhabitant approach, flood mitigation works performed for a design storm frequency of 1 in 50years was found to be optimal or comparable to the recommended budget. The study shows a disparity in defining a project's budget and the Optimal Design Storm Frequency using both approaches for decision/policy makers, and various stakeholders although both are acceptable.

\*Tel.: +1-868-773-5146.

E-mail Address: vishmaraj@civent.org

# **The Value of Hydrometry in Reducing Fluvial Flooding Footprints across The Caribbean – A Case Study in Dennery, Saint Lucia**

**Fazir Khan<sup>1</sup>, Fey Mohammed<sup>1</sup>**

<sup>1</sup>AEDL - Alpha Engineering & Design (2012) Ltd.,  
Trinidad, W.I.

## **ABSTRACT**

The work reported in this paper was initially carried out by Alpha Engineering & Design (2012) Limited (Alpha) for the Government of Saint Lucia (GOSL) on a World Bank (WB) Disaster Vulnerability Reduction Project (DVRP) for Flood Mitigation. Part of the scope involved setting up rainfall and streamflow gauges in the Dennery Watershed to observe rainfall depth and river stage for a limited period congruent with the engineering consultancy contract, to guide the selection of hydrological parameters and calibrate hydraulic models. Alpha then sought to extend the observation period so that larger datasets could be captured to improve the reliability and utility of the data. The aim of this paper is to present the real-world benefit of investing in hydrometric instrumentation to increase one's capacity when analyzing the hydrological and hydraulic impacts of storm events in Caribbean Watersheds and improve reliability in flood mitigation analyses for more resilient solutions. This is done through a case study in Dennery Village, Saint Lucia. This paper briefly presents the challenges associated with setting up and maintaining gauging stations, describes the technology used, lists the high benefits for the comparatively low cost of the investment, and finally the analyses of the data using standard methodologies in engineering hydrology and hydraulics to generate catchment-specific information relating to rainfall and runoff especially in terms of flooding, such as the role of antecedent moisture content on the severity of floods and the impact of rainfall structure, in space and time, on a flood hydrograph for specific catchments.

**Keywords:** Rain-Gauge, Streamflow-Gauge, River Stage, Stage Discharge, Flood *Hydrograph*, *Hydrological Parameters*, *Watercourse baseflow*, *Irrigation*

\*Tel.: +1868 735 6662

E-mail address: alphaengtt@gmail.com

# Considerations for Use of Permeable Pavement Systems within Urban Settings across Caribbean Small Island Developing States

John J. Monroe<sup>1\*</sup>, Kiran Tota-Maharaj<sup>2</sup>

<sup>1</sup>AECOM, San Fernando, Trinidad and Tobago

<sup>2</sup>Aston University, Birmingham, UK

## ABSTRACT

Increasing imperviousness caused largely from urban development coupled with global warming, sea-level rise and change in weather patterns contribute immensely to frequent flooding events across numerous urban municipalities across Caribbean Small Island Developing States (SIDS). Existing conventional drainage systems fail to meet stormwater runoff peak flow and volume demands generated by today's changing environment. Land or service constraints often restrict expansion of these drainage systems. Despite those challenges, Caribbean SIDS authorities and drainage engineers continue to recommend and use conventional drainage systems as the dominant infrastructure for the collection and conveyance of stormwater away from urban areas. Sustainable Urban Drainage Systems (SUDS) or Low Impact Development (LID) practices such as porous or Permeable Pavement Systems (PPS) are designed to effectively manage stormwater runoff at the source as opposed to conventional drainage systems. PPS reduce urban runoff and peak flows via development of on-site temporary storage measures for potential water reuse and minimisation of impervious areas. Water quality benefits of PPS include thermal mitigation and reduced pollutant loadings of suspended solids, heavy metals, hydrocarbons, and some nutrients to receiving natural waters. It is recommended that SUDS such as PPS be incorporated within urban drainage systems across Caribbean SIDS to help mitigate the frequent flooding events being experienced annually. PPS installations must be fit for purpose and this paper discusses key considerations for use of PPS within urban settings across Caribbean SIDS.

*Keywords: Permeable Pavements, Stormwater Management, Sustainable Urban Drainage Systems (SUDS), Small Island Developing States (SIDS), Surface runoff*

\* Tel.: +18683636563

E-mail address: john.monrose@aecom.com.

# Analysing Climate Gentrification in Coastal Neighbourhoods: A Case Study of Lagos, Nigeria

Godson Chizara Wogu<sup>1\*</sup>, Kemi Adeyeye<sup>2</sup>, Alex Copping<sup>3</sup>

<sup>1,2,3</sup>*Department of Architecture & Civil Engineering, University of Bath, UK*

## ABSTRACT

The concept of climate gentrification emerged to redefine our understanding of how climate change impacts (sea-level rise, flooding, water storms, tsunami) and adaptations drive inequality in human settlement and probable displacement of low-income households through changes in housing property value. However, the concept of climate gentrification lacks adequate parameters for application in diverse coastal locations. In response, this qualitative case study proposes a climate resilience integrated approach (framework) for identifying the parameters to analyse climate gentrification in the coastal neighbourhoods of Lagos (Nigeria). In doing so, a pilot investigation was conducted using naturalistic observation to explore events and lived experiences of residents in Lagos coastal neighbourhoods. Findings indicate a preference for built/engineered resilience infrastructures and higher return on physical asset investments as core variables driving climate gentrification patterns in Lagos coastal neighbourhoods.

