**National Hydraulic Engineering Conference 2022**

**Advancing Hydraulic Engineering For Infrastructure Resiliency**

# Welcome Letter

NHEC2022 National Hydraulic Engineering Conference Advancing Hydraulic Engineering For Infrastructure Resiliency

Welcome to the 2022 National Hydraulic Engineering Conference (NHEC). Our theme "Advancing Hydraulic Engineering for Infrastructure Resiliency" defines the goal of sharing knowledge, technology, and practices for the purpose of providing more robust transportation in the form of roads and bridges. Topics covered during this conference include:

- Resilient Design
- Hydrology
- Riverine Hydraulics
- Coastal Hydraulics
- Using climate data for engineering
- Hydraulic Structures
- Stream Morphology & Sediment Transport
- Aquatic Organism Passage
- Scour
- Drainage Design
- Stormwater Management & Water Quality

The Steering Committee is comprised of members from The Georgia Institute of Technology (Georgia Tech), The Georgia Department of Transportation (GDOT), AASHTO's Technical Committee on Hydrology and Hydraulics, The Federal Highway Administration (FHWA), and the Transportation Research Board (TRB) Technical Committee on Hydraulics and Hydrology (AKD50). We have provided two workshops, 14 sessions (56 presentations), two field trips, two committee meetings, and updates from FHWA, TRB, and AASHTO.

Georgia Tech, founded in 1885, is a public research university here in Atlanta and a proud host to the NHEC. Georgia Tech is a leading transportation research facility and offers a highly capable and robust hydraulic laboratory and computer CFD modeling. It also offers a wealth of experience researching transportation materials, traffic flow, human interaction, and transportations interaction with the environment.

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GDOT is the host DOT for the conference and consists of 7 regional districts and the General Office in Atlanta. The Department is responsible for planning, constructing, maintaining, and improving the state's roads and bridges. In addition, it provides planning and financial support for other modes of transportation such as mass transit and airports. Policy is set by the General Office as well as major project design. The districts are responsible for other project design and the day-to-day operation and maintenance of the state route system.

We would like to acknowledge the selfless efforts of those on the 2022 NHEC Steering Committee:

Dr. Susan Burns, Georgia Tech
Erik Carlson, MDOT & AASHTO TCHH
Jennifer Freeman, Georgia Tech
Megan Frye, FHWA
Julie Heilman, WSDOT & AASHTO TCHH
John Hunt, TRB AKD50
Matt Lauffer, NCDOT, TRB AKD50 AASHTO TCHH
Brad McManus, GDOT & AASHTO TCHH
Wesley Peck, TDOT & AASHTO TCHH
Dr. Mike Perez, Auburn University TRB AKD50
Roberto Ruiz, SCDOT & AASHTO TCHH
Daniel Sharar-Salgado, FHWA
Jeff Syar, ODOT & AASHTO TCHH

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# Contents

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# Program Agenda

| | |
|---|---|
| **Monday - August 15, 2022** | |
| **8:00am – 5:00pm** | |
| | |
| ***AASHTO TCHH Annual Committee Meeting – Invite*** only – Theater | |
| ***FHWA Meeting – Invite*** only – Crystal, projectors, wifi, tables, chair, breakfast, no lunch | |
| | |
| **Tuesday- August 16, 2022 –1 Break Provided for Attendees** | |
| **8:00am-11:30am** | |
| **Conference Registration/Vendor Setup-** | |
| **Workshop A -** ***Using Climate Data in Hydrologic Analysis*** | **Workshop B-** ***HEC 23 Proper Counter Measure Design*** |
| **Crystal Room** | **Theater** |
| **Roger Kilgore & Dano Wilusz** | **Laura Girard & Scott Hogan** |
| | |
| **Conference Begins - Theater 12:30pm** | |
| | |
| **Opening Remarks - 15 minutes – Meg Pirkle** | |
| **Keynote Speech 45 minutes – Dr. Brian Bledsoe** | |
| **Mark Miles Award 30 minutes – Joe Krolak to present award** | |
| **Break – 2:00-2:15** | |
| | |
| **FHWA Update – 30 minutes – Joe Krolak** | |
| **AASHTO Update – 10 minutes – Jeff Syar** | |
| **Transportation Research Board Update (AKD) – 5 minutes – Dr. Mike Perez** | |
| | |
| **3:00pm to 5:00pm Ice Breaker/Poster Session/Virtual Reality -** | **3:00pm to 5:00pm Georgia Tech Lab Tour Time Slot 1-** |
| | **Bus leaves conference at 3:10 and leaves lab at 4:45** |

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| **Wednesday- August 17, 2022 – Breakfast, 2 breaks, and Lunch Provided for Attendees** | | | | |
|---|---|---|---|---|
| **8:00am-10:10am** | | | | |
| ***Moderated by: Matt Lauffer (North Carolina DOT)*** | | | ***Moderated by: Solomon Woldeamlak (Minnesota DOT)*** | |
| ***Session Topic/Title*** | ***Room/Presenter*** | | ***Session Topic/Title*** | ***Room/Presenter*** |
| ***Operational Resilience:*** | ***Theater*** | | **2D Modeling and Advanced Computing** | ***Crystal Room*** |
| **1**<br>Real-Time Flood Emergency Response for TxDOT | Dr. David Maidment | | **1**<br>Automation of Hydraulic Modeling with Python Scripting/ Cloud Computing | Dr. Xiaofeng Liu |
| **2**<br>Hidden Impacts to Transportation in Vermont post Hurricane Irene | Nicole Buck | | **2**<br>Bridge Deck Afflux Modeling – Benchmarking of CFD and SWE Codes to Real-World Data | Dr. Bo Juza<br>Dr. Greg Collecutt |
| **3**<br>FIMAN-T: Real-Time Monitoring and Visualization of Road and Bridge Flood Impacts | Matthew Dudley | | **3**<br>Key Advances in 2D Hydraulic Modeling - SRH-2D Interface Features | Dr. Alan Zundel |
| **4**<br>Asset Monitoring for Metric 18 Compliance and Digital Plans of Action using BridgeWatch Software-as-a-Service | Joe Scannell | | **4**<br>A Tale of 2's: 2D Modeling of 2+2 Construction in 2 Floodways | Matt McConville |
| | | | | |
| **10:10am -10:25am Break – *The Rotunda*** | | | | |
| | | | | |
| **10:25am-12:35pm** | | | **10:30am-12:00pm** | |
| **Moderated by: Jen Mora (FHWA)** | | | **Shuttle leaves conference at 10:30 and lab at 12:00** | |
| **Session Topic/Title** | **Room/Presenter** | | **Field Trip** | **Location/Presenter** |
| ***FHWA Program Updates*** | ***Theater*** | | **Georgia Tech Hydraulics Lab Visit Time Slot 2** | ***Hydraulics Lab*** |
| **1**<br>Federal Flood Risk Management Standard - What will FFRMS Mean for You? | Joe Krolak | | Hydraulic Modeling of an Ogee Spillway and its Energy Dissipators | Georgia Tech |
| **2** | Laura Girard | | | Georgia Tech |

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|---|---|---|---|---|
| Promoting Resilient Transportation from PROTECT to Planning and Programming | David D'Onofrio | | Hydrodynamics of an Idealized Wildland-Urban Interface (WUI) with Implications to Wildfire Management | |
| **3**<br>Overview of the FHWA Hydraulic Manual Updates | Ryan Lizewski | | Interactive Stream Table & Bed Forms Culvert Flume | FHWA |
| **4**<br>Status of the new National culvert removal, replacement, and restoration grant program | Joe Krolak | | Highways in the Coastal Environment Wave Flume Demonstrations | South Coast Engineers |
| | | | | |
| **11:30-1:30 Rotating Lunch *Downstairs*** | | | | |
| | | | | |

| **12:40pm-2:50pm** | |
|---|---|
| **Moderated by: Casey Kramer (Natural Waters)** | |
| **Session Topic/Title** | **Room/Presenter** |
| **FHWA Scour Session** | ***Theater*** |
| **1**<br>Programmatic Synopsis of the FHWA Bridge Scour Program: Scour Evaluation and Assessment Processes and Scour Plans of Action | Paul Sharp |
| **2**<br>Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (HEC-23) | Laura Girard |
| **3**<br>Geotech for Hydraulics/ NextScour Program | Daniel Alzemora<br>Dr. Kornel Kerenyi<br>James Pagenkopf |
| **4**<br>Current state of the practice for bridge hydraulic and scour analysis tools | Scott Hogan |

| **1:00pm-2:30pm** | |
|---|---|
| **Shuttle leaves conference at 1:00 and lab at 2:30** | |
| **Field Trip** | **Location/Presenter** |
| **Georgia Tech Hydraulics Lab Visit Time Slot 3** | ***Hydraulics Lab*** |
| Hydraulic Modeling of an Ogee Spillway and its Energy Dissipators | Georgia Tech |
| Hydrodynamics of an Idealized Wildland-Urban Interface (WUI) with Implications to Wildfire Management | Georgia Tech |
| Interactive Stream Table & Bed Forms Culvert Flume | FHWA |
| Highways in the Coastal Environment Wave Flume Demonstrations | South Coast Engineers |

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| 2:50-3:05 Break - *The Rotunda* | | | | |
| | | | | |
| 3:05pm-5:10pm | | | | |
| **Moderated by: Mike Orth (Kansas DOT)** | | | **Moderated by: Daniel Sharar-Salgado (FHWA)** | |
| **Session Topic/Title** | **Room/Presenter** | | **Session Topic/Title** | **Room/Presenter** |
| **Hydrology** | ***Theater*** | | **Coastal and Advanced Hydraulic Modeling** | ***Crystal Room*** |
| **1**<br>CDOT's Post-Wildfire Debris Response in Real-Time: Strategies and Observations for 2020-2022 | Steven Griffin | | **1**<br>Nature-Based Solutions Enhance Coastal Highway Resilience | Dr. Bret Webb |
| **2**<br>GSHHA-based hydrological modeling of coastal roadways considering sea-level rise scenarios | Dr. Bruno Sousa | | **2**<br>Updated Coastal Resilience Guidance in HEC-25 Third Edition | Beau Buhring |
| **3**<br>Discovering Flood Regions and Predicting Flood Flow Metrics to Inform Bridge Scour Studies in the Conterminous United States | Dr. Jared Smith | | **3**<br>Sea Level Rise & Coastal Design – A Probabilistic Perspective | Jeffrey Oskamp |
| **4** | | | **4**<br>Study on the impact from surge events on the pier scour for coastal bridges | Dr. Chao Huang |
| | | | | |
| 5:30pm 7:30pm | | | | |
| **Session Topic/Title** | **Room/Presenter** | | **Session Topic/Title** | **Room/Presenter** |
| ***TRB AKD50, and AASHTO TCHH Combined Meeting -*** Open to Public | **AOM Theater** | | | |

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|---|---|---|---|---|
| **Thursday- August 18, 2022 – Breakfast, 2 breaks, and Lunch Provided for Attendees** | | | | |
| **8:00am-10:05am** | | | | |
| ***Moderated by:*** ***David Spinks (Tennessee DOT)*** | | | ***Moderated by:*** ***Susan Jones (FHWA)*** | |
| ***Session Topic/Title*** | ***Room/Presenter*** | | ***Session Topic/Title*** | ***Room/Presenter*** |
| **Scour Session** | ***Theater*** | | **Stormwater Management** | ***Crystal Room*** |
| **1**<br>Development of 3D CFD Modeling of Scour using Open Source OpenFOAM Software | Dr. Hubert Ley | | **1**<br>Approaches for assessing flows, concentrations, and loads of highway and urban runoff and receiving-stream stormwater with the Stochastic Empirical Loading and Dilution Model (SELDM) | Greg Granato |
| **2**<br>NCHRP Project 24-47; Revised Clear-Water and Live-Bed Contraction scour Analysis | William DeRoset & Dr. Pete Lagasse | | **2**<br>A decision-support tool to assess the impacts of highway runoff in North Carolina using SELDM | Dr. Charles Stillwell |
| **3**<br>Clearing the Hurdles on Clear Creek: Utilizing SRH-2D for Emergency Scour Countermeasure Design and Sediment Transport | Donald Hendon<br>Dr. Dragi Stephanovic | | **3**<br>Coastal Strategies for Drainage Resilience and Permitting in Florida | Carlton Spirio |
| **4**<br>Scour Risk Prioritization for SC Bridges | Dr. Max Shih<br>Daniel Johnson | | **4**<br>Full Spectrum Stormwater Systems Asset Management at MDOT SHA | Kiona Leah |
| **10:05am -10:25am Break – *The Rotunda*** | | | | |
| **10:25am-12:35pm** | | | **10:30am-12:00pm** | |
| **Moderated by: Roberto Ruiz (South Carolina DOT)** | | | **Shuttle leaves conference at 10:30 and lab at 12:00** | |
| **Session Topic/Title** | **Room/Presenter** | | **Field Trip** | **Location/Presenter** |
| **Resilient Design** | ***Theater*** | | **Georgia Tech Hydraulics Lab Visit Time Slot 4** | ***Hydraulics Lab*** |
| **1**<br>Incorporating Climate Change and Policy for Highway Infrastructure Design | Dave Claman | | Hydraulic Modeling of an Ogee Spillway and its Energy Dissipators | Georgia Tech |
| **2** | | | | Georgia Tech |

