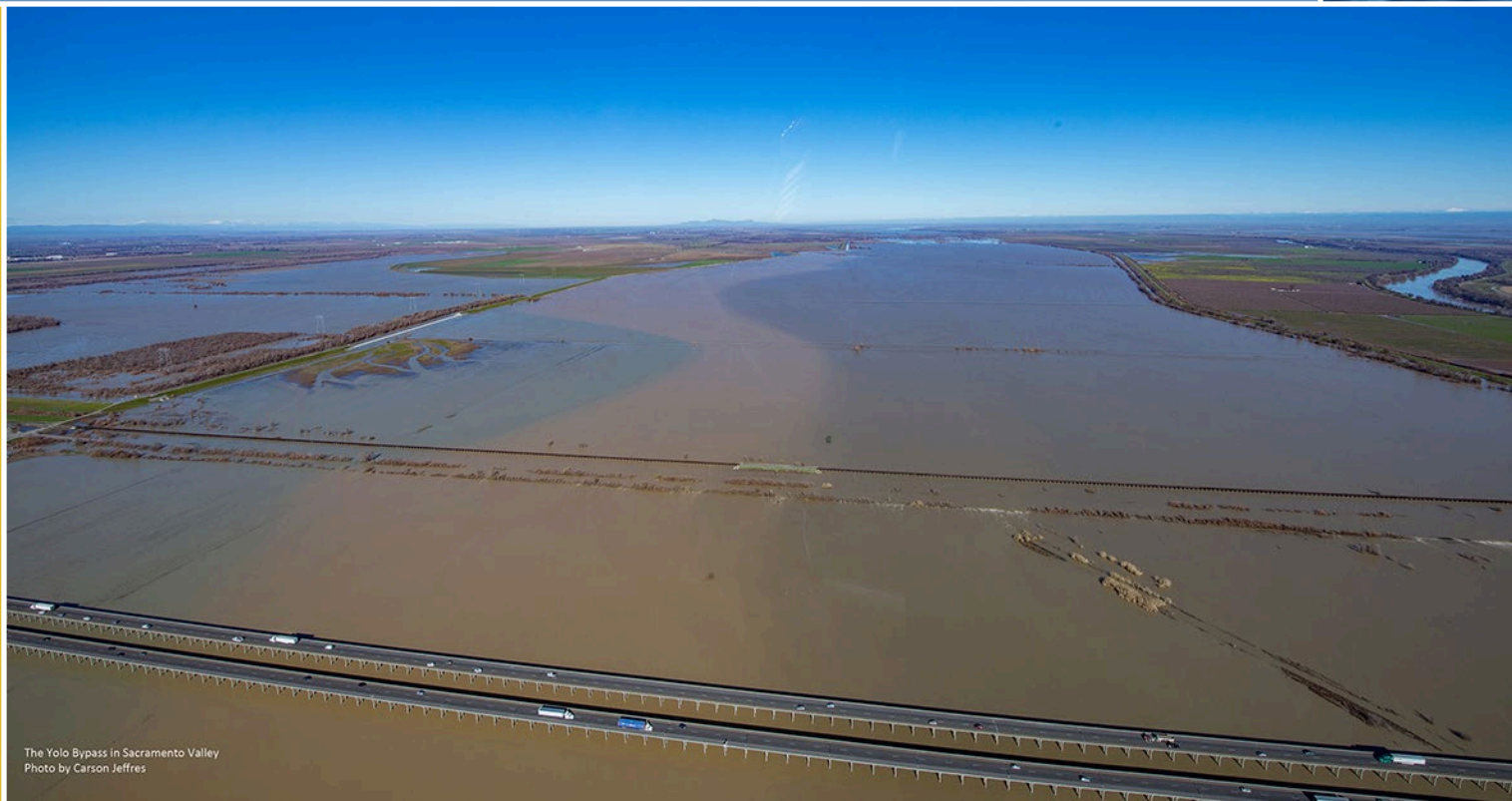
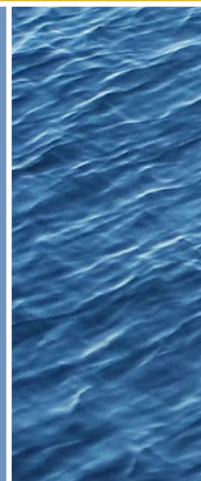


