World Environmental and Water Resources Congress 2019

Water, Wastewater, and Stormwater; Urban Water Resources; and Municipal Water Infrastructure

Selected Papers from the
Proceedings of the
World Environmental and
Water Resources Congress 2019

Pittsburgh, Pennsylvania
May 19–23, 2019

ASCE

Edited by

Gregory F. Scott, P.E.

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Preface

We are excited to offer the proceedings of the 2019 World Environmental and Water Resources Congress. The proceedings include published papers from an engaging and challenging array of technical sessions, posters, and workshops at the Environmental and Water Resources Institute's (EWRI) 19th Annual Congress, held in Pittsburgh, Pennsylvania, May 19-23, 2019. This conference is a leading venue for professional interaction among engineers and scientists, covering disciplines related to water and environmental resources and infrastructure.

America's infrastructure is in urgent need of attention. The 2017 American Society of Civil Engineers' Report Card for America's Infrastructure estimates that an investment of over $4.5 trillion is needed to return the nation's infrastructure to a state of good repair. Of critical importance to the public's health and safety are the needs of water focused infrastructure. The Environmental Protection Agency (EPA) estimates that wastewater and stormwater collection and treatment needs are $271 billion as of January 2012 and drinking water utilities needs are $472.6 billion as of March 2018. While significant, the needs are not limited to the United States alone. According to the World Health Organization (WHO), contaminated drinking water is estimated to cause 502,000 diarrheal deaths each year, and by 2025, half of the world's population will be living in water-stressed areas. Compounding the state of water infrastructure are on-going changes to the climate. Scientific evidence unequivocally indicates these changes are accelerating. While debate remains as to the causes and how best to slow, stop and/or reverse these changes, it falls to professionals in the water fields to address the challenges to rebuilding the world's water infrastructure to be more resilient and reducing direct impacts such as flooding and indirect impacts such as disruption of critical economical services.

The 2019 EWRI Congress covers a wide range of topics that attempt to provide innovative and sustainable solutions to ensure that our water and environmental infrastructure and resources will be improved and built to secure and protect them for the future. We proudly host the Congress under the auspices of the American Society of Civil Engineers (ASCE).

Within the six (6) volumes of the proceedings, more than 150 written scientific and technical papers from nearly 800 oral and poster presentations focusing on the subject areas of various EWRI Councils are included. A list of subject area tracks is included in the acknowledgements below. We hope these proceedings serve to enhance your knowledge and encourage you to follow up with more detailed publications by the same authors, and related papers, typically found in ASCE technical journals.

This collection contains papers organized by the following EWRI Councils:

- **Water, Wastewater and Stormwater Council** whose purpose is to create, organize and manage the activities of various technical committees dealing with the engineered infrastructure and its effect on the environment, particularly water resources. Attention will be focused on assessing the effects and the important interrelationships of water resources, facilities and installations and necessary environmental and public health protection measures/systems needed for the functioning and sustainability of an adequate infrastructure.
- **Symposium: Stormwater**
  Urban Water Resources Council whose purpose is to advance engineering knowledge and practice through stimulating and guiding research and assisting the financing thereof in the field of urban hydrology; to organize research projects; in cooperation with professional committees, to interpret the findings of research; and to make available information and recommendations resulting from such research. The content fosters the development of improved or advanced urban watershed management and best management practices.
- **Municipal Water Infrastructure Council** whose purpose is to work with professionals in the public and private sectors directly involved in urban water infrastructure. This committee provides a community for practical professional practice individuals to develop products with an emphasis on owner/operator perspectives.

Acknowledgments

Preparation and planning for this Congress strongly depends on the dedication of those individuals who plan session topics, solicit abstracts and papers, oversee reviews of all submissions. We are deeply grateful to all who have provided this considerable effort, especially the track chairs listed below:

17th Groundwater Symposium	Paul Mathisen & Amy Chan-Hilton
Emerging & Innovative Technologies	Barak Fishbain
Environmental	Wendy Cohen & Lisa Hayes
History & Heritage	Larry Magura & Jerry Rogers
Hydraulics & Waterways	Fabian Bombardelli
Hydro-climate/Climate Change Symposium	Levent Kavvas
International Issues	Erfan Goharian & Ali Mirchi
Irrigation & Drainage	Stuart Styles
Planning and Management	Mashor Housh & Debora Piemnonti
Standards	Dr. Kathlie S. Jeng-Bulloch
Stormwater Symposium	Bill Hunt & Sarah Waickowski
Student Competition	Wes Lauer
Sustainability	Joshua Peschel
Watershed	Levent Kavvas & Don Frevert
WDSA	Terra Haxton
New Professionals	Erfaneh Sharifi
Desalination Symposium	Luzma Nava
Water, Wastewater and Stormwater	Bridget Wadzuk & Arnie Strasser
Professional Practice	Kristin White
Education	Angelica Huerta

We also acknowledge the members of the Congress Organizing Committee, without whose time and efforts the event would not be possible.

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Finally, we acknowledge and thank EWRI staff who, in the end, makes this conference a reality.

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Contents

Stormwater Symposium