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|---|---|---|---|---|
| Nonstationarity in flood frequency in the midwestern United States | Dr. Thomas (Tom) Over | | Hydrodynamics of an Idealized Wildland-Urban Interface (WUI) with Implications to Wildfire Management | |
| **3**<br>Updated One-year Coastal Flood Elevation as a Threshold of Coastal Flooding | Dr. Kaveh Zomorodi | | Interactive Stream Table & Bed Forms Culvert Flume | FHWA |
| **4**<br>An investigation into future rainfall extremes within North Carolina for state transportation needs | Dr. Jared Bowden | | Highways in the Coastal Environment Wave Flume Demonstrations | South Coast Engineers |
| | | | | |
| **11:00-2:00 Rotating Lunch *Downstairs*** | | | | |

| | | | | |
|---|---|---|---|---|
| **12:40pm-2:50pm** | | | **1:00pm-3:00pm** | |
| **Moderated by: Jeff Syar (Ohio DOT)** | | | **GDOT shuttle will leave conference at 1:00pm and return at 3:00pm** | |
| **Session Topic/Title** | **Room/Presenter** | | **Field Trip** | **Location/Presenter** |
| **Watershed Modeling** | **Theater** | | **Bioretention Stormwater Field Trip** | **I-20 and I-70** |
| **1**<br>Two-dimensional Watershed Modeling with SRH-2D | Dr. Yong Lai | | Design, construction, and monitoring of the two bioretention basins on I-20 at the Capitol Avenue overpass on site. | Dr. Gary Hawkins<br>Alfie Vick |
| **2**<br>Assessing the state of the practice of hydrologic modeling in the context of roadway design | Dr. Xing Fang | | | |
| **3**<br>Watershed Approach to Mitigating Hydrologic Impacts of Highway Projects | Roger Kilgore | | | |
| **4**<br>Missouri River Modeling for Resiliency | Rusty Jones<br>Dr. Andy McCoy<br>Iris Brenner | | | |
| | | | | |
| **2:50-3:05 Break - *The Rotunda*** | | | | |

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|---|---|---|---|---|
| **3:05pm-5:10pm** | | | | |
| **Moderated by: Charlie Hebson (Maine DOT)** | | | **Moderated by: Erik Carlson (Michigan DOT)** | |
| **Session Topic/Title** | **Room/Presenter** | | **Session Topic/Title** | **Room/Presenter** |
| **AOP/ Water Quality** | **Theater** | | **Drainage And Erosion Control** | ***Crystal Room*** |
| **1**<br>UPDATE ON MONITORING PROTOCOL FOR ASSESSING AQUATIC ORGANISM PASSAGE AT WATER CROSSINGS | Justin Lennon<br>Casey Kramer | | **1**<br>Three-Dimensional Computational Fluid Dynamics Modeling of Hydraulic Efficiency of Road Drainage Structures | Dr. Marta Sitek |
| **2**<br>Bedform Evolution and Bank Importance in Aquatic Organism Passage (AOP) Culverts | Jennifer Mora | | **2**<br>New NCDOT Hydroplaning Policy, Analytical Tool Development, and Mitigation Strategies | Matthew York<br>Katie Earp<br>Rick Renna |
| **3**<br>Minebank Run Restoration and WQ Improvements | Dana Havlik | | **3**<br>Urban Drainage Design (HEC-22) Fourth Edition Manual Update and Curb Opening Inlet Equations | Ryan Lizewski<br>James Pagenkopf |
| **4**<br>APPROACHES FOR SIMULATING LARGE WOODY MATERIAL (LWM) IN TWO-DIMENSIONAL (2D) MODELS | Dr. Achilles Tsakiris | | **4**<br>Effects of Bridge Construction on Overland Erosion and Downstream Sediment Regime | Dr. Habib Ahmari |
| | | | | |

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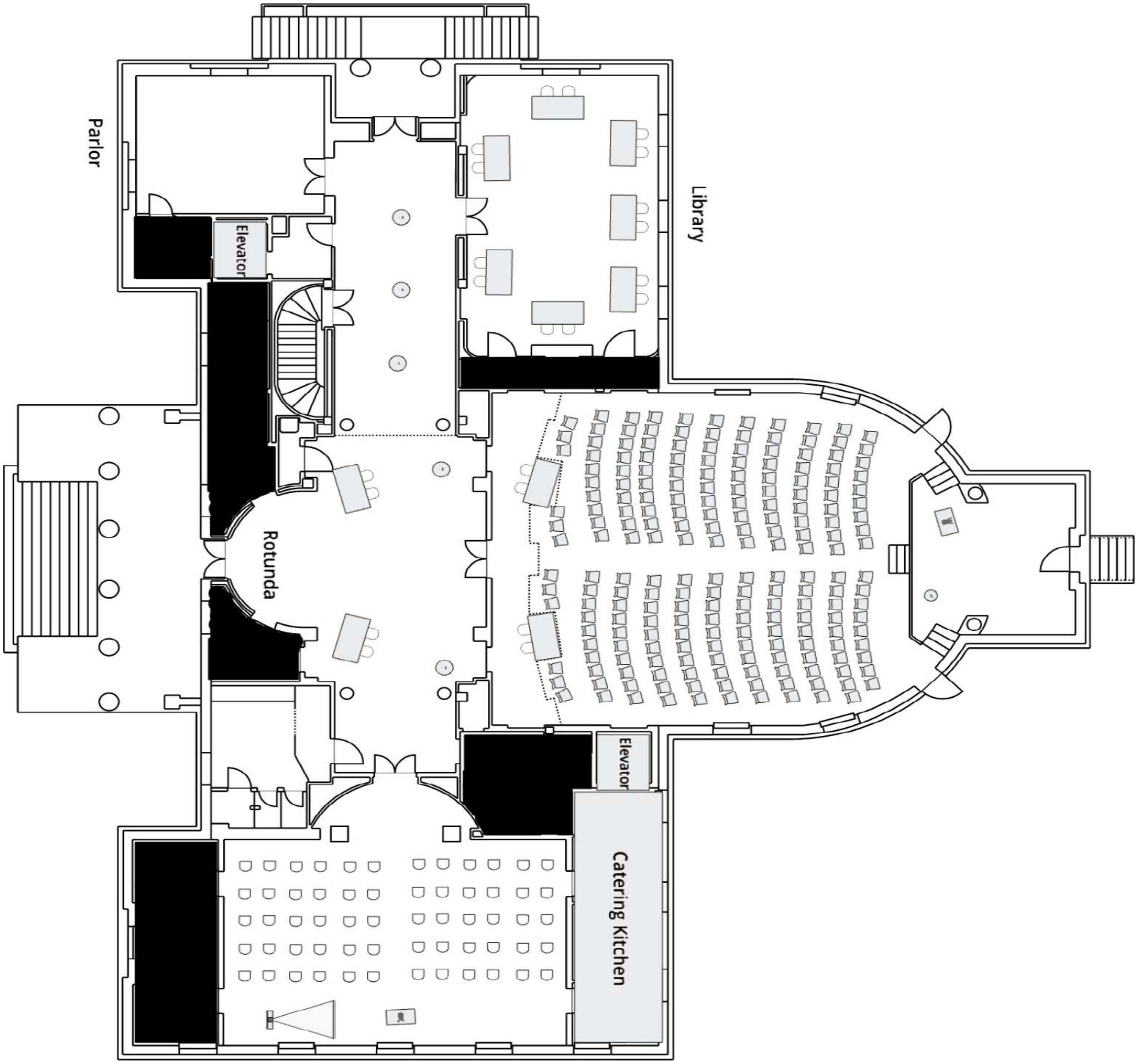
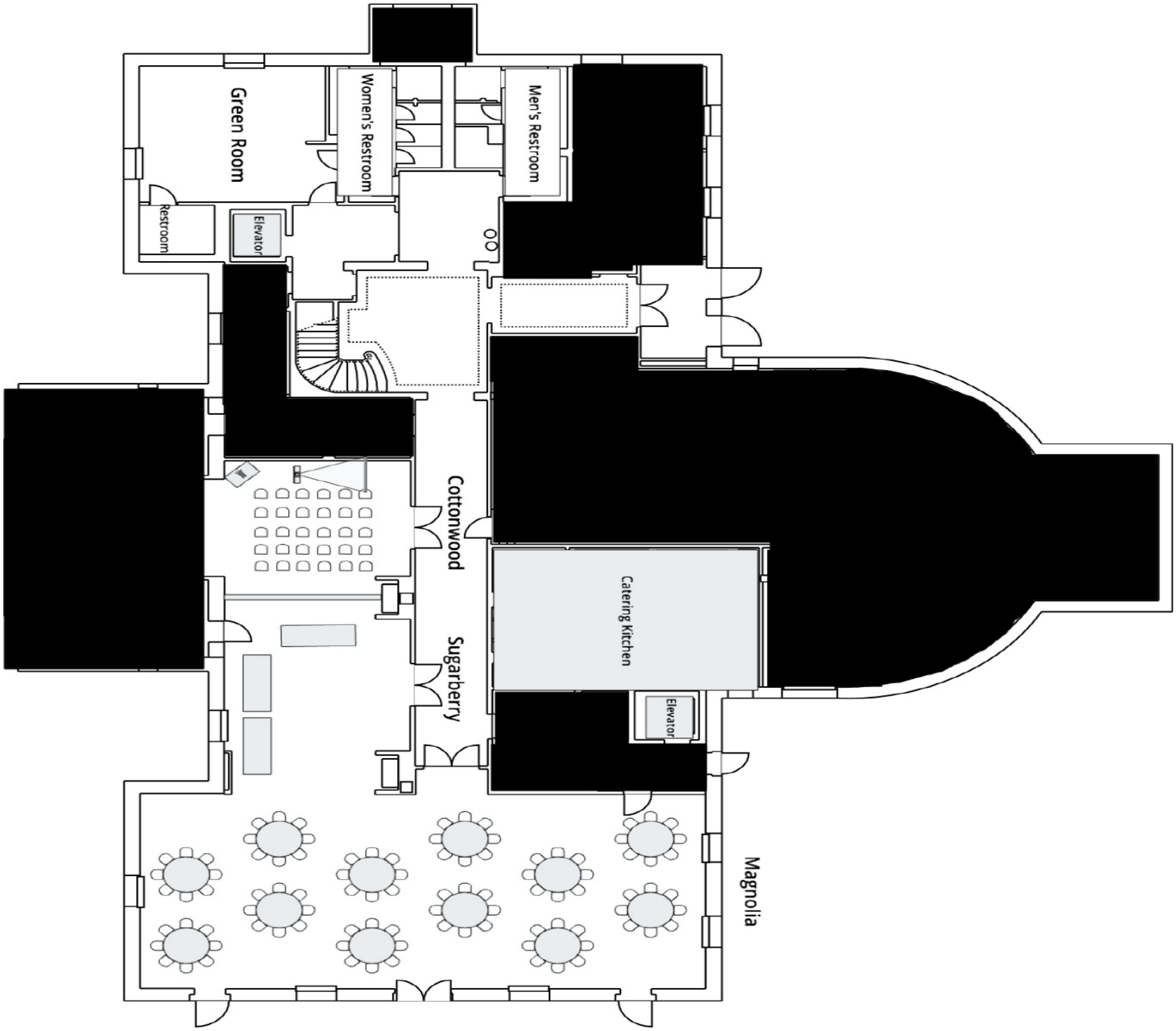
| **Friday- August 19, 2022 – Breakfast and 1 break Provided for Attendees** | | | | |
|---|---|---|---|---|
| **8:00am-10:00am** | | | | |
| ***Moderated by:*** **Peter VanKampen (New York DOT)** | | | ***Moderated by:*** **Paul Sharp (FHWA)** | |
| ***Session Topic/Title*** | ***Room/Presenter*** | | ***Session Topic/Title*** | ***Room/Presenter*** |
| **Programmatic Resilience** | ***Theater*** | | **Stream Morphology & Sediment Transport** | ***Crystal Room*** |
| **1** Traffic Must Flow: NCDOT's Steps to Prepare for Future Flood Hazards with Digital Solutions | Ken Ashe | | **1** Morphodynamic Modeling of Gravel Bar Formation at a Bridge Replacement | Steven Griffin |
| **2** Colorado Department of Transportation 2D Quick Check Statewide Initiative | Kalli Wegren<br>Sara Johnson | | **2** Coupling Hydro-Morphodynamic Numerical Modeling and Fiber-Optic Distributed Temperature Sensing to Improve Bridge Scour Prediction | Dr. Celso Castro-Bolinaga |
| **3** Mississippi's Advancing the State of Practice for Hydraulic Engineers, Designing with Depth and Breadth: A Deep Dive into the Evolution of the Bridge Hydraulic Design Process featuring Best Practices in Mississippi including the use of SRH-2D | Rachel Westerfield | | **3** Application of Incised Channel Evolution Theory and Engineering Geomorphology to Roadway Erosion Mitigation Design | Caroline Ogg |
| **4** The Benefits of Compiling and Analyzing Hydraulic-Design Data for Bridges | Stephen Benedict | | **4** Making Mississippi's bridges more resilient to lateral migration | Blake Mendrop |
| | | | | |
| **Break 10:00 – 10:15** | | | | |
| **Wrap Up /Close-Out** | | | | |
| **10:15 – 10:45** | | | | |

# Venue Map

## Top Floor



## Bottom Floor



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## Opening Remarks

**Meg Pirkle, P.E.**

Meg Pirkle is the Chief Engineer of the Georgia Department of Transportation (GDOT), a position she has held since January 2015. As Chief Engineer, she oversees management of GDOT's engineering, construction, project management, and P3 program delivery for the Department's $2.5 Billion statewide capital program. Pirkle also oversees statewide maintenance, traffic operations and intermodal activities.