# World Environmental and Water Resources Congress 2017



The Yolo Bypass in Sacramento Valley  
Photo by Carson Jeffres

## Hydraulics and Waterways and Water Distribution Systems Analysis

Selected Papers from the Proceedings of the  
World Environmental and Water Resources Congress 2017  
Sacramento, California ■ May 21-25, 2017



EDITED BY  
Christopher N. Dunn, P.E., D.WRE



ENVIRONMENTAL &  
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# WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS 2017

*HYDRAULICS AND WATERWAYS AND WATER DISTRIBUTION  
SYSTEMS ANALYSIS*

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SELECTED PAPERS FROM THE WORLD ENVIRONMENTAL AND  
WATER RESOURCES CONGRESS 2017

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May 21–25, 2017  
Sacramento, California

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

EDITED BY  
Christopher N. Dunn, P.E., D.WRE  
Brian Van Weele, P.E., D.WRE



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## Preface

We are excited to offer an engaging and challenging array of technical sessions, posters, and accompanying published papers at our Environmental and Water Resources Institute's (EWRI) 17<sup>th</sup> annual Congress in Sacramento, California. This meeting is a leading venue for professional interaction among engineers and scientists, covering disciplines relating to the needs of critical infrastructure in water and environment. As is pointed out in the American Society of Civil Engineers' Report Card for America's Infrastructure, an investment of over \$3.6 trillion is needed to return the nation's infrastructure to a state of good repair. This Congress contributes in many ways to innovative solutions to this critical problem. We proudly host the meeting under the auspices of the American Society of Civil Engineers (ASCE).

Within the five (5) volumes of the proceedings of the Congress you will find nearly 300 written technical papers from more than 700 oral and poster presentations dealing with the subject areas of the EWRI Councils; a list of subject area tracks is included in the acknowledgements below. Our profession advances through presentations in special state-of-knowledge tracks represented at the Congress. We hope these proceedings serve to enhance your knowledge in these areas and encourage you to follow up with more detailed publications by the same authors, typically found in ASCE technical journals.

*World Environmental and Water Resources Congress 2017: Hydraulics and Waterways and Water Distribution Systems Analysis* contains papers organized by the following EWRI Councils, Committees and conference Symposium:

- **Hydraulics and Waterways Council** whose purpose is to represent EWRI in technical matters pertaining to all aspects of hydraulic engineering of natural and man-made environmental systems. The Council promotes responsible water resources management and protection to foster sustainability and enhancement of the environment through the development, collection and dissemination of information and technology regarding the advancements and application of hydraulic engineering.
- **Symposium: WDSA (Committee)**: Water distribution systems analysis (WDSA) involves the quantitative planning, design, operations, management, modeling, and monitoring of hydraulics and water quality of water distribution systems. The purpose of the committee is to provide coordination for all activities within EWRI related to the field of water distribution systems analysis.

## Acknowledgments

Preparation and planning for this Congress strongly depends on the dedication of those who plan track subjects, solicit abstracts and papers, oversee reviews of all this material 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
Hydro-Climate/Climate Change Symposium	Dr. M. Levent Kavvas – Volume 3
14th Urban Watersheds Management Symposium	Shirley Clark – Volume 5
Groundwater Symposium	Dr. Amy Chan Hilton – Volume 3
Water Distribution Systems Analysis Symposium	Juan Saldarriaga – Volume 4
Education	Colleen Bronner – Volume 1
Emerging Technologies	David Hill – Volume 1
Environmental	Wendy Cohen, Lisa Hayes – Volume 3
History and Heritage	Lawrence Magura, J. David Rogers – Volume 1
Hydraulics and Waterways	Christina Tsai – Volume 4
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Municipal Water Infrastructure Symposium	Ruth Hocker – Volume 5
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Sustainability	Joseph Threadcraft – Volume 3
Smart Water Symposium	Sudhir Kshirsagar
Water, Wastewater, and Stormwater	Sri Kamojjala, Bridget Wadzuk – Volume 5
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We also acknowledge the Congress Organizing Committee members, without whose time and efforts the event would not be possible. We also thank others not mentioned here.