**Keywords:** *Climate Change, Sea Level Rise, Flooding, Climate Gentrification, Housing Displacement.*

\* Tel.: +44 (0) 7447484748  
E-mail address: gcww20@bath.ac.uk

# Multi-Step Flood Forecasting in Urban Drainage Systems Using Time-series Data Mining Techniques

Farzad Piadeh<sup>1</sup>, Kourosh Behzadian <sup>\*1</sup>, Amir Alani<sup>1</sup>

<sup>1</sup> School of Computing and Engineering, University of West London, St Mary's Rd, London, W5 5RF, UK

## ABSTRACT

While early warning systems are recognised as the most cost-effective solution in urban flood risk management, highly accurate flood forecasting is limited to short-term timesteps, usually less than a few hours especially for prediction of overflowing in urban drainage systems. This study aims to provide a framework for more accurate overflow predictions for longer lead times by using data mining models applied to time series data for multi-step flood forecasting. The framework including event identification, feature analysis and developing models is demonstrated by its application to a pilot study in London. All numerical rainfall data and water levels in urban drainage systems are first turned to the categorical events on which 6 common weak learner models are developed. Then, three new time-series models, including overflowing-based, non-overflowing-based, and accuracy-based, are developed based on these models to predict overflow states among all identified events. Three weak learner models, i.e. discriminant analysis, naive Bayes, and decision tree are considered as the best models based on accuracy, total overflowing detection and total non-overflowing detection. Furthermore, while the accuracy of these models is changed between 95 to 85% from 1 to 12-step ahead of prediction, these models can detect the non-overflow conditions better than overflow detection. To cover this gap, new time series developed models could significantly reduce the overestimation and underestimation of water levels, including correct predicting of 50% of the total events after 12-step ahead by overflow-based model. This result shows the potential of using time-series data-demanding models for effective and highly accurate predictions of overflow events.

*Keywords: Data mining; Drainage system; Flooding classification; Multistep prediction  
Overflow prediction*

\* Tel.: +44 (0) 20 8231 2466  
E-mail address:

# **#2. Resources, environment, and climate change**



# Suitability of the SCS Type Temporal Distributions for Local Rainfall in Trinidad and Tobago, West Indies

Queena Edwards<sup>1\*</sup>, Vincent Cooper<sup>2</sup>

<sup>1</sup> Graduating civil engineering student

<sup>2</sup>Lecturer <sup>1,2</sup> Department of Civil and Environmental Engineering, The University of the West Indies, St. Augustine Campus, Eastern Main Road, St. Augustine, Trinidad and Tobago

## ABSTRACT

Stormwater management facilities are intended to convey the peak flows generated by some critical storm. A major feature of that storm controlling the resulting peak flow is its temporal distribution, that is, how the rainfall depth is distributed in time. The chosen distribution should be representative of the rainfall observed in the local vicinity of the facilities, and this is obtained by analysing fine temporal resolution records (between 5 minutes to 1-hour intervals) collected from local rainfall stations. Often, the only records available are ones collected on a daily scale, which are too coarse for the small watersheds that typify small island states. For estimating design peak flows, designers frequently refer to the temporal distributions published within the SCS peak flow estimation procedure. The problem is these temporal distributions were developed for the United States and they may be markedly different from local distributions. This study analysed fine resolution data from a few stations in Trinidad. It found that the representative temporal distributions were bi-modal, unlike the strong uni-modal distributions in the SCS procedure. A comparison of peak flows derived from the various distributions found that the NRCS distributions over-estimated peak flows by more than 100%. Although this may suggest the possibility of oversizing infrastructure for drainage, caution is required in realizing that while not frequent, from time to time, recorded storms have mimicked the SCS curves. Clearly the work needs to be extended to consider longer rainfall series, from a larger number of rainfall stations across the country.

*Keywords: Rainfall temporal distribution; SCS hydrologic procedure; oversizing infrastructure; HEC-HMS; Trinidad and Tobago*

\* Tel: (868)323-6091

Email address: queena.edwards@my.uwi.edu

# **Examining the feasibility of GeoAI and IoT for Smart Flood Early Warning Systems for Local Communities in Caribbean Urban Spaces**

**M. Codling<sup>1</sup>, B. Ramlal<sup>2</sup>, D. Davis<sup>2</sup>**

*<sup>1</sup>University of West Indies, St. Augustine, Trinidad, and Tobago*

*<sup>2</sup>University of West Indies, Department of Geomatics Engineering and Land Management,  
St. Augustine, Trinidad and Tobago*

## **ABSTRACT**

Over the last few decades, flooding has resulted in many problems that significantly impact countries in the Caribbean. This has been especially challenging in urban areas where widespread damage has occurred. In addition, given that over 50% of the world's population lives in urban areas, these locations are deemed to be vulnerable to climate-related disaster events that would further exacerbate the challenges in the region. These urban spaces in the Caribbean have limited access to real-time flood monitoring data for formulating and supporting policies for disaster practitioners to coordinate timely preparedness and mitigation efforts. While flooding is complex, with a series of negative impacts on social and economic sectors, it is essential to provide a basis to support decision-making information on vulnerability and resilience through early warning systems (EWS). However, the main obstacle in creating early warnings in the Caribbean is the suitability and availability of data for real-time flood prediction (Aliasgar, 2010). Consequently, there is a research gap from the perspective of short-term forecasting for sudden rainfall events in urban spaces in the Caribbean. Given the early warning system culture in the Caribbean has an environment of real-time data of scarce resources, it is necessary to forge an approach for real-time forecasting flooding impact in urban spaces. The paper will provide a preliminary analysis of the feasibility of machine learning and IoT use in supporting EWS in Caribbean urban spaces.

*Keywords: GeoAI, Machine Learning, Internet of Things*



# Advancing Solar Energy driven Heterogeneous Photo-Fenton processes for River Water Remediation

Kiran Tota-Maharaj<sup>1\*</sup> and Simeon Keates<sup>2</sup>

<sup>1</sup>Associate Dean for External Engagement and Reader in Civil & Environmental Engineering (Water and Environmental Engineering) Department of Civil Engineering, School of Infrastructure & Sustainable Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, UK;

Email: [k.tota-maharaj@aston.ac.uk](mailto:k.tota-maharaj@aston.ac.uk)

<sup>2</sup>Deputy Vice-Chancellor (Research), University of Chichester, College Lane, Chichester PO19 6PE, UK; Email: [s.keates@chi.ac.uk](mailto:s.keates@chi.ac.uk)