Pirkle earned a bachelor's degree in Civil Engineering from Vanderbilt University, a master's degree in Civil Engineering from Georgia Tech and is a registered professional engineer.

## Key Note Speaker

Dr. Bledsoe has over 25 years of experience as an engineer, hydrologist, and environmental scientist in the private and public sectors. Before entering the professorate, he worked in the private sector as a consulting engineer and surveyor, and for the State of North Carolina as a watershed restoration specialist and state nonpoint source program coordinator. Brian’s research is focused on the interface of hydrology, ecology, and urban water sustainability with an emphasis on green infrastructure including streams, floodplains, and stormwater systems. He received an NSF CAREER Award in 2006, and served as a Fulbright Scholar in Chile in 2008.

# Mark Miles Distinguished Hydraulic Engineer Award

The biennial Mark Miles Distinguished Hydraulic Engineer Award recognizes the outstanding work and contributions to the transportation hydrologic and hydraulic engineering profession by an individual. The award honors Mr. Mark D. Miles, P.E, who died at the 2004 National Hydraulic Engineering Conference. Mark was a long-serving member of the AASHTO Task Force on Hydrology & Hydraulics and with the Alaska Department of Transportation. Mark made significant contributions and furthered the understanding of the transportation hydraulic engineering profession.

## Eligibility:

Individuals who have contributed to the transportation hydrologic and hydraulic engineering profession via work at or for state departments of transportation, universities, federal agencies, or private consulting firms.

## Award Criteria:

A recipient of the award must demonstrate contributions to the transportation hydrologic and hydraulic engineering profession, such as through longstanding service at or to a DOT, participation in research projects, participation in national technical committees, development of national guidance, etc.

## Selection:

The National Hydraulic Engineering Conference Committee reviews the nominations and makes a final selection.

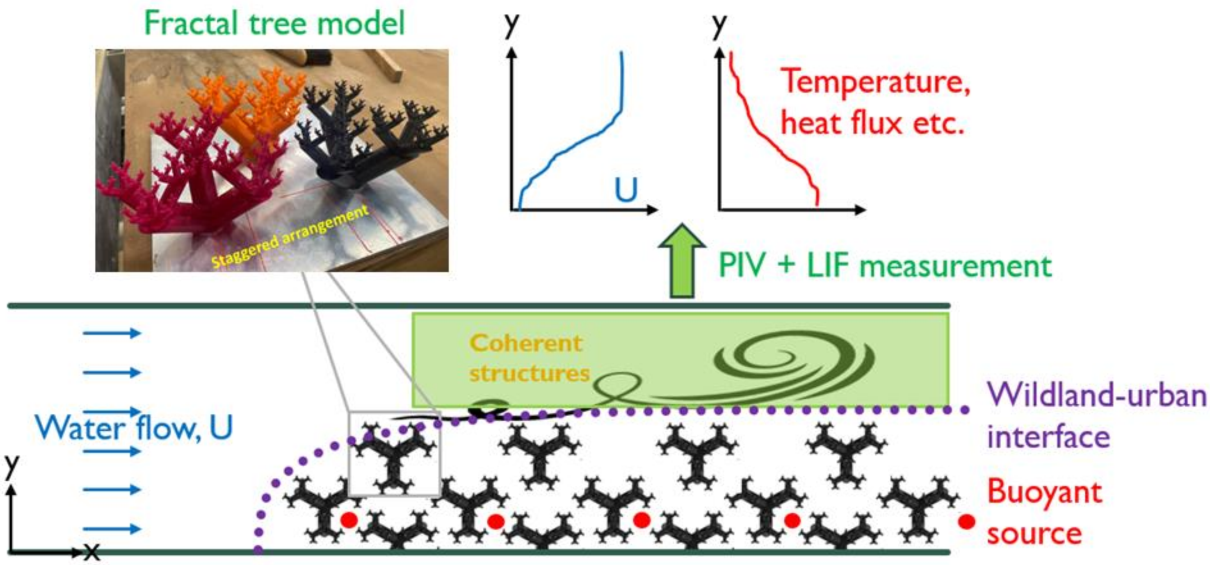
## Presentation of Award:

Presentation of the award will be made during the 2018 National Hydraulic Engineering Conference. The recipient does not need to attend to receive the award.

# Field Trip, Workshop and Presentation & Descriptions

## Georgia Tech Hydraulics Lab Visit

### Experimental investigations on the hydrodynamics of an idealized wildland-urban interface (WUI) with implications to wildfire management




The wildland-urban interface (WUI) is characterized by a sharp transition between vegetated land and non-vegetated or paved land. The change in land conditions greatly affects the propagation of wildfires across the interface, which is known as the edge effect in the literature of vegetated canopy flows. Vegetation plays a critical role in determining the propagation speed and the direction of fire. It is well-known that fire spread (speed) positively correlates with wind speed (Linn et al. 2002 and 2005). The latter, in turn, is governed by the interactions between the approaching wind, the canopy structure, and the fire (Keeley and Syphard (2019)). Thus, any predictions of fire spread must begin with the understanding on the fluid dynamics of canopy flows. A conundrum in fire containment is that the clearing of trees to create an area void of fuel (fuel-break) is not always effective in stopping the advancement of fire (Pimont et al. (2009)). In some cases, it actually accelerates fire propagation. This seems to contradict the fire triangle – fire needs heat, fuel, and oxygen to sustain and the removal of any of one of them halts fire. This conundrum can be resolved by realizing that the supply of heat is governed by canopy flows and that the clearing of trees speeds up the local wind such that heat from one location can reach another location with trees (fuel). If any fire risk mitigation efforts are to be successful, one must again consider the fluid dynamics of canopy flows. We present a preliminary experimental study to address two hypotheses: (1) near the ground the spread of fire is mostly governed by a horizontal mixing layer whereas at the top of canopy both vertical and horizontal mixing layers are active, and (2) the multiscale nature of trees enhances turbulent mixing and results in a faster fire spread. Our experiments consist of a lab-scale fractal tree canopy model placed inside a water flume and point buoyant sources are distributed within the canopy to mimic fire behavior. We considered two canopy parameters – canopy density and the presence/absence of a midstory.

Planar particle image velocimetry (PIV) and laser-induced fluorescence (LIF) were used to quantify turbulent mixing of a passive tracer (heat).

## Hydraulic modeling of an Ogee spillway and its energy dissipators for minimizing scouring in tailwaters

A hydraulic model was built to optimize the gate operation of an existing Ogee spillway built in the 60s/70s; the study was commissioned by the South Florida Water Management District (SFWMD) in 2014. Due to today's higher river flows, the original gate opening schedule created serious scouring problems in the downstream river. The model study aimed to find a new schedule to eliminate scouring.

## Interactive Stream Table

The hands-on FHWA Stream Table model simulates river, floodplain, and infrastructure interactions. The Stream Table uses small-scale models of bridges, culverts, bank protection, and other infrastructure components to visualize key concepts such as points of soil erosion and how rivers meander and migrate.

## Highways in the Coastal Environment Wave Flume

The hands-on wave flume is currently used as a demonstration tool in the Highways in the Coastal Environment NHI Course. This flume allows for visualization of the different characteristics of waves, as well as various wave and infrastructure interactions.

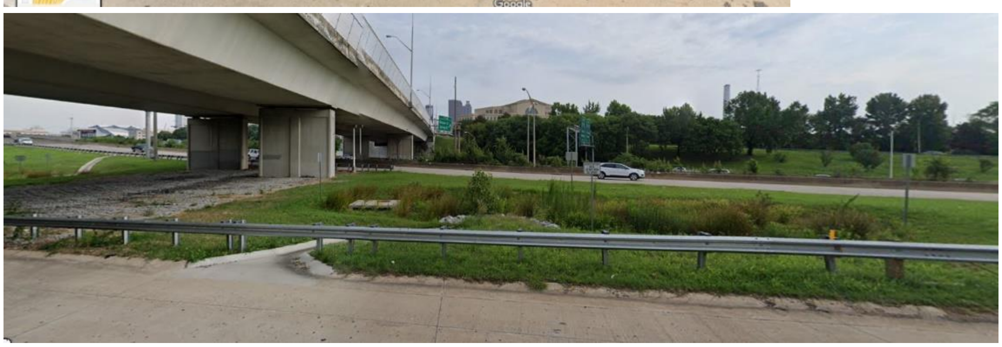
## Bedforms Culvert Flume

The aquatic organism passage (AOP) Culvert Flume investigates how interior banks and other roughness elements interact with water flow within culverts. It helps to understand whether banks are necessary to provide the hydraulic conditions for successful AOP and find alternatives that could serve the same purpose. It also supports the development of guidelines that can facilitate the design of more cost-efficient and resilient AOP culverts in the natural environment.

## Virtual Reality Headsets

The FHWA Virtual Reality (VR) Headsets provide an immersive experience for visualizing natural river processes. The VR headsets allow participants to get up close and see bridges in a 3D environment, and watch processes that they may have only heard of or viewed through pictures previously.

## Bioretention Field Trip



Dr. Gary Hawkins and Dr. Alfie Vick will be discussing the design, construction, and monitoring of the two bioretention basins on I-20 at the Capitol Avenue overpass on site. Also included will be a discussion on recommendations when the inlet and outlet are near each other. This was a joint effort between the City of Atlanta, American Rivers, GDOT, and business groups. GDOT funded the construction of the project while the City of Atlanta performs the maintenance.

**BIOs:** Dr. Gary L. Hawkins works for the University of Georgia as the Water Resource Management Specialist in the Crop and Soil Science Department. He is an Agricultural Engineer and graduated from Clemson University, Auburn University and the University of Tennessee. He is responsible for extension programming in the areas of water quality, water quantity and water resources. His current extension and research programs are related to water resource issues in the areas of soil and water conservation, stormwater, well water protection and education, septic systems, water retention, nutrient movement, water quality, water quantity and small scale irrigation.

Alfred Vick is the Georgia Power Professor in Environmental Ethics at the University of Georgia and Director of the Environmental Ethics Certificate Program. He is a licensed landscape architect and a LEED Fellow. His work focuses on preserving and enhancing the functioning of natural systems while effectively and attractively integrating human use. At the University of Georgia's College of Environment & Design he teaches landscape ecology and sustainable design, collaborates with other researchers in the Sustainability and Landscape Performance Lab and serves on the Faculty of the Institute of Native American Studies. His academic research focuses on green infrastructure and sustainable site design, native plant communities, and American Indian ethnobotany. He earned a BS in Engineering Psychology from the University of Illinois and a Master of Landscape Architecture degree from the University of Georgia. He continues to practice professionally and his work has included several LEED-certified buildings such as the LEED Platinum headquarters of the Southface Energy Institute in Atlanta, Georgia. Alfred is past-Chair of the Sustainable Sites Technical Advisory Group for the US Green Building Council, Founding Chair of the Athens Branch of the US Green Building Council and has served on the board of several environmental organizations.

# Workshops

## Using Climate Data in Hydrologic Analysis

**Workshop Description**: How can hydraulic engineers account for climate change when designing transportation infrastructure? Use the Guide! This interactive workshop will introduce participants to the provisional "Design Practices Guide for Applying Climate Information to Hydrologic and Coastal Design of Transportation Infrastructure". Developed under NCHRP Project 15-61, the Guide aims to augment state DOT guidance and procedures with practical tools to consider and, as needed, account for the effects of climate change in hydraulic design. In the first half of the workshop, participants will learn about procedures in the Guide including methods to estimate the design storm, the design flood, and sea level rise under various climate change scenarios. Participants will work in groups to evaluate case examples. In the second half, participants will learn best practices for using the Guide based on recent pilot studies at eight state DOTs. The workshop will close with a facilitated discussion of opportunities and challenges for considering climate change in design.

**BIOs:** Roger Kilgore (Kilgore Consulting and Management) is a Professional Engineer and board certified in water resources engineering. Based in Denver Colorado he has over 30 years of experience in hydrology and hydraulics, stormwater management, water quality, and flood mitigation. He has written several design manuals for the Federal Highway Administration including Highways in the River Environment - Floodplains, Extreme Events, Risk, and Resilience (HEC-17) and Highway Hydrology (HDS-2). He also served as the Principal Investigator of NCHRP 15-61 "Applying Climate Change Information to Hydrologic and Hydraulic Design of

Transportation Infrastructure" and NCHRP 25-60 "Watershed Approach to Mitigating Hydrologic Impacts of Transportation Projects."

Dr. Dano Wilusz is a water resources professional with 15 years of experience in engineering, hydrology, integrated water resources management, and project management. Dano leads and supports small technical teams to solve water supply and management problems using water quality modeling, floodplain mapping, climate change risk assessment, and stormwater drainage design for city, state, and federal clients.

In 2018 Dano completed a PhD in advanced watershed modeling. Prior to graduate school, Dano was a foreign affairs officer at the U.S. Department of State, where he oversaw over $1M in water-related foreign assistance and helped launch several global water and environment initiatives.

## HEC 23 Proper Countermeasure Design

**Workshop Description:** The FHWA Scour Program is an integrated national effort to address or mitigate erosion of streambed or bank material due to flowing water; including erosion localized around bridge abutments and piers. FHWA provides guidance manuals and documents to assist bridge owners and their designers and ensure their bridge designs are in compliance with FHWA's regulations found within the Code of Federal Regulations (CFR), Title 23, Highways (23 CFR). This is important to make certain that a project is eligible for Federal-aid reimbursement or other FHWA participation or assistance. Research continues to reveal the need to improve the effectiveness of bridge countermeasures; FHWA's HEC-23 manual is currently being updated to address these findings. Our goal in this workshop is to highlight various solutions and best practices to address erosion in the vicinity of bridges and provide recommendations for the selection of, and design of, bridge scour countermeasures. Case studies will be presented to demonstrate countermeasure designs and promote discussion amongst the participants.