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Finally, we acknowledge and thank the staff of the EWRI of ASCE who, in the end, makes it all happen. Most particularly, we thank Gabrielle Dunkley, EWRI's Manager, whose patience, perseverance, good humor, and great organizational talent ensure yet another successful EWRI Congress!

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# Contents

## *Hydraulics and Waterways*

<b>Impacts and Functioning of In-Stream Structures.....</b>	<b>1</b>
Kurt M. Smithgall, P. A. Johnson, and Chaopeng Shen	
<b>Complex Unsteady Flow Patterns at a River Junction and Their Relation with Fish Movement Behavior .....</b>	<b>8</b>
Yong G. Lai, R. Andy Goodwin, David L. Smith, and Ryan L. Reeves	
<b>Three Dimensional Computational Modeling of Flows through an Engineered Log Jam.....</b>	<b>16</b>
Yong G. Lai, David L. Smith, David J. Bandrowski, Xiaofeng Liu, and Kuowei Wu	
<b>Probabilistic Shoreline Change Modeling Using Monte Carlo Method .....</b>	<b>24</b>
Yan Ding, Sung-Chan Kim, and Ashley E. Frey	
<b>Effect of Soil Mix on Overtopping Erosion .....</b>	<b>35</b>
G. S. Ellithy, G. Savant, and J. L. Wibowo	
<b>A Mass-Conservative Finite-Element Numerical Code for Three Dimensional Flows .....</b>	<b>50</b>
G. Savant, Charlie Berger, Corey J. Trahan, and Tate O. McAlpin	
<b>Model Development and Application to Manage Inflow and Deposited Sediment in Paonia Reservoir.....</b>	<b>64</b>
Jianchun Huang, Blair Greimann, and Sean Kimbrel	
<b>Application of the Generalized Flow Equation to All Flow Conditions at Spillways .....</b>	<b>73</b>
Zhiming Chen, Matahel Ansar, and Menjiang Chen	
<b>Two-Dimensional Sediment Transport Modeling under Extreme Flood at Lower Cache Creek, California.....</b>	<b>83</b>
Tongbi Tu, Kara J. Carr, Ali Ercan, Toan Trinh, M. Levent Kavvas, Kevin Brown, and John Nosacka	
<b>Comparison of Solutions of Coupled and Uncoupled Models for the Henry Problem.....</b>	<b>89</b>
Wissam Al-Taliby and Ashok Pandit	