## ABSTRACT

Water is essential for life. Many of the countries across the globe that have poor management of potable water resources and lack critical infrastructure for managing wastewater. As the population of the Earth grows exponentially, the demand for water increases. More than 1 billion people across the world do not have access to potable water and they are struggling with epidemic level disease outbreaks, limited water supply among other large-scale public health risks. Large-scale critical infrastructure chains are required in order to produce potable water from raw water sources, and developing countries continue to struggle economically and cannot afford the same treatment chains as the developed world. This research project evaluated the feasibility of two photocatalytic and photo-Fenton solar reactors on their capabilities to breakdown water contaminants present in natural hydrosystems and freshwater resources namely rivers. The approach adopted to achieve this was the photo-Fenton reaction and solar-photochemical reactors designed constructed and tested for the removal efficiencies of Chemical Oxygen Demand (COD), ammonia, nitrates, nitrites and phosphates via LCK curvette tests, in addition to turbidity and colour. The water quality analysis and results showed that oversaturation of the photo-Fenton reagents reduces the effectiveness of the reaction, and that finding the correct chemical balance has a greater impact on the removal efficiencies of the five pollutants than the use of UV light catalyst. The difference in the reactor builds was their diameter, and the results showed that the reactor of smaller diameter achieved the best removal efficiency across all five pollutants.

**Keywords:** Photo-Fenton, Heterogeneous Fenton, Photochemical treatment, Solar Energy, River Water, Detoxification, Drinking water, Solar radiation

\*Tel: +44 (0) 121 204 4296

E-mail address: [k.tota-maharaj@aston.ac.uk](mailto:k.tota-maharaj@aston.ac.uk)

Web: <http://www.watersecuritynetwork.org/>

# Potential Impact of Oil Spills in Coastal Waters on Water Supply

Portia Felix<sup>1\*</sup>

<sup>1</sup>The University of the West Indies, St. Augustine

## ABSTRACT

It is apparent that oil exploration poses an inherent risk to water resources and water quality. This is exemplified by oil spills resulting from broken pipelines, underwater blowouts and oil transport vessel accidents. In these instances, water is usually the first casualty, as some form of water body is vulnerable to spilled oil, resulting in oil contaminated water. The freshwater resources of Small Island Developing States (SIDS) are often said to be stressed from anthropogenic pollution, which can lead to freshwater scarcity. In an effort to ensure the sustainability of freshwater resources resilience in SIDS, desalination is increasingly being used to provide potable water. Hence the quality of seawater deserves serious consideration. It is in this light that oceanic oil spills are of significant relevance to the provision of a guaranteed supply of potable water. For an oil producing small island developing state as Trinidad and Tobago, which has considerable oil and gas activities on land and in shallow waters along its coasts, the island's oceanic water can become increasingly stressed from oil spills, possibly leading to the shutting down of seawater intakes in the desalination process. A real-life seawater surface oil spill in the Gulf of Paria, south-west coast of Trinidad, not far from the largest desalination plant in the Caribbean, is investigated and its behaviour modelled, using numerical mathematical modelling techniques to produce trajectory plots. These plots are analysed to infer the potential impacts of the oil behaviour in the coastal waters on the island's domestic water supply.

*Keywords: Small Island developing states (SIDS), oil spills, coastal water quality, freshwater resources, desalination, numerical mathematical modelling, Gulf of Paria, Trinidad*

\* Tel.: +1 868 764-5427.

E-mail address: portiafelix30@gmail.com.

# The Impact of Climate Change on the Navet Reservoir, Trinidad.

Ravi Baboolal<sup>1\*</sup>, Vincent Cooper<sup>2</sup>

<sup>1</sup>The University of Trinidad and Tobago

<sup>2</sup>The University of the West Indies, St. Augustine

## ABSTRACT

A hydrologic study of the Navet reservoir and its catchment was conducted to investigate and evaluate the potential impacts of climate change on it, using the Soil Moisture Accounting algorithm in HEC-HMS to perform continuous simulations. The catchment is partially gauged, with a single rainfall gauge located within it and with the absence of a stream gauge, stage data from the reservoir was used to evaluate catchment response.

The selection of model parameters was based on previous work done on the nearby Nariva catchment and were improved on by a manual optimization technique. The model was subject to a split-sample test with a calibration period of 24 months (2003, 2004) on a daily time-step followed by validation over a period of 60 months (2005-2009).

Upon successful validation, the model was used to evaluate the system's response to climate change. The meteorological data for this was generated by the PRECIS software for this region. The model was subject to three scenarios based on the SRES A1B scenario. The results of simulations for the period 2030-2096 showed that for successful operation, production rates at the Navet reservoir requires a 40% reduction of present values for two of these scenarios and by 30% for the most optimistic scenario.

*Keywords: Continuous Hydrologic Modelling; Soil Moisture Accounting; HEC-HMS; Navet Reservoir*

\* Tel.: +1-868-686-9854

E-mail address: ravi.baboolal@utt.edu.tt

# Cumulative Fatigue Damage of Small-Bore Piping Subjected to Flow Induced Vibration

Rajesh Ragoobir<sup>1</sup>, Richard Bachoo<sup>2\*</sup>

<sup>1,2</sup>*Department of Mechanical and Manufacturing Engineering  
University of the West Indies St. Augustine, Trinidad and Tobago*

## ABSTRACT

The structural fatigue of a vertically oriented small-bore connection due to flow induced turbulence emanating from an upstream piping manifold is experimentally investigated. Dynamic strain measurements are taken at two perpendicular locations on a small-bore connection and the method of rain flow counting is used to determine the cumulative damage incurred. The influence of a number of factors on the cumulative damage are investigated and explained. These include the effects of (1) single phase and multiphase flow, (2) the upstream flow path through the manifold, and (3) steady-state and transient conditions. Specifically, key observations that may be useful to piping designers and engineers are observed and reported. For instance, for single phase water or air the largest bending stresses are due to the out-of-plane vibration of the small-bore piping, whereas the pulsating characteristics of the multiphase flow results in significantly larger in-plane bending stresses. It is also observed that under certain manifold outlet conditions, transient effects upon pump start-up can produce more than 300 times the cumulative fatigue damage compared to steady-steady operation.