**BIOs:** Mr. Scott Hogan (PE) has spent more than 30-years working in the field of river engineering hydraulics. For the past 16 years, he has worked with the US Federal Highway Administration (FHWA) and was a consulting engineer prior to that. He graduated from Colorado State University with a B.S. and M.S. in Civil Engineering.

Mr. Hogan specializes in bridge hydraulic modeling and design, scour analyses, sediment transport, counter measure design, and floodplain analysis. For more than 25 years he has been an instructor for several hydraulics training courses through FHWA National Highway Institute (NHI). He has a sincere passion for hydraulic engineering and advancing the state of our practice.

Laura Girard is a Senior Hydraulic Engineer with the Federal Highway Administration's (FHWA) Resource Center. Ms. Girard has spent the last two decades of her career wading in, measuring, modeling, and studying riverine systems. She provides technical support to bridge owners on resilience-related hydraulic design. As a Hydraulic Engineer for FHWA, she has designed hydraulic structures in some of our country's most sensitive riverine systems, including National Parks, National Forests, and Wildlife Refuges. Her experience includes work as a researcher on three NCHRP hydraulic studies and author of the corresponding reports, co-author of Hydraulic Engineering Circular 23 (HEC-23), and instructor for seven National Highway Institute courses on scour, resilience, stream dynamics, and modeling of river encroachments.

# Presentations

## Operational Resilience

### Real-Time Flood Emergency Response for TxDOT

**Abstract:** The University of Texas at Austin and the US Geological Survey are conducting a research project with the Texas Department of Transportation to leverage flood forecasting from the National Water Model to support improved flood emergency response at TxDOT. Radar streamflow sensors are being installed by the USGS on 80 TxDOT bridges to measure water surface elevation and velocity and calculate discharge. An automated method for extracting bridge deck and streambed cross-section profiles from LIDAR point clouds is being used to create simplified hydraulic models of bridges. A shared system of web map services is being created between the National Weather Service and TxDOT to create a common operating picture of current and anticipated future flood conditions. These maps include NWS precipitation and streamflow forecasts customized for TxDOT District and Maintenance Section areas, conversion of discharge to water surface elevation to provide warning of bridge flooding, and maps of flood inundation including flood depth on the road network. The utility of these maps is being tested using flood emergency response exercises conducted by the Homeland Security Exercise and Evaluation Protocol. The approach is illustrated using example application for Tropical Storm Imelda in the TxDOT Beaumont District.

### Hidden Impacts to Transportation in Vermont post Hurricane Irene

**Abstract:** The transportation infrastructure along two river systems in southwestern Vermont have experienced significant flooding impacts during relatively minor precipitation events in the decade following Hurricane Irene. In 2011, Hurricane Irene caused unprecedented erosion and sediment transport throughout the Green Mountains by combining extreme tropical storm rainfall with high antecedent precipitation conditions. Since 2011 residents along these river corridors have experienced road overtopping flood events multiple times per year. Because of the rural nature of the region, the cause of such systemic change was not immediately evident to regional transportation engineers and planners. Infrastructure design repair and maintenance work led to a wider search for causes and solutions. Initially, 2-Dimensional flow models of the individual systems were developed to investigate simple solutions such as adding or expanding culverts. However, the 2-D models highlighted systemic problems that were beyond simple solutions. Subsequent

geomorphic and field investigations of problematic locations showed excessive sedimentation was the likely cause of the regional flooding issues. In the modeled regions, large volumes of sediments, likely destabilized by Irene, have caused continued aggradation further exacerbating problems to this day. Solutions to flooding issues are further complicated by competing interests, including: communities having historic structures and land use patterns; towns built on and at the base of active alluvial fans; Vermont's very strong wetland and stream protection regulations; and the main stem river frequently being cited as one of top trout fisheries in New England. This presentation shows the power of 2-Dimensional flow modeling to assist in understanding the cause of systemic regional flooding challenges and highlights the type of challenges water resource engineers will face designing a more resilient transportation system in the face of climate change.

## FIMAN-T: Real-Time Monitoring and Visualization of Road and Bridge Flood Impacts

**Abstract:** During Hurricane Florence, the State of North Carolina experienced significant flooding that included unprecedented impacts to the transportation system in the eastern part of the state. Many roads, including Interstate Highways were inundated and closed for days, impacting not only routine travel throughout the state, but the ability for emergency responders to reach areas in need. During and immediately following the event, many questions concerning impacts to the transportation system arose from Sr leadership that could not be readily answered. To assist the NCDOT, ESP is developing FIMAN-T, a web application that can be used to provide real-time and forecasted flood inundation /depths along roads, bridges, and other NCDOT assets. FIMAN-T was developed in conjunction with North Carolina Emergency Management. The application expands upon the successful FIMAN application that was already in place to monitor flood levels along streams and provide real-time inundation mapping and impacts to buildings. This presentation will provide a brief history of the FIMAN application and explain the drivers for development of FIMAN-T. The system architecture will be overviewed prior to providing a walk-through of the application highlighting its features and use. Finally, future steps to further enhance and grow the application will be presented.

## Asset Monitoring for Metric 18 Compliance and Digital Plans of Action using BridgeWatch Software-as-a-Service

**Abstract:** This presentation will span four State Departments of Transportation's bridge asset monitoring for environmental hazards such as Hurricanes, Floods, Earthquakes and Severe weather events. From the experiences of Pennsylvania, North Carolina, South Carolina, and Georgia, each state will present an overview of their policy and protocol for using the BridgeWatch web-based Software-as-a-Service (SaaS) application to meet Metric 18 compliance, digital Plans of Action (POA), improved interagency communication, and embedding of application into agency workflows.

## 2D Modeling & Advanced Computing

### Automation of Hydraulic Modeling with Python Scripting & Cloud Computing

**Abstract:** Computational hydraulics models have been used extensively in engineering practice. Most models have graphical user interfaces (GUIs) which make it convenient for a modeler to preprocess, run, and postprocess simulation cases. However, most models and their GUIs currently lack automation. While convenient, manual operations with GUIs for certain tasks may be tedious, time consuming, and prone to human error. Some examples of such task are parametric studies, Monte Carlo simulations, calibrations, and parallel runs of simulation cases. In essence, automation is desired where the workflow is well defined and the work is repetitive. Automation also helps to offload some of the computing in hydraulics modeling to the cloud. This talk will present a Python package, pyHMT2D, which is designed to automate hydraulics modeling (https://github.com/psu-efd/pyHMT2D). It currently supports SRH-2D and HEC-RAS. The Python package can parse and modify the inputs and outputs of the supported models. It can also control the model runs. With the versatile scripting capability and powerful software ecosystem of Python, pyHMT2D can automate many of the modeling workflows that a hydraulic engineer routinely performs. The package also provides many other functionalities, such as converting HEC-RAS mesh to SRH-2D for fair model intercomparison.

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**BIO:** Dr. Xiaofeng Liu is an associate professor in the Department of Civil and Environmental Engineering at Penn State. He got his Ph.D. in Civil Engineering from the University of Illinois at Urbana-Champaign. Dr. Liu's research interest includes computational hydraulics, sediment transport, and environmental fluid mechanics. His group specializes in the development and utilization of computational models for problems in environmental and water resource engineering. His research has been funded by many federal and state agencies, including NCHRP. His current NCHRP project works on the guidelines for Manning's n in 2D models.

## Bridge Deck Afflux Modeling – Benchmarking of CFD and SWE Codes to Real-World Data

**Abstract:** Many bridge decks become partially or completely submerged by the river during significant rain events, with the presence of the bridge then increasing water levels and flood extents upstream of the structure. Traditional flood modelling methods to determine the increase in water levels (afflux) use an empirical energy loss factor, usually as a function of upstream and/or downstream water levels. Currently, there is a level of uncertainty within industry as to the best approach and the input parameters to utilize for these empirical models. To better understand this problem, the Queensland Department of Transport and Main Roads (TMR), Australia, partnered with TUFLOW researchers in 2019 to investigate and produce guidelines for modeling bridge deck losses. Initially, simple bridge deck structures were modelled numerically by means of two different computational fluid dynamics (CFD) codes to determine energy loss mechanisms and coefficients. The energy loss factor as a function of water level was found to fit a simple function that could be parametrized according to the basic bridge dimensions, resulting in a new parametric formulation being integrated into the TUFLOW 2D Shallow Water Equation (SWE) code. In a parallel development, TUFLOW's 3D SWE code has built in new functionality to represent bridge decks and blockages within the 3D layered mesh.

The second stage was to validate the developments with real-world data by installing gauges upstream and downstream of a low-level bridge in a collaborative effort between Moreton Bay Regional Council and TMR to provide measurements of bridge deck energy losses and affluxes. The Queensland 2022 floods, and some minor events in 2021, have now provided invaluable data on affluxes upstream of the bridge over a range of river levels – from deck surcharging to full submergence (water over the guard rails). Video footage taken during the 2022 floods provides useful visualization of the hydraulic formations over the deck. Two CFD and 1D, 2D and 3D hydrodynamic models were developed and benchmarked to the measurements resulting in beneficial findings for industry practitioners. These findings are being used by TMR to provide guidance on empirical approaches to modeling bridge deck hydraulic losses, thus reducing modeling uncertainty and produce better civil road and bridge designs.

## Key Advances in 2D Hydraulic Modeling - SRH-2D Interface Features

**Abstract:** Over that past decade the state of the practice for hydraulic modeling has progressed from traditional 1D riverine models to 2D depth averaged models. This advance has been driven by two key factors. First, the FHWA-EDC initiative identified the capability and benefits of 2D models and promoted their

application to the state of the practice. Second, model and interface developments sponsored by FHWA (SRH-2D) and USACE (HEC-RAS 2D) have illustrated the relative ease of applying these technologies.
This presentation will demonstrate many of the new advancement in interface and modeling approach that make 2D hydraulic modeling more attractive in today's environment. Topics of the presentation will include:

- Lidar data import and processing tools (Ease and efficiency)
- Import and use of CAD and terrain data in 2D modeling
- Import and use of GIS data in 2D modeling
- Efficient mesh development
- Multiple scenario analysis
- Floodway analysis tools
- Automated model calibration
- 1D model export
- Project summary reports

**BIO:** Dr. Alan Zundel leads the Aquaveo, LLC software development team. He was the original architect of the Surface-water Modeling System (SMS) developed under contract to both the Federal Highway Administration (FHWA) and the Engineering Research and Development Center of the Army Corps of Engineers (ERDC). This package is now used around the world and is available in a freely available "Community Model" version.

Dr. Zundel has managed multiple custom software development projects as well as hydraulic modeling projects over the past 30 years. Development project have included software development applications for several riverine, coastal, water quality, sediment transport and wave engines. He has developed multiple hydraulic modeling courses and short courses for all models included in the SMS package and acted as the instructor for these courses.

## A Tale of 2's: 2D Modeling of 2+2 Construction in 2 Floodways

**Abstract:** This presentation will provide a background of the US 275 Scribner to West Point project and illustrate how the SRH-2D model was efficiently and effectively used to inform roadway and bridge design and support a successful CLOMR application and Section 408 Authorization.

US-Highway 275 (US-275) is a critical highway in Nebraska's transportation network that connects Northeast Nebraska to Interstate 80 (I-80) and the Omaha metropolitan area and provides access to critical services in the region which includes employment opportunities, social services, health care and education services. NDOT has invested over $450 million into the expressway system over the years and has steadily advanced US-275 expressway construction. However, there are 44 miles of the US-275 expressway that still remain unfinished.

The US-275 Scribner – West Point segment of the US-275 expressway is expanding approximately 18.5 miles of U.S. Highway 275 (US-275) from a two-lane highway to a four-lane divided expressway from Scribner to West Point. NDOT plans to construct the majority of this project using a 2+2 approach, which will construct two new lanes with new pavement parallel to the existing lanes that will continue to accommodate traffic.

The design included various challenges like balancing roadway and bridge design in the dynamic and complex reach of the Elkhorn River that is prone to flooding. An iterative process was used to balance roadway and bridge design with hydraulic design and minimization of floodplain impacts to provide a more resilient roadway, subject to less frequent flooding. Additionally, the project involved coordination with the City of Scribner to relocate an existing levee next to Pebble Creek and incorporate the new realigned levee into the 4-lane bypass embankment around the community. Permitting activities consisted of a Conditional Letter of Map Revision (CLOMR) for both the Elkhorn River and Pebble Creek, as well as Section 408 Authorization.

Successful floodplain permitting and Section 408 Authorization was accomplished through 2-dimensional hydraulic modeling using SRH-2D, which was instrumental in understanding the complex hydraulic issues to optimize the roadway and bridge design. It also proved to be critical in development of a 1-dimensional HEC-RAS model, which was required for the CLOMR.

**BIO:** Matt McConville is a Senior Water Resource Engineer and Associate Vice President with HDR Engineering in Omaha, NE. He has been with HDR for 17½ years and has experience in program management, water resource management, 1D/2D hydraulic modeling, floodplain permitting, hydraulic design and scour. He provides technical support to both private and public clients, including transportation agencies, railroads, cities/municipalities, and natural resources agencies. He is a graduate of the University of Iowa, with B.S. Civil and Environmental Engineering ('03) and M.S. Civil Engineering ('05) and a Registered Professional Engineer in the state of Nebraska.

