World Environmental and Water Resources Congress 2020

Emerging and Innovative Technologies and International Perspectives

Selected Papers from the Proceedings of the World Environmental and Water Resources Congress 2020

Henderson, Nevada • May 17–21, 2020

ASCE

EDITED BY

Sajjad Ahmad, Ph.D.

EWRI ASCE ENVIRONMENTAL & WATER RESOURCES INSTITUTE

WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2020

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Preface

Welcome to the proceedings of the 2020 World Environmental and Water Resources Congress! These proceedings contain technical papers associated with the diverse set of talks, posters, and workshops presented at the American Society of Engineers' (ASCE) Environmental and Water Resources Institute's (EWRI) 20th Annual Congress, held in Henderson, NV, May 17-21, 2020. Engineers and scientists from around the world gather at the EWRI Congress to discuss the latest innovative research, case studies, and developing best practices in water resources and the environment.

The theme of this year's conference is, "Be Smart and Sustainable: Don't Gamble with your Infrastructure." Across the globe, infrastructure is in urgent need of investment and careful attention. ASCE's 2017 Infrastructure Report Card found the national grade for infrastructure remains near the bottom of the scale at a "D+" and estimates that an investment of over $4.5 trillion is needed to return the nation's infrastructure to a state of good repair. The ASCE Failure to Act study notes that "deteriorating infrastructure, long known to be a public safety issue, has a cascading impact on our nation's economy, impacting business productivity, gross domestic product (GDP), employment, personal income, and international competitiveness". If this investment gap is not addressed throughout the nation's infrastructure sectors by 2025, the economy is expected to lose almost $4 trillion in GDP.

Internationally, water infrastructure is critically important to the public's health, safety and security. The ASCE Report Card rated components of water infrastructure separately, assigning America's drinking water, inland waters and dams a "D," wastewater a D+, and bridges a "C+". The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. Sustainable Development Goal (SDG) 6 focuses on ensuring availability and sustainable management of water infrastructure and sanitation for all. Compounding the state of water infrastructure are the variability and uncertainty of future changes in climate. A systems approach is needed to address these complex challenges that cross the boundaries of water, energy, health, environment and the economy. Professionals in the water and environmental fields are in the best position to find creative and practical solutions to build resilience and sustainability into the world's water infrastructure.

The 2020 EWRI Congress covers a wide range of topic areas related to drinking water, groundwater, wastewater, stormwater, waterways, and irrigation and drainage infrastructure. Many overarching themes such as sustainability, smart water, security, systems analysis, and innovative technologies will also be addressed.

Within the six (6) volumes of the proceedings, more than 160 written scientific and technical papers from nearly 850 oral and poster presentations focusing on the subject areas of various EWRI Councils are included. A list of the subject area technical tracks is included in the acknowledgements below. We hope these proceedings enhance your knowledge base and inspire you to read other publications by the same authors or on similar topics that can be found in ASCE technical journals and publications.

The collection of papers in this volume of the Proceedings of the *World Environmental and Water Resources Congress, 2020, Be Smart and Sustainable: Don't Gamble With Your Infrastructure* contains papers organized by the following EWRI Councils:

- **Emerging and Innovative Technologies Committee (Interdisciplinary Council)** whose purpose is to develop and apply emerging and innovative technologies to support the functioning of EWRI , to advance the development , knowledge, and application of emerging and innovative technologies for the planning and management of water resources and the protection and enhancement of the environment; to encourage the reporting, discussion of technical and social issues, and information transfer of applications of emerging and innovative technologies; and to foster the multidisciplinary use of these technologies.
- **International Council** whose purpose is to undertake and facilitate a variety of technical and liaison activities in support of international collaboration and international promotion of the role of the Institute.
- **Symposium: Smart Water (Interdisciplinary Council):** The Smart Water Symposium explored the development of emerging and innovative technologies through three technical sessions: Smart Sensing, Smart Water Grid and Intelligent Analytics. The papers cover interesting applications of "smart" technologies to drinking water, wastewater, stormwater and source water
- **Cyber-physical Security of Urban Water Infrastructure:** The continuous modernization of critical infrastructure relies on the integration of physical processes and assets with networked devices that monitor and control the operations of the entire system. While digitalization significantly improves the automation and performance of urban water infrastructure, it also exposes it to cyber threats—as demonstrated by the recent, sharp increase in the number of attacks to water utilities. These papers discuss topics broadly related to cyber-physical security of urban water infrastructure.