*Keywords: Cumulative damage, Fatigue, Flow induced vibration, Rainflow counting, Small bore connections.*

\* Tel.: 18686622002 Ext: 83169.  
E-mail address: Richard.Bachoo@sta.uwi.edu

# Improving Monetary Valuation Methods used in Cost Benefit Analysis of Water Infrastructure Projects

**Dino Ratnaweera\***

*<sup>1</sup>Doscon AS, Østre aker vei 19, 0581 Oslo, Norwa*

## **ABSTRACT**

An assessment of social utility and project benefits in the water sector should include financial, environmental and socioeconomic impacts that are comparable over the same unit in an analysis. Cost benefit analysis (CBA) is a decision support tool that can cover impacts identifiable within these three impact categories. However, most water sector CBA are only invested in forecasting future financial cost-benefits, while environmental and socioeconomic impacts are assessed by environmental impact assessments (EIA), life cycle assessments (LCA) and other qualitative assessments, or entirely ignored. Studies identify a need for more guidance on application of relevant monetary valuation methods to water infrastructure specific project impacts. This is feasible if a more approachable and implementable CBA framework tailored for the sector is made available. This paper suggests a universal set of umbrella categories for wastewater treatment plant (WWTP) impacts across the five project phases that comprise a project lifespan. The paper identifies literature on accessible and relevant monetary valuation methods for each impact category typical to a WWTP infrastructure project. The findings originate from literature on current practices in the water sector, academic innovations theoretically applicable to water sector projects, and methods borrowable from comparable sectors. These origins are the building blocks for consolidating knowledge of monetary valuation methods relevant to the water sector, which we tabulate in a reference matrix.

*Keywords: CBA, WWTP, roadmap, monetary valuation methods*

\* Tel.: +47 9300 3882  
E-mail address: dino@doscon.no

# Rainwater Harvesting Design Approaches

Jeremy Gibberd<sup>1\*</sup>

<sup>1</sup>CSIR, Meiring Naude Rd, Brummeria, Pretoria, South Africa

## ABSTRACT

Different approaches have been developed to design rainwater harvesting systems. However, these have not been widely applied in schools and are not well understood. This paper presents findings from a study in which different rainwater water harvesting design approaches are selected and applied to a case study school. The approaches are introduced and the results of their application to the case study school are critically evaluated. The study finds that the methodologies have different strengths and weaknesses. A critical analysis of the results indicates that one approach may be too simplistic and provide misleading results. Another approach does not provide adequate outputs to fully design rainwater harvesting systems. A third methodology is complex to apply and requires data that is difficult to obtain. Based on the study, recommendations are made on how the selected approaches can be improved to enable these to be used more easily to design school rainwater harvesting systems.

*Keywords: Schools, rainwater harvesting, rainwater harvesting modelling and calculators*

\* Tel.: +00 27 12 343 1941.  
E-mail address: [jgibberd@csir.co.za](mailto:jgibberd@csir.co.za).

# **School Water and Rainwater Use Modeller**

**Jeremy Gibberd** *Jeremy Gibberd*<sup>1\*</sup>

<sup>1</sup>*CSIR, Meiring Naude Rd, Brummeria, Pretoria, South Africa*

## **ABSTRACT**

With climate change, schools in hot and dry areas are increasingly experiencing water shortages. This can affect the health of students and teachers, disrupt education and in the worst case, lead to school closures. Rainwater harvesting can help address water shortages by providing a safe alternative source of water. However, there is limited research and guidance on how rainwater harvesting systems can be applied to schools. A lack of guidance and knowledge has meant that schools are not aware of the potential of rainwater harvesting systems and do not adopt these systems. There is a need, therefore, for a simple tool that can be used by schools to understand the potential of rainwater harvesting systems at schools. This study aims to address this gap by developing the School Water and Rainwater Use Modeller (SWARUM). The modeller is presented and applied to a case study school in a drought-stricken area of Southern Africa. The findings of the application and the modeller are critically evaluated. The study finds that the modeller can be used to show the potential of a rainwater harvesting system at schools and enables different scenarios to be modelled and understood. The study makes recommendations for the improvement of the modeller and its application.

*Keywords: Schools, rainwater harvesting, School Water and Rainwater Use Modeller*

\* Tel.: +00 27 12 343 1941.  
E-mail address: [jgibberd@csir.co.za](mailto:jgibberd@csir.co.za).

# An Elementary Review of Wave Energy Potential at Mauritius Island

Antonia Chatzirodou<sup>1\*</sup>, Hugo Harel<sup>2</sup>

<sup>1,2</sup> University of the West of England, Coldharbour Ln, Stoke Gifford, Bristol BS16 1QY

## ABSTRACT

During the last decade renewable energy sector has attracted a significant interest from a range of stakeholders. Ocean Renewables in specific are an attractive solution for covering countries' high energy demand with low or no environmental impacts. Within this context wave energy power generation potential around small islands have extendedly been investigated as well. Following that a review has been carried out in here, to compile existing research findings on wave energy potential, in specific around Mauritius Island. The island is geographically favoured for ocean energy extraction in the context of energy extraction from offshore winds, waves and currents, and ocean thermal and saline energy. Mauritius relies on fossil fuels to cover its energy needs. But the island has set a target to be able to cover its electricity needs by utilizing 35% from renewable energy sources by 2025. From the reviewed literature and a range of secondary calculations two sites come through as highly favourable locations for WECs (Wave Energy Converters) installation. Findings highlight that the wave source itself is abundant stressing out the need for further research to understand when and if WECs at the Mauritian sites could be fully commercialized in the future. For these sites and from the point of better understanding the spatial distribution of wave energy resource, high resolution wave transformation and hydro-morphodynamic numerical modelling is further suggested. Numerical modelling can support exercises to identify precise locations for WECs deployment along the coastline, prior to reaching any commercialization.