## FHWA Programmatic Update

### Federal Flood Risk Management Standard - What will FFRMS Mean for You?

**Abstract:** In May 2021, President Biden reinstated the January 2015 Executive Order 13690 and the Federal Flood Risk Management Standard (FFRMS). While the legal aspect may appear the same, the underlying aspects of science, engineering, and establishment of all three aspects has evolved over the years. In this presentation, the Federal Highway Administration (FHWA) will describe the past, present, and future status and implications of this reinstituted FFRMS as related to our transportation community. What will FFRMS require – and just as importantly – what doesn't FFRMS require. The presentation will provide insights on how

practitioners may consider applying FFRMS to their particular programs and projects, for example grant programs associated with the recent Bipartisan Infrastructure Law.

**BIO:** Mr. Joe Krolak is the Principal Hydraulic Engineer and Leader of the Hydraulic and Geotechnical Engineering Team in the FHWA Office of Bridges and Structures.

His primary responsibilities include leading policy, program, and technical direction and developing guidance for Hydrology, Culverts, Bridges, Extreme Events, Scour, Floodplains, and Coastal Hydraulics for both FHWA and the USDOT.

Mr. Krolak has over 37 years of experience and specializes in hydrologic, hydraulic, coastal, natural hazards, and environmental processes. He has worked for both private and public sector entities. Mr. Krolak has served as an adjunct instructor at Catholic University of America for both undergraduate and graduate courses in hydrology and hydraulics.

Mr. Krolak has a BS in Civil Engineering, University of Maryland, College Park, MD 1984

He is a registered Professional Engineer in Civil Engineering; Member of the AASHTO Technical Committee on Hydrology and Hydraulics; member of ASCE and EWRI; a technical reviewer for the ASCE Journals; and a member of various NCHRP Panels (National Academies).

## Promoting Resilient Transportation from PROTECT to Planning and Programming

**Abstract:** The Bipartisan Infrastructure Law has created new opportunities to incorporate resilience into transportation planning and project development. A new program in the law – Promoting, Resilient Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT) – provides contract authority for billions of dollars from the highway trust fund to address infrastructure and community resilience. State DOTs, Metropolitan Planning Organizations (MPOs), local governments and other groups will be eligible to take advantage of these funds to plan for, design, retrofit and construct new infrastructure to improve the resilience of the transportation system to current and future extreme weather and climate hazards. The implementation of this law will offer new opportunities and challenges for engineers, transportation planners, and project managers. An interdisciplinary approach – where a broader coalition of disciplines work closely together is necessary. Facilitating connections between engineers, who will ultimately select resilience adaptations on a project-by-project level, and planners, who will have a key role in identifying vulnerable and at-risk infrastructure, will be key to successfully benefit from these new opportunities. This session will focus on informing participants on relevant information from the Bipartisan Infrastructure Law, highlighting the key connections between planning and engineering for system resilience and laying a foundation for an interdisciplinary approach.

**BIO:** Laura Girard is a Senior Hydraulic Engineer with the Federal Highway Administration's (FHWA) Resource Center. Ms. Girard has spent the last two decades of her career wading in, measuring, modeling, and studying riverine systems. She provides technical support to bridge owners on resilience-related hydraulic design. As a Hydraulic Engineer for FHWA, she has designed hydraulic structures in some of our country's most sensitive riverine systems, including National Parks, National Forests, and Wildlife Refuges. Her experience includes work as a researcher on three NCHRP hydraulic studies and author of the corresponding reports, co-author of Hydraulic Engineering Circular 23 (HEC-23), and instructor for seven National Highway Institute courses on scour, resilience, stream dynamics, and modeling of river encroachments.

David D'Onofrio is an Environmental Protection Specialist with the Federal Highway Administration's Office of Natural Environment. David started his federal career in FHWA's Resource Center in 2019 as an air quality specialist. His work has focused on issues related to transportation, climate resilience and air quality. Before joining FHWA, David worked for more than 9 years as an air quality and climate change planner at the Atlanta Regional Commission. David holds an undergraduate degree in Earth and Atmospheric Science and a dual Master's degree in urban planning and atmospheric science from Georgia Tech.

## Overview of the FHWA Hydraulic Manual Updates

**Abstract:** The Federal Highway Administration (FHWA) Resource Center (RC) Hydraulics Team has been working on updating several hydraulic reference manuals to better reflect current industry trends and research. Mr. Ryan Lizewski from the FHWA RC Hydraulics Team will briefly review the status of several, soon-to-be-released, publications. These manuals include:

- Hydraulic Engineering Circular No. 22 (HEC-22) - Urban Drainage Design Manual (Fourth Edition);
- Hydraulic Engineering Circular No. 19 (HEC-19) - Emerging Methods, Tools, and Data for Highway Hydrology (New Manual);
- Hydraulic Design Series No. 2 (HDS 2) – Highway Hydrology (Third Edition);
- Hydraulic Engineering Circular No. 23 (HEC-23) - Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (Fourth Edition);
- Hydraulic Design Series No. 7 (HDS 7) - Hydraulic Design of Safe Bridges; and
- Hydraulic Engineering Circular No. 16 (HEC-16) - Highways in the River Environment: Roads, Rivers, and Floodplains (New Manual);

In conjunction with the manual publications, the Resource Center Hydraulic Team also supports technical content updates to the associated National Highway Institute (NHI) courses reflecting new hydraulic material, guidelines, and learning outcomings. This presentation will outline the proposed updates and new training courses, which will be available through the NHI training program.

**BIO:** Ryan Lizewski is a hydraulic engineer with FHWA's Resource Center having 15 years of experience in the field of hydraulic engineering. Ryan was hired into the Resource Center last year with his prior experience in the private sector providing consulting services in the Northeast. Ryan specializes in many areas of hydraulic engineering including urban drainage, stormwater management, floodplains analysis, and hydraulic modeling. Ryan is currently the technical lead for the HEC-22 Urban Drainage Design manual update and several of FHWA's National Highway Institute courses. He graduated from Worcester Polytechnic Institute with a bachelor's degree in Civil Engineering.

## Status of the new National culvert removal, replacement, and restoration grant program

**Abstract:** In November 2021, President Biden signed the Bipartisan Infrastructure Law (BIL). Of particular interest to the Hydraulic community was the creation of the new "National culvert removal, replacement, and restoration grant program" [Title 49 U.S.C. §6703]. The program is an annual competitive, discretionary grant program to award eligible entities for culvert (or weir) replacement, removal, and repair projects with a goal to *"… meaningfully improve or restore fish passage for anadromous fish."* The White House and U.S. Department of Transportation (USDOT) assigned the Federal Highway Administration (FHWA) to develop and administer the program. As practice terms culverts that facilitate aquatic organism passage (AOP) as "AOP culverts" the FHWA refers to this new grant opportunity as the "Culvert AOP program."

Eligible grant recipients include States, local government units and Tribal governments. The cost share is 80% (federal) to 20% for State and local recipients, and 100% for Tribal governments.

Congress required USDOT/FHWA to consult with the Undersecretary of Commerce for Oceans and Atmosphere (NOAA) and Director of the United States Fish and Wildlife Service (USFWS) to establish a process for determining criteria for awarding grants and procedures to prioritize awarding grants (consistent with priorities identified in the BIL). The Culvert AOP program will need to address gaps in essential process, standards, and data prior to issuing a Notice of Funding Opportunity (NOFO).

The presentation will inform participants on status and details of this exciting and well-needed new program.

**BIO:** Mr. Joe Krolak is the Principal Hydraulic Engineer and Leader of the Hydraulic and Geotechnical Engineering Team in the FHWA Office of Bridges and Structures.

His primary responsibilities include leading policy, program, and technical direction and developing guidance for Hydrology, Culverts, Bridges, Extreme Events, Scour, Floodplains, and Coastal Hydraulics for both FHWA and the USDOT.

Mr. Krolak has over 37 years of experience and specializes in hydrologic, hydraulic, coastal, natural hazards, and environmental processes. He has worked for both private and public sector entities. Mr. Krolak has served as an adjunct instructor at Catholic University of America for both undergraduate and graduate courses in hydrology and hydraulics.

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## FHWA Scour Session

### Programmatic Synopsis of the FHWA Bridge Scour Program: Scour Evaluation and Assessment Processes and Scour Plans of Action

**Abstract:** On September 16, 1988 FHWA issued Technical Advisory (TA) T 5140.20 “Scour at Bridges” that established the FHWA Scour Program. FHWA retained Ayres Associates Inc to assist with researching and producing a Synthesis Report to organize and describe the programmatic aspects of the FHWA Bridge Scour Program as it has evolved since 1988. The intent of the Report is to provide an understanding of the actions that led to the development of FHWA’s bridge scour program including, both the legal requirements of 23 CFR 650 subpart C and the guidance documents issued by FHWA and AASHTO that support the program. The Report captures guidance for performing scour evaluations and, subsequently, the requirement for developing and implementing Plans of Action (POA) for scour critical and unknown foundation bridges. The Synthesis Report is intended to serve as a compendium of the programmatic elements of the bridge scour program suitable for use by FHWA Division Offices and FHWA’s transportation partners. The Synthesis Report includes the following topics: •Interim procedures and technical advisories. • Code of Federal Regulation requirements and NBIS compliance. • FHWA memoranda on the Scour Program, Coding Guide and Plans of Action. • Memoranda on information for unknown foundations and non-destructive testing. • Current guidance in Hydraulic Engineering Circulars and TechBriefs. • Current AASHTO publications and guidance. • A chronology and graphical timeline of activities from 1988 to the present. • A summary of requirements and an application example.

**BIO:** Paul Sharp (PE) is a graduate of Tennessee Technological University with a BSCE degree in Civil Engineering. He is a licensed engineer in Tennessee. He has 40 years of experience serving as a Structural Design Engineer, Bridge Inspection and Evaluation Manager and the State Hydraulics Engineer for the

Tennessee DOT and he has served as the FHWA Tennessee Division Bridge Engineer. Paul currently serves as the FHWA Senior Scour Engineer in HQ.

His current responsibilities include the advancement of the FHWA Scour Program as it relates to establishing and interpreting policy, research implementation and deployment of scour design and scour countermeasures activities. He also assists owners in their compliance with the scour-related topics within the National Bridge Inspection Standards.

## Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (HEC-23)

**Abstract:** The Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance Hydraulic Engineering Circular 23 (HEC-23) is currently being updated. This presentation will present some of the methods, procedures, and updates presented in the next HEC-23 edition. The discussion will include clarification on the use of countermeasures at abutments for foundation stability, new recommendations for protection at narrow bridges and shallow foundations, new Design Guidelines for Rockeries and Engineered Log Jams, and an expanded discussion on Nature-Based Solutions.

**BIO:** Laura Girard is a Senior Hydraulic Engineer with the Federal Highway Administration's (FHWA) Resource Center. Ms. Girard has spent the last two decades of her career wading in, measuring, modeling, and studying riverine systems. She provides technical support to bridge owners on resilience-related hydraulic design. As a Hydraulic Engineer for FHWA, she has designed hydraulic structures in some of our country's most sensitive riverine systems, including National Parks, National Forests, and Wildlife Refuges. Her experience includes work as a researcher on three NCHRP hydraulic studies and author of the corresponding reports, co-author of Hydraulic Engineering Circular 23 (HEC-23), and instructor for seven National Highway Institute courses on scour, resilience, stream dynamics, and modeling of river encroachments.

## Geotech for Hydraulics/ NextScour Program

**Abstracts:** According to HEC 18, scour is an erosion process and is due to the displacement of soil particles caused by flowing water. Based on this description there are two components that impact scour, the load from the flowing water and the resistance from the soil. The first is the hydraulic parameters which are developed through various models for a given design criteria. These parameters include depth of flow, velocity, and shear stress. The second is the material being eroded. Given that the material being eroded is soil, a good understanding of the type of soil and how this material is distributed across the site as well as changes with depth would be an important consideration to accurately predict scour. The information on the materials being eroded should be collected, analyzed, and considered in the scour calculations. This material

can vary not only across the site but can change with depth. The typical analysis for scour depth assumes a uniform granular (sand) material across the site hat is infinitely deep. This assumption can be conservative if the material changes to a cohesive soil or to bedrock which erode but at a different rate than a material like sand. These differences should be considered. HEC 18 includes a chapter on geotechnical considerations and recognizes the different behavior for different soil types. The presentation will provide an introduction to sampling and testing of soils as well as the geotechnical data that can be used to help classify the erodibility of these materials. The intent of this presentation is to provide an overview of the differences between these materials as well as how these materials erode. Geotechnical engineers already collect a significant amount of data for the design and construction of the foundations. This presentation will provide suggestions on how hydraulic and geotechnical engineers could collaborate to develop a better understanding of the materials so that they may be considered when calculating scour depths.

The Federal Highway Administration (FHWA) is developing NextScour, a next-generation scour research initiative to improve scour analysis and provide more accurate scour depth estimates for bridge foundation design. NextScour considers the two major components of scour: hydraulic loads and the erosional resistance of soils. Traditional hydraulic analysis typically utilizes one- and two-dimensional (1D and 2D) models to predict flow conditions at a proposed bridge site which are then used for the scour calculations. NextScour proposes utilizing computational fluid dynamics (CFD) modeling to compute bed shear stresses directly at the bridge components. Eventually, CFD models will generate adjustment factors of hydraulic load for 1D/2D models to determine bed shear stresses governing soil erosion, instead of channel friction components due to vegetation and bedform irregularity. Hydraulic load decay functions are developed with laboratory flume scour tests and accompanying CFD modeling within the scour hole.