Acknowledgments

The EWRI Congress depends on the dedication of volunteers who plan technical session topic areas, solicit abstracts and papers, oversee reviews of submitted abstracts and papers, identify moderators, and ensure the overall success of the program. We appreciate the efforts of everyone involved, especially the track chairs listed below:

Cyber Physical Security of Urban Water Infrastructure	Mohsen Aghashahi, Ph.D.
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Groundwater Symposium	Paul Mathisen, P.E., M.ASCE
History & Heritage (Nevada & California Water History Symposium)	Larry Magura, P.E., D.WRE(Ret.), F.ASCE
Hydraulics & Waterways	Fabian Bombardelli, A.M.ASCE
Hydro-climate/Climate Change Symposium	Levent Kavvas, Ph.D., Dist.M.ASCE
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Smart Water Symposium	Sudhir Kshirsagar, P.E., M.ASCE
Stormwater Symposium	Sarah Waickowski, E.I. Ryan Winston, Ph.D., P.E., M.ASCE
Student Competition	Wes Lauer, Ph.D., P.E., M.ASCE
Sustainability	Joshua Peschel, Ph.D., A.M.ASCE Kelly Sanders, Aff.M.ASCE

Water Distribution Systems Analysis Symposium	Mohsen Aghashahi, Ph.D.
Water, Wastewater and Stormwater	Arnold Strasser, P.E., M.ASCE Bridget Wadzuk, Ph.D.
Watershed	Levent Kavvas, Ph.D., Dist.M.ASCE Don Frevert, Ph.D., P.E., D.WRE(Ret.), F.ASCE
Watershed Management Conference (co-located with the EWRI Congress)	Rosanna LaPlante, P.E., F.ASCE

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 make this conference possible.

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Contents

Securing the Digitally Managed Water Supply

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ABSTRACT

Water system managers increasingly operate in distributed information exchange environments characterized by internal and external data communications. These sensor-controller-machine intensive environments must communicate internally (within and between device-level rings, within and between subsystems, and/or within and between systems) and externally (with and between original equipment manufacturers and/or with and between credentialed third parties). In critical infrastructure, cyber risk is magnified due to the heterogeneous nature of the technologies, protocols, and standards. Such an environment requires an approach that goes beyond information technology practices incorporating the unique needs of operational technologies. Protecting blended topologies requires a multi-dimensional framework integrating logical segmentation, cyber hygiene, network oversight, and human reliability. Logical segmentation compartmentalizes the network to align with service delivery. Cyber hygiene provides intrusion detection/prevention, identity services, malware protection, and network behavior analysis. Network oversight monitors network activity detecting and automatically responding to non-compliant actions with response policies that are service delivery fail-safe cognizant. Human reliability recognizes the potential for inadvertent and/or purposeful harmful actions and places digital safeguards at critical points to avoid compromise. Each dimension is significant itself but, collectively, they dramatically reduce the potential for gap and blind-zone formation with technologies and practices that are deployed in industrial and control system network operations today. This paper summarizes recent cyber-physical threat events and describes best practices in use across small and large critical infrastructure enterprises. Findings highlight the role network architecture design and operational practices to reduce attack surfaces and, at the same time, increase operational efficiency, ensure data integrity, and provide operational resilience in the face of evolving threats to cyber-physical systems.

INTRODUCTION

Achieving and maintaining a heightened cyber-physical security posture proves to be a challenge for organizations of all sizes across all domains. The difficulty is driven by many factors including the constantly changing threat landscape, the diverse sets of sensors and commutation protocols, the continuous need to update software applications patches, the demand for remote access, and the constant need to develop and maintain user and administrative personnel proficiency in cyber and physical security practices. The constant change means that gaps will continually emerge. When gaps emerge and are unchecked in one or more dimensions, they can generate threat opportunities putting the organization at high risk for a cyber event. Forensic review of cyber-physical attacks routinely identifies gap intersection sequences revealing the role of threat dynamics, entry points, policy failures, process failures, human