*Keywords: Mauritius Island, Wave Energy Converter (WEC), Ocean Wave Energy, Renewable Energy, Small Island*

\* Tel.: +4411732 85233  
E-mail address: Antonia.Chatzirodou@uwe.ac.uk



## #3. Sustainable transitions



# **Digitalisation in the Water Sector: Opportunities and Challenges in the Next Decades**

**Harsha Ratnaweera**

*Norwegian University of Life Sciences, PO Box 5003, 1432 Aas, Norway*

## **ABSTRACT**

The water sector is undergoing rapid digitalisation providing new opportunities for improved, more efficient and economical services. Digitalisation may efficiently enable water utilities to overcome numerous challenges in the next decade by implementing, for example, real-time detection of water quality, process optimisation, efficient management of transport systems' rehabilitation, and reduction of utilities' physical and energy footprints. Many countries consider water supply and wastewater management critical services, and small islands are not an exception. Disruption of these services can lead to devastating consequences for the functioning of a society. In addition to natural catastrophes, the increasing number of man-made disruptions requires the earliest possible detection. The rapid digitalisation of the water sector has increased its vulnerability to cyberattacks, making it the third most attacked sector based on probability. Preparedness for immediate control of the attacks and the recovery actions after the incident is vital and should be planned. When a utility is under attack, identification is also critical, as man-made attacks can last several hours or days before being identified. This paper presents the emerging opportunities of digitalisation and the challenges associated with cyberattacks. Examples requiring increased preparedness, efficient detection, and the use of digital tools to minimise the impacts are outlined.

*Keywords: water utilities, digitalization, remote control, cyber risks*

\*Tel +47 6723 1587  
Email address: harsha@nmbu.no

# **Potential Implications for Deployment of Low Carbon Construction Materials in the Water Industry**

**CD Hills, N Tripathi, K Tota-Maharaj\* and JE Hills\*\***

*Indo:UK Centre for Environment Research and Innovation*

*School of Engineering, University of Greenwich, Chatham Maritime, Kent ME4 4TB*

*\*Civil and Environmental Engineering, Aston University, Birmingham B4 7ET*

*\*\*Southern Water, Yeoman Road, Worthing, West Sussex BN13 3NX*

## **ABSTRACT**

The introduction of sustainable and low-carbon construction materials into the built environment is one approach to reduce emissions of greenhouse gases to the atmosphere. By increasing the use of renewable energy and waste, new materials and processes can be incorporated into the materials supply chain. The present work relates to the mineralisation of anthropogenic CO<sub>2</sub> gas in construction materials, and their potential for use in water treatment, particularly in small island nations. We provide an overview of developments in this area of interest, with specific reference to the capture and use of point-source emissions, carbonate-able cementitious binders, and waste in the manufacture of construction aggregates/monolithic products, including concrete and potential filter media. As the amount of construction materials used in new and existing water-related infrastructure is significant, there is potential for meaningful long-term carbon sequestration. In respect of this, we discuss the potential sustainability gains from replacing/reducing carbon intensive materials, quarried and crushed stone with low-carbon substitutes with particular reference to typical water supply and wastewater treatment facilities in the SE of England. Further, we estimate this potential more widely in order to gain a 'global' for carbon storage potential figure within fresh and wastewater infrastructure.

# **Development of Sustainable Building Design in Hong Kong: Exploring Lean Capabilities**

**Edmond WM Lam<sup>1\*</sup>, Albert PC Chan<sup>2</sup>, Timothy O. Olawumi<sup>3</sup> Irene Wong<sup>2</sup>  
and Kayode O. Kazeem<sup>1</sup>**

*<sup>1</sup>College of Professional and Continuing Education, The Hong Kong Polytechnic University,  
Hong Kong, China*

*<sup>2</sup>Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong,  
China*

*<sup>3</sup>School of Computing, Engineering and the Built Environment, Edinburgh Napier University,  
United Kingdom*

## **ABSTRACT**

When a building design fails to meet the end-users' requirements after construction, it is regarded as a faulty design. Faulty designs often lead to renovation, demolition, and material waste. The need to implement innovative tools and systems that continuously provide designers with the end-users' design requirements and feedback in the built environment cannot be ignored. This study explores the potentiality of implementing a Lean Premise Design (LPD) scheme in Hong Kong to facilitate sustainability practices, ensure energy conservation, promote innovative green technologies and water efficiency, and reduce abortive works in high-rise residential (HRR) buildings. A comprehensive review of literature on concepts similar to the LPD scheme and sustainability practices in the design and development of high-rise buildings was undertaken. In addition, interviews were adopted to validate the identified barriers and drivers to the LPD scheme. These facilitated the identification of perceived barriers to the LPD scheme adoption in the local context. Furthermore, the relevant drivers that can promote its implementation were examined. The study focused on sustainable building design relating to users' behaviour patterns and expectations, social needs, green maintenance technologies, and government initiatives. About 77% of the experts affirmed the availability of comprehensive building codes and guidelines. Nevertheless, 62% of the experts confirmed the insufficiency of the current regulations to promote sustainable building design. Similarly, the literature review revealed that while there are many sustainable concepts in the development of high-rise buildings, little or none of these concepts focused on LPD.

**Keywords:** High-rise buildings; Lean Premise Design; Residential buildings; Sustainability, Waste; Hong Kong.

\* Tel.: +852 3746-0776

E-mail address: edmond.lam@cpce-polyu.edu.hk

# Higher Education Institutions in the Sustainable Transition: A Study at the University of Aveiro

**Sara Bona<sup>1</sup>, Armando Silva Afonso<sup>1,2</sup>, Ricardo Gomes<sup>3</sup>, Carla Pimentel-Rodrigues<sup>1,2</sup> and Fernanda Rodrigues<sup>1</sup>**

<sup>1</sup> RISCO, Civil Engineering Department, University of Aveiro,

<sup>2</sup> ANQIP, Civil Engineering Department, University of Aveiro,

<sup>1,2</sup> Campus Universitário de Santiago, 3810-193, Aveiro, Portugal

<sup>3</sup> INESC Coimbra and SMAS de Leiria, Civil Engineering Department, Polytechnic of Leiria, Campus 2 Morro do Lena – Alto do Vieiro, 2411-901, Leiria, Portugal