On the resistance side, NextScour focuses on improving estimates of the critical shear stress of layered soils, especially cohesive soils, using soil erosion testing. FHWA has developed multiple in-situ and ex-situ soil erosion testing devices that can be used to estimate the erodibility of cohesive soil samples and their corresponding critical shear stresses. Additional geotechnical tests are also conducted on these samples in order to fully characterize the soils tested.

Due to uncertainties related to flood occurrence, channel roughness estimates, and natural variability of field soils, the NextScour initiative is also developing a probabilistic scour analysis that considers the variability of the loads and the resistance.

Through a Transportation Pooled Fund (TPF) study, FHWA has partnered with several State departments of transportation (DOTs) to provide soil and erosion testing services for bridge scour evaluations. The presentation covers an overview of the NextScour initiative, discusses current and proposed methods to evaluate hydraulic loads and soil erosion resistance, case studies, and applications of NextScour.

**BIOs:** Kornel Kerenyi is a hydraulics research engineer in the Federal Highway Administration's (FHWA's) Office of Infrastructure Research and Development (R&D). He coordinates hydraulic and hydrological research activities with State and local agencies, academia, and various partners and customers. He also manages the FHWA Turner-Fairbank Highway Research Center (TFHRC) J. Sterling Jones Hydraulics Research Laboratory. He was previously a research engineer at a private company and supervised support staff in the laboratory. Dr. Kerenyi holds a Ph.D. in Fluid Mechanics and Hydraulic Steel Structures from the Vienna University of Technology in Austria.

James Pagenkopf is a hydraulics research engineer in the FHWA's Office of Infrastructure R&D, providing support for hydraulic and hydrological research activities conducted at TFHRC Hydraulics Research Laboratory. He was previously a research engineer providing over 12 years of contracting support at TFHRC for both the Hydraulics and Aerodynamics Laboratories. Mr. Pagenkopf holds M.E. and B.S. degrees in Mechanical Engineering from the University of Virginia.

Daniel Alzamora, P.E.

- Senior Geotechnical Engineer with FHWA – RC
- Geotechnical team lead at the Resource Center
- Professional Engineer – Georgia
- 32 years Geotechnical experience
  - 12 years private practice
  - 20 years with FHWA
- BSCE – University of Connecticut
- MSCE – University of Colorado

## Current state of the practice for bridge hydraulic and scour analysis tools

**Abstract:** This presentation is intended to be part of the FHWA bridge scour session. IT will highlight the latest best practices for evaluating bridge hydraulics and scour, including 2D modeling bridge scour tools and new features in the FHWA Hydraulic Toolbox.

**BIO:** Mr. Scott Hogan (PE) has spent more than 30-years working in the field of river engineering hydraulics. For the past 16 years, he has worked with the US Federal Highway Administration (FHWA) and was a consulting engineer prior to that. He graduated from Colorado State University with a B.S. and M.S. in Civil Engineering.

Mr. Hogan specializes in bridge hydraulic modeling and design, scour analyses, sediment transport, counter measure design, and floodplain analysis. For more than 25 years he has been an instructor for several hydraulics training courses through FHWA National Highway Institute (NHI). He has a sincere passion for hydraulic engineering and advancing the state of our practice.

## Hydrology

### CDOT's Post-Wildfire Debris Response in Real-Time: Strategies and Observations for 2020-2022

**Abstract:** Post-wildfire conditions in the foothills and mountains of Colorado regularly involve debris flows. These flows are often triggered by intense, shorter duration precipitation events during the state's monsoon season of May to September. While much research has been conducted, and continues to be conducted, on these events and their effects upon the transportation infrastructure, CDOT finds itself in the midst of a time of critical decision making as we enter our second full season of post-wildfire conditions for the Grizzly Creek/Glenwood Canyon Fire, Cameron Peak Fire, and East Troublesome Fire recovery areas. I aim to briefly survey some of the principal variables which we are considering when planning for pre-emptive road closures, cleanup operations post-slide, and infrastructure repair/replacement/upgrades. I also plan on discussing the role which technology plays in these responses. sUAS/drone surveys, hydrologic and hydraulic modelling, soil testing, automated alerts, and remote monitoring all play important roles as we execute our emergency action plans – yet, each also has significant limitations in CDOT's post-wildfire context which must be carefully understood and communicated to management levels, stakeholders, and the public. Further, I plan to highlight some of the key differences in our current fire recovery strategies. Not every post-wildfire setting can, or should, be treated with the same recovery philosophy. I will illustrate this point by briefly discussing both the I-70 Glenwood Canyon/Grizzly Creek Fire area and the CO 14 Poudre River/Cameron Peak Fire area - two dramatically different transportation corridors with unique topography, unique traffic patterns, unique hazards, and thus unique plans of action for the 2022 debris flow season. Finally, I will briefly discuss messaging strategies which we have found effective. These include briefings to our internal management such as the Chief Engineer and Executive Director, as well as messaging to external stakeholders such as USFS, CO Parks and Wildlife, local agencies, and the media and traveling public. The unpredictability of debris slide timing and magnitude adds a layer of challenge to efficient and effective communication.

Acknowledging that CDOT is in the midst of real-time decision making for the upcoming debris season, it will hopefully be informative for the NHEC assembled colleagues and partners to see how one agency is managing its post-wildfire response even as we adapt our strategy to take advantage of new research and hard-won wisdom from other DOTs and Federal agencies such as USFS. We know we have much to learn as

we continue to develop these best practices, and eagerly anticipate discussion and fruitful exchange of ideas with our colleagues as we move forward.

**BIO:** Steven Griffin is the Hydraulic Engineer covering Northern and Eastern Colorado, and has served 14 years with the Colorado Department of Transportation. He holds a Masters degree in Hydraulics from Colorado State University and is currently pursuing his PhD, hoping to research post-wildfire hydrology and recovery from a DOT perspective.

## GSHHA-based hydrological modeling of coastal roadways considering sea-level rise scenarios

**Abstract:** Extreme hydrologic events such as floods can impact roadway infrastructure, degrading its performance through saturation of the subbase of the pavement. In coastal areas, this effect is anticipated to worsen due to sea-level rise which will decrease the conveyance of drainage infrastructure placed in roadways. A hydrologic modeling investigation in in Baldwin County, Alabama along Alabama State Route 180 (AL-180) is being performed to study the impact of severe coastal storms to roads due to flooding. AL-180 is an important road as it serves as an evacuation route, and which connects Fort Morgan Peninsula with Dolphin Island via a ferry system. This road has also a history of flooding and locations with standing water, and the implementation of natural and nature-based features (NNBF) is expected to increase this road resiliency. The analysis aims to assess the road vulnerability to inundation and elevated groundwater tables. A model based on the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) tool is being created to perform systematic analysis of various hydrological stressors at selected sections of AL 180. We chose this tool as it resolves sub-hillslope overland and shallow groundwater flow dynamics, enabling the evaluation of the interaction of these components with the pavement. High-resolution elevation data is needed to produce an acceptable model resolution for the selected modeling sites. The Coastal National Elevation Database (CoNED) will be used along with USGS's groundwater monitoring wells and weather stations as well as on-site groundwater wells and precipitation gauges. Systematic changes in water table elevation combined with various rainfall scenarios will be used to assess the change of moisture in the unsaturated zone in critical segments of the road so that this data can be used to investigate the potential impact on the pavement subbase. This model will be used in the future where alternative NNBF are used to quantify the gain in resiliency obtained with these techniques. It is hoped that this methodology could then be applied widely in the US Coastal Plains as a means of quantifying the role of NNBFs to improve road resiliency in future scenarios with sea-level rise and more intense coastal storms.

## Discovering Flood Regions and Predicting Flood Flow Metrics to Inform Bridge Scour Studies in the Conterminous United States

**Abstract:** Bridge scour studies rely on accurate flood flow information to inform designs and maintenance programs. For bridges that are not near streamflow gages, models are required to predict flood flow metrics, such as the frequency, duration, volume, and peak flow. The physical processes that generate floods vary across the conterminous United States (CONUS), which can challenge the ability of prediction models to generalize across CONUS. In this study, we use cluster analysis to discover geographic regions with different flooding processes across CONUS and compare machine learning (ML) model predictions of flood flow metrics for selected regions. We focus on minimally altered catchments so that observed flood events are likely driven by hydroclimatic signatures. We use 1380 gages across CONUS with at least 20 complete years of record for this study. We use hierarchical agglomerative clustering on seasonally computed flood flow metrics, with the goal of estimating cluster regions that capture spatial differences in the typical annual pattern of floods. We compute metrics for flood magnitudes ranging from the 50th to 95th non-exceedance percentile of daily flow at each gage. The cluster analysis reveals spatial groupings of gages even though no spatial information was provided to the algorithm, suggesting that the regions correspond to different large-scale flood processes. For two separate regions with snowmelt- and rainfall-dominated flooding, we train ML models on gages within a single region and then evaluate model performance on gages in the other region. The results provide insight for the transferability of models to predict flood flow metrics accurately for bridges in ungaged locations and across catchments with different flooding processes.

## Coastal & Advanced Hydraulic Design

### Nature-Based Solutions Enhance Coastal Highway Resilience

**Abstract:** There are over 60,000 miles of coastal highways in the United States exposed to, or occasionally exposed to, storm surge, waves, and erosion. These coastal highways, consisting of roads, bridges, tunnels, and their associated drainage infrastructure are vulnerable to extreme events today. Those vulnerabilities may increase over time as sea levels rise. Strategies for improving the resilience of coastal highways today can lead to enhanced resilience to future changing ocean and weather conditions. Such strategies include, either individually or in combinations: policy, structural, natural, and nature-based solutions. Combining traditional engineering (i.e., structural) approaches with nature-based solutions offer risk reduction benefits across a wide range of event frequencies and magnitudes, while simultaneously providing co-benefits such as water quality improvements, habitat enhancements, and opportunities for recreation and education. However, transportation professionals operating across the spectrum of project delivery (e.g., planners, scientists, engineers, maintenance staff) lack guidance on the implementation of nature-based solutions—marshes, mangroves, maritime forests, reefs, beaches, and dunes—when considering design, repair, restoration, or resilience alternatives for their infrastructure. The United States Department of Transportation Federal

Highway Administration has developed an Implementation Guide for Nature-Based Solutions that seeks to address this and other barriers to implementation. The guide is organized into chapters that sequentially follow the transportation project delivery cycle. The benefits and typical costs of nature-based solutions are described first, followed by chapters on planning and funding; site characterization; design considerations; permitting; construction; and monitoring and maintenance. The goal of this guide is to provide transportation organizations (e.g., state departments of transportation, metropolitan planning organizations, regional transportation authorities, and others) with relevant and timely information to aid in the implementation of nature-based solutions for coastal highways.

**BIO:** Dr. Bret Webb is a Professor of Coastal Engineering at the University of South Alabama and Senior Coastal Engineer and Vice President of South Coast Engineers. Bret is a licensed professional engineer and a board certified coastal engineer. Bret's research and consulting focus on coastal resilience, specifically resilience of the built and natural environments to extreme events and sea level rise.

## Updated Coastal Resilience Guidance in HEC-25 Third Edition

**Abstract:** The Federal Highway Administration has released the Third Edition of HEC-25: Highways in the Coastal Environment. The manual presents tools for the planning, design, and operation of roads and bridges that are constantly or occasionally influenced by coastal water levels and waves. This presentation will summarize "What's New?" for HEC-25. Most importantly, this new edition incorporates the best available and actionable engineering and science on coastal resilience. It recommends a reasonable and adaptable approach to incorporating sea level rise projections into the design and planning of coastal highways, it provides a framework for assessing the vulnerability of coastal infrastructure, and it offers adaptation strategies to address sea level rise in the future and improve coastal resilience today.

## Sea Level Rise & Coastal Design – A Probabilistic Perspective

**Abstract:** Changing sea levels introduce two unique challenges to evaluating coastal flooding: 1) the risk of flooding in the future is expected to be different from what it is today, and 2) there is significant uncertainty regarding what the future flood risk will be. Probabilistic methods are well suited for assisting designers with these two challenges. Recent advances in climate science have provided for the development of probabilistic models for sea level rise (SLR). Probabilistic SLR projections allow engineers to consider the diverse range of future flood risks and make risk-informed decisions for infrastructure design projects. The authors will present work from recent probabilistic SLR studies conducted for the North Carolina Department of Transportation. The studies report back information regarding how the annual flood risk may change throughout the life of a project, as well as discussing how the cumulative flood risk (integrated over the project life) can inform the

design process. The studies integrate tide and storm surge levels with probabilistic SLR projections using Monte Carlo Simulations. The studies also provide an example of how nonlinear effects between SLR and storm surge can be calculated and included in the estimation of future flood probabilities.

**BIO:** Jeffrey Oskamp has nine years of experience in coastal, marine, and ocean engineering, including planning, design, and analysis. He is experienced with numerical modeling, including coastal/offshore hydrodynamics, flood analysis/assessment, and vessel mooring/berthing analyses, as well as design of coastal features such as navigation channels, dredging, beach nourishment, living shorelines and shore protection structures. He has experience with various aspects of the design of port structures, including establishing design water levels and other metocean conditions, calculating mooring loads with dynamic mooring simulations, and designing fender systems. He is an active member of PIANC MarCom Working Group No. 211 to update the guidance for designing fender systems.

Jeffrey is knowledgeable about the current state of science for sea level rise, including methods for incorporating sea level rise into a probabilistic flood hazard analysis. He is a member of the ASCE COPRI Sea-Level Change Task Committee, contributing to the guidance for performing risk assessments.

