World Environmental and Water Resources Congress 2018

Selected Papers from the Proceedings of the World Environmental and Water Resources Congress 2018

Minneapolis, Minnesota
June 3–7, 2018

Water, Wastewater, and Stormwater; Urban Watershed Management; Municipal Water Infrastructure; and Desalination and Water Reuse

Edited by
Sri Kamojjala, P.E., D.WRE

ASCE

EWRI ASCE ENVIRONMENTAL & WATER RESOURCES INSTITUTE

WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2018

WATER, WASTEWATER, AND STORMWATER; URBAN WATERSHED MANAGEMENT; MUNICIPAL WATER INFRASTRUCTURE; AND DESALINATION AND WATER REUSE

SELECTED PAPERS FROM THE WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2018

June 3–7, 2018
Minneapolis, Minnesota

SPONSORED BY
Environmental and Water Resources Institute (EWRI)
of the American Society of Civil Engineers

EDITED BY
Sri Kamojjala, P.E., D.WRE

Published by the American Society of Civil Engineers

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org

Errata: **Errata, if any, can be found at https://doi.org/10.1061/9780784481431**

ISBN 978-0-7844-8143-1 (PDF)
Manufactured in the United States of America.

Front cover: Photo courtesy of the U.S. Army Corps of Engineers, St. Paul District

Preface

We are excited to offer the proceedings of the 2018 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) 18th annual Congress, held in Minneapolis, Minnesota, June 3-7, 2018. This conference is a leading venue for professional interaction among engineers and scientists, covering disciplines related to water and environmental resources and infrastructure.

Within the five (5) volumes of the proceedings, nearly 200 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.

The collection of papers in this book, *World Environmental and Water Resources Congress, 2018: Water Wastewater, and Stormwater; Urban Watershed Management; Municipal Water Infrastructure; and Desalination and Water Reuse* 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: Desalination and Water Reuse (Committee)** Develop appropriate educational material, symposiums, webinars, and/or workshops on concentrate management in desalination and water reuse facilities; develop ASCE/EWRI guidance or guideline documents on concentrate management in desalination and water reuse and support the development of ANSI standards and/or other manuals of practice for the professional practice of concentrate management in desalination and water reuse.
- **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 provide a community for practical professional practice individuals to join in developing papers, preparing

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 and then "encourage" all authors to provide their material in a timely manner! We are deeply grateful to all who have provided this considerable effort, especially the track chairs listed below:

Track	Chairs
16th Groundwater Symposium	Paul Mathisen
Desalination Symposium	Bridget Wadzuk
Education	Cecilia Elmore
Emerging & Innovative Technologies	David Hill and Barak Fishbain
Environmental	Wendy Cohen and Lisa Hayes
History & Heritage	Larry Magura
Hydraulics & Waterways	Fabian A. Bombardelli
Hydro-climate/Climate Change Symposium	Levent Kavvas
International Issues	Ali Mirchi and Erfan Goharian
Irrigation & Drainage	Tom Ley
Planning and Management	Mashor Housh and Kaveh Madani
Professional Practice	Greg Scott
New Professionals	Colleen Bronner
Smart Water Symposium	Sudhir Kshirsagar and Branko Kerkez
Standards	Kathlie S. Jeng-Bulloch
Stormwater Symposium	Bill Hunt, Ruth Hocker and Bridget Wadzuk
Student Competition	Wes Lauer
Sustainability	David Cowan
Watershed	Don Frevert and Levent Kavvas
Water Distribution System Analysis (WDSA) Symposium	Regan Murray
Water, Wastewater and Stormwater	Bridget Wadzuk

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

General Chair
Rebecca Teasley, Ph.D., A.M.ASCE
University of Minnesota Duluth

Technical Program Chair
Sri Kamojjala, P.E., D.WRE, M. ASCE
Las Vegas Valley Water District.

Local Arrangements Chair
Brett Staeden, P.E.
Terracon Consultants, Inc

Technical Program Coordinators
Melissa Wetzig, P.E., M. ASCE
Colorado Springs Utilities

Veera Gnaneswar Gude, Ph.D., P.E., BCEE, M.ASCE
Mississippi State University

Congress Steering Committee Members
Paul Bizier, P.E., D.WRE, BCEE, F.EWRI, F.ASCE
Gabrielle Dunkley
Mark Gable
Sridhar Kamojjala, P.E., D.WRE, M.ASCE
John “Wes” Lauer, P.E., M.ASCE
Eric Loucks, P.E., D.WRE, M.ASCE
Brian Parsons, M.ASCE
Brett Staeden, A.M.ASCE
Steve K. Starrett, Ph.D., P.E., D.WRE, F.EWRI, F.ASCE
Rebecca Teasley, A.M.ASCE

Congress Program Committee Members
Amy B. Chan-Hilton, Ph.D., P.E., F.EWRI, M.ASCE
Gabrielle Dunkley
Kathlie S. Jeng-Bulloch, Ph.D., P.E., D.WRE, CFM, M.ASCE
Sridhar Kamojjala, P.E., D.WRE, M.ASCE
Karen Karvazy, P.E., M.ASCE
Morris Maslia, P.E., D.WRE, F.EWRI, M.ASCE

Gretchen Miller, Ph.D., P.E., M.ASCE
Monica Palomo, Ph.D., P.E., M.ASCE
Dennis Richards, P.E., D.WRE, F.EWRI, F.ASCE
Jerry R. Rogers, Ph.D., P.E., D.WRE, Dist.M.ASCE
Veronica Webster, Ph.D., M.ASCE

Finally, we acknowledge and thank the staff of the EWRI and ASCE who, in the end, makes this conference a reality. In particular, we thank Gabrielle Dunkley, EWRI's Manager, whose patience, perseverance, good humor, and great organizational talent ensure yet another successful EWRI Congress!

Director, EWRI
Brian K. Parsons, M.ASCE

Manager, EWRI
Gabrielle Dunkley

Technical Manager, EWRI
Barbara Whitten

Manager of Member Services, EWRI
Jennifer Jacyna

Senior Conference Manager
Mark Gable

Operations Coordinator
Shingai Marandure

Sponsorship and Exhibit Sales Manager
Drew Caracciolo

Contents

Desalination and Water Reuse Symposium

Stormwater Symposium