## ABSTRACT

In accordance with the United Nations 2030 Agenda for Sustainable Development, Higher Education Institutions (HEIs) play a key role in raising environmental awareness and implementing practices to contribute to the Sustainable Development Goals (SDGs), in a scenario of protecting the environment and promoting innovation and resilience – social, cultural, scientific, and technological. Considering HEIs as active agents of change in the global network for sustainability, the present study aims to present the main strategies and current initiatives of HEIs in the implementation and development of sustainable campus, regarding institutional physical interventions. Using the literature review, it is intended to identify the various contributions of HEIs in the Portuguese and European panorama for this emerging challenge, about the categories evaluation that include energy, greenhouse gas (GHG) emissions, waste, procurement practices and the built environment, mobility, biodiversity, water and food security, also highlighting the initiatives to increase environmental sustainability on the campuses of the University of Aveiro (UA). The conclusions of this research indicate that the HEIs, at the European level are implementing good practices in the management of the campus as a living and evolving laboratory, but there are potential interventions, still little explored, to make the operations of the HEIs more sustainable and effective.

*Keywords: Sustainable Campus, Circular Economy, Higher Education Institutions, University of Aveiro.*

E-mail address: [sara.cbona@ua.pt](mailto:sara.cbona@ua.pt)

# **#4. Water efficiency and demand management**

# Nearly Zero Water Buildings: Contribution to Adaptation and Mitigation Processes in Urban Environments

Armando Silva-Afonso<sup>1,3</sup> and Carla Pimentel-Rodrigues<sup>1,2\*</sup>

<sup>1</sup>University of Aveiro/RISCO (Portugal) and ANQIP (Portugal), 3810-193 Aveiro, Portugal

<sup>2</sup>ISCIA (Portugal) and ANQIP (Portugal), 3810-193 Aveiro, Portugal

<sup>3</sup>Standing Technical Committee on Water, World Federation of Engineering Organizations (WFEO), Paris, France

## ABSTRACT

Extreme weather events related to heat waves and heavy rainfall are expected to intensify in the coming decades in various regions of the planet as a result of climate change. The impacts of these events on urban environments will be particularly significant, given that, according to the United Nations, around two-thirds of the world's population will live in cities by 2050. Buildings and other urban infrastructures therefore have an important role to play in the processes of mitigation and adaptation to climate change. The implementation of nearly zero energy buildings (NZEB), for example, can contribute to very significant reductions in greenhouse gas emissions, which is why the European Union has established special requirements in new buildings. However, “nearly zero buildings” for all resources, not just energy, should employ integrated and enhanced construction solutions in the future, not only contributing to increasing environmental sustainability in urban areas, but also playing an important role in adaptation and mitigation in relation to climate change. In the case of “nearly zero water buildings”, they can increase the resilience of urban environments in the face of extreme events such as prolonged droughts or extreme precipitation and, considering the water–energy nexus, can also contribute to a significant reduction in emissions. The “zero building” concept is not, however, similar for all resources. In the case of energy, the usual concept of NZEB does not mean a circular use of the resource, but rather that the total amount of resource used by the building is approximately equal to the amount of renewable resource produced or available on the site. In the case of water, part of the resource can be used in a circular way (water recycling), but renewable local sources alternative to the supply from the public network can also be considered. The design of “nearly zero water buildings” should be based on the 5R principle of water efficiency: Reduce consumption; Reduce losses and waste; Reuse water; Recycle water; and Resort to alternative sources (rainwater, salt water, etc.). It is obvious that water efficiency is of the utmost importance in the face of prolonged droughts, but the use of rainwater in urban areas has an additional known effect in dampening flood peaks. Considering the water–energy nexus, reducing water consumption in a building (the 1st R) also produces significant energy savings. This is a result of reducing the energy needs for domestic hot water, to pressurise water in buildings, and also in public systems, in pumping and treatment of water and wastewater

*Keywords: climate change, water efficiency, zero building*

\* Tel.: +351913875500

E-mail address: anqip@anqip.pt

# Interpreting the Technical Versus the Physical as Drivers for Shower Water Use

**Kemi Adeyeye<sup>1\*</sup>, Kaiming She<sup>2</sup>, Ines Meireles<sup>3</sup>, Vitor Sousa<sup>4</sup>, Tao Wang<sup>5</sup>,  
Dahmane Bairi<sup>6</sup>**

<sup>1</sup> *Department of Architecture and Civil Engineering, University of Bath, Bath BA2 7AY, UK*

<sup>2</sup> *University of Brighton, Lewes Road, Brighton, BN1 5EL, UK*

<sup>3</sup> *Department of Civil Engineering, University of Aveiro, Aveiro, Portugal*

<sup>4</sup> *Department of Civil Engineering, Architecture and GeoResources, IST—University of  
Lisbon, Lisbon, Portugal*

<sup>5</sup> *Faculty of Art and Design, Beijing Institute of Technology, Beijing 100081, China*

<sup>6</sup> *Université de Paris, Laboratoire Thermique Interfaces Environnement (LTIE), Département  
GTE, Université de Paris, Ville d'Avray, France*

## ABSTRACT

Showering is informed by the person, their preferences and the affordances provided by the showering device and supporting systems. People shower for different reasons, including reasons of health, hygiene, wellbeing, leisure, relaxation among others. Studies have explored water use and efficiencies in showering in homes and other buildings. The lack of granularity of showering data can however mean that findings and deductions are typically made at the household or building level, rather than at the individual, shower end-user level. This study helps to address this gap about showering. This paper presents further analysis from an in-home trial with 12 adult participants: 6 male and 6 female, with a particular focus on interpreting the shower performance factors against the shower user. The findings highlight the contextual and physical characteristics e.g., shower positioning and user anthropometrics, and the showering needs (perceived shower functionality) as important drivers of water use.