## Study on the impact from surge events on the pier scour for coastal bridges

**Abstract:** Coastal bridges are vulnerable to storm surges, hurricane waves, or flood combined with surge events which commonly cause dramatic changes in flow condition within a short time period. This paper presents a case study on the impact from surge events on the pier scour for Lafayette Avenue Bridge over the Saginaw River in Michigan by using full scale 3-Dimensional (3-D) computational fluid dynamics (CFD) modeling. The bathymetry of the Saginaw River, which includes the area from 4 miles upstream of the Lafayette Avenue Bridge and extends to the Saginaw Bay, was created and processed based on the Digital Elevation Model (DEM) obtained from the United States Geological Survey (USGS) website and survey data at four locations along the river. Star-CCM+ was adopted to build the 3-D CFD models from the processed bathymetry. 36 years of water elevation time history at the estuary of the Saginaw River was obtained from the National Oceanic and Atmospheric Administration (NOAA) website. All surge events with a duration less than 48 hours were identified from the 36-year historical data. The most critical event was selected for the CFD simulation. The selected surge was combined with the 500-year flood event. The changes on the flow conditions near the bridge and the scour depth at the bridge pier were studied and compared to the scour analysis without surge consideration.

**BIO:** Dr. Chao Huang is the Lab Manager of Genex Systems, which provides support service to the FHWA's J. Sterling Jones Hydraulics Research Laboratory. Dr. Huang earned his Ph.D. degree from South China University of Technology in 2010, pursued post-doc research at SUNY Buffalo and joined the hydraulics lab in 2014. He specializes in the hydraulic performance research of highway infrastructures, including culverts, bridges and coastal highways. He also has a broad knowledge and experience in research of probabilistic analysis for bridge scour and risk assessment of bridges under extreme events.

## Scour Session

### Development of 3D CFD Modeling of Scour using Open Source OpenFOAM Software

**Abstract:** Argonne National Laboratory is working with the Turner-Fairbank Highway Research Center in developing methods of applying 3D computational fluid dynamics (CFD) on high performance computer clusters to scour modeling and scour risk assessment at bridge foundations during flood events. Significant progress has been made in the development of 3D transient scour simulation using the OpenFOAM open-source software for the 3D CFD analysis. Using multiphase 3D CFD with sediment entrainment, transport, and deposition models allows for the direct calculation of scour depth development from all causes, removing the need to apply HEC 18 equations to obtain scour depths from flood flow conditions. In the CFD scour simulation, the interrelations of the types of scour, general, contraction, pressure flow, and local, are accounted for automatically providing for more accurate scour assessments. Previous versions of this model use expensive commercial for the CFD computation. Use of open-source software for scour analysis allows its use by a large community of hydraulic engineers at low cost. To be practical for broad application to assessment of scour risk at full scale bridges, the scour model should be able to complete an analysis within a day to a week and it should be able to handle erosion at, around, and under complex 3D structures such as multiple groups of piers, pile caps, piles, etc. The changing geometry as scour and downstream sediment deposition develop is challenging because the riverbed boundaries of the model are constantly deforming based on the flow solution in complex ways that are not known in advance, requiring stretching and compressing of the computational mesh and frequent remeshing. While current CFD software can handle deforming meshes, such as flow and combustion in an engine cylinder with moving piston, it frequently fails when the mesh motion is complex and not uniform. An external software program developed by Argonne was designed to address the challenges of the changing bed geometry accounting for scour and sediment deposition. A second major challenge in the scour model is the disparate flow and erosion time scales. Time steps for the flow computation are on the order of milliseconds, while the scour erosion takes place over hours to days. Computing an entire scour event at the flow time scale would take many years and is therefore not practical. A method to bridge these greatly different time scales was developed, allowing a scour analysis to compete in most cases within a day to a few days. The CFD scour model calculation yields local erosion rates on river beds from the computed bed shear stress and turbulent kinetic energy. The bed erosion rates are then used in an external software program developed by Argonne to change the bed geometry to account for scour and sediment deposition. The presentation will include an overview of the major components and functions of the methodology and a number of examples of scour simulations with comparison to flume scour

experiments. 1Argonne National Laboratory's work was supported by the U.S. Department of Transportation under interagency agreement, through U.S. Department of Energy contract DE-AC02-06CH11357.

**BIO:** Dr. Hubert Ley (speaker) started at Argonne National Laboratory in 1991 as a nuclear engineer and has worked on the development and deployment of a wide variety of simulation codes. He became the director of Argonne's Transportation Research and Analysis Computing Center in 2010, and manages now a diverse group of scientists with expertise in Computational Fluid Dynamics, Computational Structural Mechanics, Nuclear Plant Diagnostics and Optimization, and Machine Learning Applications. He also operates the TRACC High Performance Computing user facility for USDOT, providing massive computing resources to various USDOT programs. With his experience in programming and simulation, he has led the development of the OpenFOAM pier scour code development for the past 3 years.

Dr. Steven Lottes (not attending) is a scientist at Argonne National Laboratory with 35 years of experience in Computational Fluid Dynamics (CFD) analysis of multiphase and reacting flows. He plans, coordinates, and conducts research on transportation applications and provides technical support to Argonne's user community. His primary work is developing advanced 3 dimensional theoretical and computational methods for analyzing storm and flood event impacts on transportation infrastructure. He has extensive experience in 3D modeling and analysis of problems in hydrology, drainage, culverts, bridge hydraulics, scour, and storm surge impacts.

## NCHRP Project 24-47; Revised Clear-Water and Live-Bed Contraction scour Analysis

**Abstract:** NCHRP Project 24-47 was completed with the publication of NCHRP Report 971 in 2021. This report documents the results of an investigation to develop live-bed and clear-water contraction scour equations suitable for use in risk-based bridge design encompassing a wide range of hydraulic conditions. The research approach included a fundamental re-analysis of the hydraulics of open-channel flow contractions, an evaluation of existing contraction scour equations with reference to available laboratory and field data, and extensive laboratory testing to develop more reliable data on clear-water and live-bed contraction scour. Computational modeling supplemented the results of laboratory testing. Suggested modifications to the existing contraction scour equations were developed. The report includes an application example and an evaluation of the reliability of the existing and recommended analysis approaches using the laboratory data base developed under this study. This study produced a contraction scour data base for live-bed and clear-water conditions using a comprehensive suite of instrumentation techniques not available to previous researchers in this field. The report introduces a new paradigm for contraction scour estimation by recognizing that the key location where the depth of contraction scour should be measured is in the vena-contracta region, i.e., the narrowest part of flow through the contraction entrance. Based on laboratory data a vena-contracta correction coefficient, Kv was defined and applied to both the existing HEC -18 equations and the contraction scour equations developed under NCHRP Project 24-20. Application of statistical reliability analysis techniques indicates that using upstream pre-scour hydraulic conditions as input, these revised equations produce reasonable and conservative estimates of equilibrium post-scour contraction scour flow depth. The NCHRP 24-20 contraction scour equations produce less variability and are more conservative than the equations derived directly from HEC-18. Revisions to the existing clear-water and live-bed contraction scour equations based on the Kv correction factor are recommended for use when estimating contraction scour in channels whose beds are formed of relatively uniform, non-cohesive sediment with a width to depth ratio and entrance conditions comparable to those used in this study. In general, these conditions apply to bridges classified as "hydraulically narrow" by FHWA in the National Bridge Inventory (NBI). Bridges in this category constitute about one-third of the approximately 600,00 bridges in the NBI.

**BIOs:** William M. deRosset, PE. Will deRosset is a senior Hydraulic Engineer with Ayres Associates, and co-author of the 24-47 contraction scour study. His primary contribution to the effort was in the risk and reliability evaluation to support quantitative conclusions concerning the improvements to contraction scour evaluation methods developed by this study.

Peter F. Lagasse, PhD, PE. Pete Lagasse is a senior Hydraulic Engineer with Ayres Associates. Since 1995 he has served as principal Investigator or Co-Principal Investigator for eight national Cooperative highway Research program projects on a wide variety of bridge scour and stream stability projects. Most recently he was PI for a project to investigate improvements to the existing contraction scour analysis procedures.

## Clearing the Hurdles on Clear Creek: Utilizing SRH-2D for Emergency Scour Countermeasure Design and Sediment Transport

**Abstract:** Clear Creek is located in western-central Mississippi, just east of Vicksburg. The area of interest for this presentation is the Interstate 20 crossing of Clear Creek. In March of 2019, Clear Creek had started to laterally migrate into the right bank just upstream of the bridge crossing. By November of 2019, the creek had critically eroded the right bank, partially exposing a bridge debris deflector and several bridge piles. By April of 2020, almost all affected piles had been completely exposed. In February of 2021, the creek had started bypassing the main span with significant flow splitting which impacted a downstream bridge crossing as well. At the request of Mississippi Department of Transportation (MDOT), HDR has developed an emergency scour countermeasure plan in two phases: Phase-I to design robust emergency countermeasures which could be placed immediately within the existing right-of-way; and Phase-II consisting of a more resilient, long-term mitigation, including the purchase of more right-of-way. This presentation demonstrates HDR's comprehensive approach to both Phase-I and Phase-II scour mitigation, evaluating multiple options including revetment structures, rock riprap, and using two-dimensional hydrodynamics with sediment transport

modeling (SRH-2D) to prevent catastrophic failure of this highly traveled structure. The presentation also covers history of the area and the mixture of significant events which led to the mass wasting of the banks such as increased rainfall, human activity in the overbanks, and geologic soil types of the area.

**BIO:** Don is a Hydraulic and Coastal Engineer with HDR where his expertise lies in hydrodynamic numerical modeling technologies to design and analyze hydrology and hydraulic structures in both the riverine and coastal environments.. His experience includes analysis of existing countermeasures, designing replacement and new countermeasures, scour analysis of new and existing hydraulic structures, modeling moving vessel effects and storm surge modeling. He is currently the Secretary/Treasurer for the Mississippi Engineering Society, the NSPE Delegate for the State of Mississippi, and the is the Vice-President of the board for Friends of the Mississippi River Basin Model. He is a regular volunteer for MATHCOUNTS, an active member in ASCE, coach's soccer, and makes a lot of puns whenever he has an opening. He is a life-long Mississippian, who has been married for 18 years and has 4 wonderful children.

Dr. Dragoslav (Dragi) Stefanovic brings more than 30 years of experience in water resources engineering for a wide range of clients, particularly the U.S. Army Corps of Engineers (USACE). His primary area of technical expertise involves the integration of surface-water hydrology, multi-dimensional hydraulic and sediment-transport modeling, and river mechanics with fluvial geomorphology to solve flooding, sedimentation, river stability, and scour/erosion mitigation problems. Dr. Stefanovic received the Straub Award from the St. Anthony Falls Hydraulic Laboratory for his doctoral thesis in hydraulic engineering and was honored as Diplomate by the American Academy of Water Resources Engineers. He has also served as one of the lead instructors for nation-wide hydraulic and sediment transport courses related to bridge design, scour, and bank erosion (Basic and Advanced HEC-RAS) presented by the American Society of Civil Engineers (ASCE).

## Scour Risk Prioritization for SC Bridges

**Abstract:** The South Carolina Department of Transportation (SCDOT) has been working to properly document scour and foundation risks for its inventory of approximately 8,000 bridges over waterways. Given the amount of work involved in this effort, SCDOT has hired a team of consultants to help execute the work. One of the first tasks undertaken to start the process was a risk prioritization that would help identify the most critical bridges for evaluation, and that could help prioritize future efforts to reduce risks. CDM Smith led a team of experienced engineers and experts to prepare the risk analysis framework, evaluate each risk terms, assign the risk factor scores, and classify the priority class per the analyzed total risk score for each bridge. Scour related risk-based prioritization of South Carolina bridges was conducted in general accordance with Federal Highway Administration (FHWA) guidance (FHWA-HRT-15-081, May 2016), and based on the conventional definition of risk in the following general form (Moon et al. 2009): Risk = Hazard * Fragility * Consequence The total risk is defined as the combined effect of the hazard (initiating event), fragility

(resistance against scour and structural integrity of the bridge, also termed resistance), and consequence (potential damage resulting from scour caused by the initiating event) risk factors. Because risk was represented numerically, a greater total risk score in comparison to other bridges establishes the bridge with the greatest comparative risk. This presentation will provide a real-world example of implementation of a risk-based strategy for prioritization that includes the Moon method and the Delphi technique. The method setup, risk factor selection, risk factor scoring, risk term weighting and prioritization results will be presented. Additional uses for the prioritization and future applications will also be discussed.

**BIOs:** Dr. Hui-Ming "Max" Shih (PhD, PE, CFM) serves as a senior water resources engineer in CDM Smith's Denver office. He has more than 25 years of global project experience in the United States, and many countries worldwide. Dr. Shih has served as a Project Manager and Technical Lead for surface water, urban drainage, hydrology and hydraulics, bridge scour and protection, and channel sediment transport projects.

Daniel Johnson (PE) is a water resources engineer with CDM Smith in Columbia, South Carolina. He has 5 years of engineering experience in flood hydrology, transportation hydraulics, water resources, dam safety, and GIS modeling. Mr. Johnson serves as a task manager and master data chief for the Scour Critical Assessment and Management Project.