<b>Modeling Sediment Transport in the Lower American River, Sacramento, California .....</b>	<b>103</b>
Andrey B. Shvidchenko, Brad R. Hall, and Todd Rivas	
<b>North Fork Matilija Creek: A Model for Environmentally Nuanced Restoration Projects .....</b>	<b>114</b>
Ben Willardson, Tsou Jaw, and Peter Champion	
<b>Using Numerical and Physical Models to Manage Risk and Uncertainty .....</b>	<b>129</b>
Donald W. Baker and Jerry R. Richardson	
<b>Bubble-Water Surface and Turbulent Diffusion Mass Transfer in Fine Bubble Diffused Aeration Systems .....</b>	<b>138</b>
Xiangju Cheng, Yuning Xie, Dantong Zhu, Xixi Wang, and Jun Xie	
<b>Field Assessment of the Flow Field in a Lateral Canal-Marsh Junction.....</b>	<b>153</b>
S. M. Hajimirzaie and J. A. González-Castro	
<b>Towards Efficient Modeling .....</b>	<b>164</b>
Yaoxin Zhang and Yafei Jia	
<b>Calibrating a Sediment Transport Model through a Gravel-Sand Transition: Avoiding Equifinality Errors in HEC-RAS Models of the Puyallup and White Rivers .....</b>	<b>179</b>
S. Gibson, B. Comport, and Z. Corum	
<b>New One-Dimensional Sediment Features in HEC-RAS 5.0 and 5.1 .....</b>	<b>192</b>
S. Gibson, A. Sánchez, S. Piper, and G. Brunner	
<b>The Use of Ensemble Modeling of Suspended Sediment to Characterize Uncertainty .....</b>	<b>207</b>
Jenna Stewart, Balaji Rajagopalan, Joseph Kasprzyk, William Raseman, and Ben Livneh	
<b>Hybrid Physical/Analytical/CFD Modeling Approach to Design of Detroit's Wastewater Effluent Disinfection System .....</b>	<b>219</b>
Carrie L. Knatz, Mark E. Allen, Philip Kora, Sanjeev Mungarwadi, Mark J. TenBroek, Steven M. Fehniger, and Dave Werth	
<b>Preliminary Assessment of a Retrofit Strategy in Dropshafts Impacted by Geysering Using CFD .....</b>	<b>230</b>
Jue Wang and Jose G. Vasconcelos	
<b>Coupling HEC-RAS and HEC-HMS in Precipitation Runoff Modelling and Evaluating Flood Plain Inundation Map .....</b>	<b>240</b>
Balbhadra Thakur, Ranjan Parajuli, Ajay Kalra, Sajjad Ahmad, and Ritu Gupta	

<b>Towards an Automated Floodway Optimizer for HEC-RAS.....</b>	<b>252</b>
Tien M. Yee and Huidae Cho	
<b>Resolving the Paradox of the Jones Formula for Flood Discharge Estimation.....</b>	<b>262</b>
Muthiah Perumal	
<b>Ice-Cover and Jamming Effects on Inline Structures and Upstream Water Levels.....</b>	<b>270</b>
Addison Jobe, Swastik Bhandari, Ajay Kalra, and Sajjad Ahmad	
<b>Flood Risk Assessment Using the Updated FEMA Floodplain Standard in the Ellicott City, Maryland, United States .....</b>	<b>280</b>
Ranjeet Thakali, Ranjit Bhandari, Gilles-Arnaud Arif-Deen Kandissounon, Ajay Kalra, and Sajjad Ahmad	
<b>2D Unsteady Flow Routing and Flood Inundation Mapping for Lower Region of Brazos River Watershed .....</b>	<b>292</b>
Manahari Bhandari, Narayan Nyaupane, Shekhar Raj Mote, Ajay Kalra, and Sajjad Ahmad	
<b>Perennial Secondary Channel Design on Dry Creek near Healdsburg, California.....</b>	<b>304</b>
Jason Q. White, Aaron A. Fulton, Jorgen A. Blomberg, and Ann E. Borgonovo	
<b>Embankment Erosion and Retreat by Wave Action: Laboratory Experiments.....</b>	<b>318</b>
Yavuz Ozeren and Daniel Wren	
<b>Frequency Analysis of Monthly Runoff in Intermittent Rivers .....</b>	<b>327</b>
H. I. Burgan, B. Vaheddoost, and H. Aksoy	
<b>Simulating Watershed Erosion in BMGR Using AGWA Model .....</b>	<b>335</b>
Jennifer G. Duan, Michael Poteuck, Abigail Rosenberg, and Kang Zhou	
<b>On Discharge Computations in Non-Symmetrical Trapezoidal Compound Channel.....</b>	<b>345</b>
Jean G. Chatila	
<b>Effect of Rheology on Flood Wave Propagation Due to Ash Dyke Failure.....</b>	<b>359</b>
Pranab Kumar Mohapatra	
<b>Two-Dimensional Dam-Breach Flood Modeling and Inundation Mapping with Cascading Failures .....</b>	<b>368</b>
Mustafa S. Altinakar, Marcus Z. McGrath, Turgay Dabak, Wilbert Thomas, Chad Scroggins, Trey Gauntt, Hubbard Harvey, and James Kelly	