*Keywords: end-users, showerhead, showering, time, purpose, water efficiency*

\* Tel.: +44 1225 38 6113

E-mail address: k.adeyeye@bath.ac.uk



# Water Distribution Challenges in Northeast Trinidad and Tobago

**Goldie Davis<sup>1\*</sup>**

<sup>1</sup>Goldie Davis, University of the West Indies, St Augustine Trinidad and Tobago

## ABSTRACT

Provision of a reliable supply of water with adequate pressures is a paramount challenge for the water distribution network in Northeast Trinidad and Tobago. Customers in this region, served by the Water and Sewerage Authority of Trinidad and Tobago often have trouble in obtaining a pipe borne supply of water as they reside on areas of high elevation or at the farthest end of the distribution system. These areas where water supply challenges are a problem are Oropoune Gardens Piarco, Upper Five Rivers Arouca, Windy Hill Arouca, Edna Hill Arouca, Lillian Heights Arouca, The Foothills Arouca and Bon Air North that is made up of Pineridge Heights Housing Development and Ridgeview Heights Housing Development. Sources of supply for these impacted areas are the North Oropouche Water Treatment Plant, the Hollis Water Treatment Plant, Tacarigua Highlift Station and the Arouca Wells. Challenges in the water supply are a consequence of obsolete pipelines, numerous leaks, failure of mechanical equipment and the shortened duration of supply to the respective areas. The aim of this paper is to identify the inefficiencies and challenges of the water distribution system in this region by simulating flow through pipes using ANSYS Fluent simulation and the Hazen-Williams equation and advocate prospective solutions that can alleviate or even eliminate the inadequate water supply experiences faced by customers in these highly elevated areas.

*Keywords: ANSYS Fluent, Distribution pipelines, Hard-hit areas, Hazen-Williams Equation, Northeast Trinidad and Tobago, Transmission pipelines, Water distribution*

\* Tel.: +1-868-359-0582  
E-mail address: goldiedvs@gmail.com

# Impact of Climate Changes on Domestic Hot Water Consumption

Sandra Costa<sup>1</sup>, Inês Meireles<sup>1\*</sup>, Vitor Sousa<sup>2</sup>

<sup>1</sup>RISCO, Department of Civil Engineering, University of Aveiro, Campus Universitario de Santiago, 3810-193 Aveiro, Portugal

<sup>2</sup>CERIS, Department of Civil Engineering, Architecture and GeoResources, IST - University of Lisbon, Av. Rovisco Pais 1049-001 Lisbon, Portugal

## ABSTRACT

Domestic hot water consumption is the second largest source of energy consumption in residential buildings. Moreover, the growing trend towards more energy efficient buildings, from a thermal performance point of view, is increasing its relevance. As such, more accurate modeling of domestic hot water consumption is required, including the consideration of the impact of climate change. A new approach that accounts for the variability of the domestic hot water consumption and cold-water temperature throughout the months is used to forecast the amount of energy and carbon emissions associated. It was found that in climate change context, despite the forecasted increase in air temperature in the summer months, the decrease in the remaining leads to higher domestic hot water consumption and, proportionally, higher energy and carbon emissions.

*Keywords: domestic hot water consumption, energy consumption, carbon emissions, climate change*

\* Tel.: +351234370049  
E-mail address: imeireles@ua.pt.

# Water Demand Modelling and Analysis United Kingdom, North American and Sri Lankan Data

Seevali Surendran <sup>1\*</sup> and Shelini Surendran<sup>2</sup>

<sup>1</sup>The Environment Agency, England, UK

<sup>2</sup>School of Biosciences and Medicine, University of Surrey, Guildford, Surrey, GU2 7XH

## ABSTRACT

The aim of this research is to study real water consumption data to determine the most appropriate statistical distribution function to address the peak water demand. Furthermore, the study is expected to contribute to finding a better fitting water demand model, which could apply to any water network. To achieve the objective, this study selected water usage of three different countries with diverse socio-economic backgrounds, climate, and geography to get an overall picture of water usage patterns. The countries selected for the analysis were United Kingdom, North America, and Sri Lanka. The most widely used probability distribution functions to represent a continuous random variable such as normal, log-normal, exponential, logistic, log-logistic, 3- parameter log-logistic and Weibull were applied to comprehend the suitability of fitting. The normal, log-logistic and 3- parameter log-logistic distributions are suitable to represent demand data with lower and high demand values and were selected for further analysis and is described here to provide their suitability for modelling water demand.

*Keywords: uncertainty in water demand, log-logistic distribution, 3- parameter log-logistic distribution, probability distribution function, sustainable design*

\* Tel.: +44 7789926825

E-mail address: seevali.surendran@environment-agency.gov.uk

# #5. Water quality



## Microbial Activity in Potable Water Storage Tanks of Barbados

Katelyn Long<sup>1\*</sup>, Katherine Alfredo<sup>1</sup>, Elon Cadogan<sup>2</sup>

<sup>1</sup>University of South Florida, USA

<sup>2</sup>Caribbean Community Climate Change Centre, Barbados

### ABSTRACT

As water supplies are strained, distributed infrastructure can often help stabilize a water distribution system. Recently, the Barbados Water Authority, in collaboration with Caribbean Community Climate Change Centre, installed 400, 450, and 1000-gallon potable water storage tanks to residential and school properties to increase the reliability of distributed drinking water to residents. However, there is minimal knowledge on the potential microbial impact of these storage tanks on water delivered to the tap. Preliminary data from this project confirmed that temperatures within these tanks can exceed 25 degrees Celsius, the lower threshold for increased growth of the premise plumbing pathogen *Legionella*. Inhalation and ingestion of *Legionella pneumophila* is known to cause Legionnaire's disease, a life-threatening lung disease with pneumonia-like symptoms and tends to grow with long water stagnation periods, low disinfectant residuals and elevated temperatures.

Seven sites located in the northern parishes of Barbados and one site located in a western parish were tested for temporal fluctuations of temperature, nitrate, total chlorine, total coliforms, and *Escherichia coli* (*E. coli*) with *Legionella* tested at select times of the day. Five of these sites were installed within the past year and three were installed up to four years prior to this study. All tanks showed values below the nitrate recommended range of less than 10 mg/L given by the USEPA. Only three tanks maintained the minimum chlorine residual of 0.2 mg/L given by the USEPA. Five sites showed positive total coliform tests and three sites showed positive *E. coli* tests and *Legionella* tests. With these results in mind, more quality assurance testing must be performed to ensure the true activity inside these tanks at various times of the year, location on the island and with continually flushed and finished systems. Unintended consequences from infrastructure upgrades are a threat, especially as climate change will continue to strain drinking water source supplies.

*Keywords: Legionella pneumophila, water scarcity, potable, temperature, Barbados*

\* Tel.: +1 630 624 7018.

E-mail address: klong1@usf.edu.

# Biomass-Based Sorbents for Stormwater Treatment

**N Tripathi, CD Hills, K Tota-Maharaj\* and JE Hills\*\***

*Indo:UK Centre for Environment Research and Innovation  
School of Engineering, University of Greenwich, Chatham Maritime, Kent ME4 4TB*

*\*Civil and Environmental Engineering, Aston University, Birmingham B4 7ET*

*\*\*Southern Water, Yeoman Road, Worthing, West Sussex BN13 3NX*

## ABSTRACT

Rapid urbanisation coupled with climate change necessitates the use of bespoke facilities to treat waste and stormwater to prevent contamination of ground and surface water. The contaminants of interest are wide-ranging including heavy metals, organic pollutants and micro plastics. There is mounting interest in the management of significant amounts of biomass waste available around the world and the exploration of utilisation potential. For example, large amounts of filter media including 'active' materials such as charcoal and plant-based fibres are used. Nevertheless, the use of biomass-based sorbents and filter materials are of importance as they can offer both technical and economic advantages over traditional treatments. For example, studies are on-going on biomass-based sorbents coupled with conventional filter media such as graded sand and gravel gravity filters. The present work reviews developments in this area and introduces new potential materials for consideration, including biowaste from crustaceans, shells, and agriculturally derived biomass waste. With reference to example water supply and wastewater treatment facilities in the SE of England, the potential scale and benefits for resource recovery of biomass waste whilst also harnessing its water remediation potential will be discussed.

# Renewable Energy-Powered Reverse Osmosis Desalination: Solutions and Opportunities for Large-Scale Implementation

Mohamed T. Mito<sup>1\*</sup>, Xianghong Ma<sup>2</sup>, Hanan Albuflasa<sup>3</sup>, Philip Davies<sup>4</sup>

<sup>1</sup>Mechanical Engineering Department, College of Engineering and Technology, Arab Academy for Science, Technology and Maritime Transport, Abu-Qir, Alexandria, Egypt.

<sup>2</sup>Mechanical Engineering Department, School of Engineering and Technology, Aston University, Birmingham B4 7ET, UK.

<sup>3</sup>Department of Physics, College of Science, University of Bahrain, Kingdom of Bahrain.

<sup>4</sup>School of Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK.

## ABSTRACT

Operating reverse osmosis (RO) systems using renewable energy (RE) is fundamental for meeting water security challenges, especially for small islands and developing states. Their integration requires RO systems to accommodate variations from RE sources to avoid reliance on backup systems. This study presents the outcomes of a research project that aimed to optimise the operation of RE powered RO by improving their variable-speed and modular operation for handling a wide range of RE variations. An industrial-scale pilot RO plant with 3.2 m<sup>3</sup>/h production capacity was designed, commissioned and tested at Aston University, UK, to be the basis for this project. It includes an isobaric pressure exchanger and delivers similar performance to large RO systems to develop solutions suitable to such scale. Several operation strategies were investigated for operating RO systems using RE. An advanced control system using Model predictive control was developed to control the RO power consumption based on RE variation. RE availability prediction using neural networks was developed for scheduling the startup/shutdown cycles of RO units during modular operation. The project concluded that operation at variable recovery and constant brine flowrate delivered the lowest specific energy consumption and widest operation range for systems using an isobaric energy recovery device. Model predictive control enhanced energy utilization compared to a proportional-integral controller leading to a 2.35% improvement in permeate production for a defined power input. Overall, the solutions developed showed that RO systems can operate efficiently by direct RE using variable operation, which showcased the opportunities for further testing and development towards large-scale implementation.

*Keywords: Reverse osmosis; renewable energy; variable operation; model predictive control; wind speed prediction.*

\* Tel.: +44 7588340139.

E-mail address: mohamed.mito@aast.edu – mohamed.mito@gmail.com.

# Comparative Study of Solar-Enhanced Advanced Oxidation Processes for Water Treatment

Rikhi Ramkissoon<sup>1\*</sup>, Krishpersad Manohar<sup>2</sup> and Kiran Tota-Maharaj<sup>3</sup>

<sup>1</sup>Independent Researcher

<sup>2</sup> Faculty of Engineering, Department of Mechanical and Manufacturing Engineering, The University of the West Indies, St Augustine, Trinidad and Tobago.

<sup>3</sup>Department of Civil Engineering, School of Infrastructure & Sustainable Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, UK

## ABSTRACT

Water is an essential resource for human survival but in the 21<sup>st</sup> Century there is a lack of potable water in many parts of the world. In several developing countries people resort to consuming heavily polluted water obtained from rivers which contain life threatening diseases. The study used two methods, Photo Fenton and photocatalytic semiconductor as an advanced oxidation process to eliminate various water contaminants and provide an effective water treatment solution. Experiments were performed on polluted river water. Both methods were assessed by evaluating the physiochemical parameters that define the characteristics of safe water. The two methods successfully eradicated about 80-100% of pollutants that was measured in the river water samples. This shows the technology has potential in eradication of the contaminants.

*Keywords: Titanium Dioxide, Solar Photo Fenton, Solar photocatalytic semiconductor, Photocatalysis (Arial, inclined, 10 font, justified)*

\* Tel.: +1 868 4950414

E-mail address: ramkissoonrikhi@yahoo.com.



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