## Stormwater Management

### Approaches for assessing flows, concentrations, and loads of highway and urban runoff and receiving-stream stormwater with the Stochastic Empirical Loading and Dilution Model (SELDM)

**Abstract:** The Stochastic Empirical Loading and Dilution Model (SELDM) was designed to help quantify the risk of adverse effects of runoff on receiving waters, the potential need for mitigation measures, and the potential effectiveness of such management measures for reducing these risks. SELDM is calibrated using representative hydrological and water-quality input statistics. All water-quality models need input data to ensure that simulation results represent conditions at a site of interest. However, available data are scarce in comparison to the number of potential sites of interests. For example, there are about 48,000 road-stream crossings in southern New England and only about 45 long-term precipitation stations, 385 streamflow gaging stations, 69 stream-quality monitoring stations, and 19 highway runoff monitoring sites in this area. One alternative, collecting data at a site of interest is resource intensive and requires years or months to provide representative results. Furthermore, data collected to assess potential effects of runoff at a site of interest may not represent conditions after highway construction or improvement projects. Therefore, robust methods are needed to develop precipitation, flow, and water-quality statistics representing conditions at unmonitored sites of interest. Therefore the U.S. Geological Survey, in cooperation with the Federal Highway

Administrations and the Connecticut, Massachusetts, and Rhode Island Departments of Transportation, compiled data and statistics representative of conditions in southern New England and performed a series of sensitivity analyses to identify which variables had the greatest effects on simulation results. These analyses indicate that the highway and urban runoff quality and upstream water-quality statistics vary considerably from site to site and have the greatest effect on simulated results. Hydrologically, prestorm streamflow with and without zero flows are the most sensitive and therefore the most important hydrologic variables to quantify. Results of analyses also are sensitive to statistics used for simulating structural best management practices. Compared to other hydrologic and water-quality variables, results of the analyses were not sensitive to variations in precipitation statistics found in southern New England. Results indicate that exact specification of highway drainage system geometry is not crucial for event-based water-quality analyses. Examples evaluating the potential effectiveness of end-of-pipe treatment indicate that off-site treatment is warranted in developed areas and land conservation may be an effective mitigation strategy. All these results are consistent with conclusions from simulation and monitoring studies in the literature.

**BIO:** Gregory Granato is a hydrologist with the U.S. Geological Survey. He has worked with the Federal Highway Administration to develop the FHWA Stochastic Empirical Loading and Dilution Model known as SELDM and on many related issues including deicing chemical issues, streamflow statistics, runoff quality, BMP performance, and the highway runoff database. Gregory has worked with seven State DOTs on stormwater issues including California, Connecticut, Massachusetts, Nevada, North Carolina, Oregon, and Rhode Island and has provided information and training to many more State DOTs. He is author or coauthor of more than 50 technical reports, has served on 5 NCHRP research panels, and is serving on the TRB committee on hydrology, hydraulics and stormwater.

## A decision-support tool to assess the impacts of highway runoff in North Carolina using SELDM

**Abstract:** The North Carolina Department of Transportation (NCDOT) needs an efficient method to assess potential adverse effects of highway runoff on receiving waters to optimize stormwater-treatment decisions. The NCDOT, in cooperation with the U.S. Geological Survey (USGS), developed a decision-support tool based on the North Carolina version of the USGS Stochastic Empirical Loading and Dilution Model (SELDM). This tool is designed to identify potential adverse effects of highway runoff by using a criterion based on a measurable change in water quality from a surrogate pollutant (suspended sediment). Design engineers can use this decision-support tool to establish stormwater treatment goals for the project without having to learn SELDM or interpret its statistical output. The decision-support tool is an excel workbook that requires input values for various upstream basin properties (drainage area, ecoregion, etc.) and highway preliminary design specifications (length, width, etc.). The tool then generates one of three alternative stormwater treatment

goals for the project: direct discharge, basic BMP treatment, or advanced BMP treatment. NCDOT's policy is for the minimum treatment goal to include basic BMP treatments whenever possible, but direct discharge is included to demonstrate when untreated highway runoff is expected to have minimal impact to a receiving water body. The NC SELDM decision-support tool is a practice-ready method that can be adapted and modified by other DOTs and municipal permittees to quickly establish preliminary stormwater treatment goals.

**BIO:** Dr. Charlie Stillwell is a hydrologist with the U.S. Geological Survey who studies urban hydrology, stormwater management, and hydrologic alteration. He specializes in data science and employs various statistical modeling and machine learning approaches. Learn more about Charlie's work here: https://www.usgs.gov/staff-profiles/charles-stillwell.

## Coastal Strategies for Drainage Resilience and Permitting in Florida

**Abstract:** Although Florida has always been vulnerable to coastal flooding associated with tropical systems, new strategies and guidance is needed to address Sea Level Rise (SLR) and other types of nuisance flooding impacting coastal areas throughout the State. The presenter has been involved with several Peer Exchange Workshops, hosted by the Federal Highway Administration (FHWA) to discuss all types of coastal concerns, as well as identify innovative strategies to better adapt to these events. As a result of these Workshops, additional coordination has been initiated with various local municipalities, several Water Management Districts (WMDs) and with the Florida Department of Environmental Protection (FDEP) to gain more insight into their efforts related to overcoming recurring coastal flooding issues and the strategic measures needed to improve water quality to inlets, bays and estuaries Likewise, there are numerous regulatory hurdles that must be addressed to ensure regional projects satisfy the environmental permitting constraints related to sovereign submerged lands and critical species habitat. Due to the competing interests amongst the various Stakeholders within the coastal watershed, additional planning and coordination is critical in identifying solutions that are tailored to specifically protect and preserve communities and critical infra-structure given the site-specific environmental conditions involving the particular coastal region in Florida.

**BIO:** Carl Spirio's (PE) general experience is in watershed hydrology and hydraulics, integrated watershed resource planning, stormwater management and conveyance system design, environmental permitting, and coastal planning. His career spans more than 34 years, 18-years with FDOT and 16-years in the Private sector. While working for FDOT, Carl served as both the District 1 Drainage Engineer and State Drainage Engineer overseeing the drainage and permitting efforts throughout Florida. Due to the everchanging environmental permitting regulations in Florida, he has spent a considerable amount of time working with various State, Federal and Local permitting agencies addressing water quality criteria, establishing tmdls, developing Basin

Management Action Plans (BMAPs), and floodplain mitigation. Carl currently serves as a Consultant Board Member through the Florida Stormwater Association. Similarly, he previously served on the AASHTO Technical Committee on Hydrology and Hydraulics and other National Committees.

### Full Spectrum Stormwater Systems Asset Management at MDOT SHA

**Abstract:** MDOT SHA owns over 8,400 active stormwater management facilities (SWMFACs), approximately 9 million linear feet of pipe and 19 larger scale dams across the State of Maryland and is responsible for maintaining the functionality of each within this overall Stormwater System of assets. To comply with the NPDES MS4 permit and maintain safety and functionality a Stormwater Systems Asset Management program has existed for many years at MDOT. Within the program there are several exciting areas of work that can be discussed in detail or in general at the conference to share how we approach development of a compete inventory of drainage and stormwater assets as well as the functionality assessment to implemented lifecycle approach. A brief list of some activities is included below and can be done in any combination or length of presentation.

**BIO:** Kiona Leah is a Professionally Licensed engineer who graduated from Rensselaer Polytechnic Institute in Troy NY with a B.S. in Environmental Engineering. She moved from her native home in NY to MD the winter after graduation. She worked in private consulting for 10 years. She moved into serving the public sector as a Transportation Design Engineer for the Maryland Department of Transportation State Highway Administration in 2011. In the Highway Hydraulics Division, she enjoyed working on a variety of projects from simple two bioswale projects to large corridors that cover multiple jurisdictions. Her design accomplishments include an award for partnering from the Maryland Quality Initiative as part of the team that worked on the largest drainage retrofit project the Division had funded to date. In 2015 she was promoted to the Stormwater Systems Assets Manager and has worked diligently expanding and modernizing the program as the number of facilities grew from barely 3,000 to near 8,500. She has found the work rewarding and invigorating in a new and exciting way. She works with her team to increase communication and collaboration among IT, planning and maintenance staff on many activities for compliance with the agency environmental permits. Her vision is to fully integrate the program aspects of organization, design and technology to track and maintain facilities and networks that lead to cleaner waterways and enhance the environment for all. Her accomplishments and vision are recognized on national levels with a grant for the State Transportation Innovation Council to spearhead development of a document management system that will integrate across platforms to best inform operations and maintenance work on the stormwater facilities she tracks.

## Resilient Design

### Incorporating Climate Change and Policy for Highway Infrastructure Design

**Abstract:** The procedures for incorporating climate change in the design of DOT infrastructure is outlined in NCHRP Project 15-61, "Applying Climate Change Information to Hydrologic and Coastal Design of Transportation Infrastructure," March 22, 2019. The publication provides practical tools to account for climate change in hydrologic design and coastal applications and when such changes are not warranted for a project of a particular type or scale. This presentation is a case study for the replacement of dual bridges over the South Skunk River along U.S. 30 near Ames, Iowa. The location of the project along with the criticality of the highway warranted the assessment of climate change on future peak discharges. The presentation will discuss utilizing the Index Flood Method for incorporating climate change with information specifically developed for Iowa regarding the rainfall ratios and hydrologic modeling of the basin. As a result of incorporating climate change for this site, the presentation will discuss the additional conveyance needed for the project (triple RCB), an "extensible design" approach that could be incorporated for the site in the future and the policy guidance that resulted from decisions made for this project.

**BIO:** Dave Claman has over 38 years of experience in the water resource engineering field. Dave was the supervisor for the Preliminary Bridge Section of the Iowa Department of Transportation's Bridges & Structures Bureau for 26 years. Prior to working for the Iowa DOT, Dave worked for the Iowa Department of Natural Resources where he was responsible for the administration and enforcement of the State's floodplain management regulations.

Dave has been involved in many research projects on the local, state and national level regarding climate change, flood mitigation, culvert sedimentation and bridge scour and is currently a hydraulic engineer for the FHWA Resource Center.

## Nonstationarity in flood frequency in the midwestern United States

**Abstract:** Estimates of peak-flow frequencies are crucial in various water-resources management applications, including floodplain management and the design of critical structures. Federal guidelines for peak-flow frequency analyses, provided in Bulletin 17C, assume that neither the statistical properties of the hydrologic processes driving variability in peak flows nor the frequency distribution of annual peak flows changes with time, that is, they are stationary. However, better understanding of long-term climatic persistence and increased focus on the effects of climate and land-use changes have caused the assumption of stationarity to be reexamined. To that end, the U.S. Geological Survey, in collaboration with the Federal Highway Administration and state agencies in each state, has begun a multi-year study to evaluate the effects of changes in climate and land-use trends on flood-frequency distributions across nine states in the midwestern United States. In the first phase of the study, trends, change points, and autocorrelations of peak flows and climate metrics are being determined, and the relation of changes in peak flows to those in climate are being analyzed. Changes in peak flows from unregulated U.S. Geological Survey streamgages, in the climate, and in

modeled streamflow were evaluated over 30-, 50-, 75-, and 100-year periods ending in water year 2020. In subsequent phases of the study, the seasonality of peak flows, the effects of urbanization and of tile drainage on peak flows, and methods for incorporating nonstationarity in flood-frequency estimates will be investigated. An overview of the study and its components will be presented, along with results from preliminary analyses of changes in peak flows and related hydroclimatic variables.

**BIO:** Thomas (Tom) Over, Ph.D., P.E., is a Research Hydrologist with the USGS Central Midwest Water Science Center, in the Urbana, Illinois, office. Tom has worked in this Center (formerly the Illinois Water Science Center) since 2001. He is currently leading or assisting in projects investigating methods for the prediction of peak and continuous streamflow in ungaged basins, determining the uncertainty of measured and modeled streamflows, and estimating the effects of climate variation and urbanization on peak streamflows. Immediately prior to his appointment with the USGS he was a professor of civil engineering, and he began his career as a consulting civil engineer in California, helping to develop the first FEMA flood insurance rate maps for San Diego County among other projects.

## Updated One-year Coastal Flood Elevation as a Threshold of Coastal Flooding

**Abstract:** Sea level rise (SLR) causes nuisance and other minor coastal floods to be more frequent and more damaging. Low lying coastal roadways are experiencing more and longer inundations and loss of functions. Flood risk management requires a knowledge of the probability of occurrence for these flood events. Common coastal minor flood elevation indexes such as the Mean Higher High Water (MHHW), High Tide Flooding (HTF), and King-tide lack a well-defined probability of occurrence. In contrast, the 1-year coastal flood elevation ($WSE_{99\%}$) is the flood elevation with an annual exceedance probability of approximately 99%. It can serve as the annual flood elevation threshold above which there will be potentially damaging floods. The difference between 50-year and 1-year water levels has been linked to how severe SLR can cause high frequency events to occur. For many coastal locations in U.S. this difference has been observed to be less than 1.64’ and so, tomorrow’s 1-year event could become as big as today’s 50-year event. Other useful applications of the $WSE_{99\%}$ include benefit-cost analysis of coastal flood hazard mitigation and setting the tailwater condition for stormwater outlets to the sea.

The flood elevation chart included in each NOAA coastal station’s website gives the 2001 value for $WSE_{99\%}$. The 2018 values for all flood levels in these charts were simply approximated by adding the SLR depth to all flood levels. This study updates the $WSE_{99\%}$ and the extreme coastal flood elevations for all 112 NOAA stations from the mid-point of the National Tidal Datum Epoch 1983-2001 to year 2021 using SLR trends integrated into the probability distribution of flood elevations at each station. However, there is no viable method to extend the station $WSE_{99\%}$ to other locations. While extreme coastal flood levels (e.g. 100-year) are available from FEMA flood insurance maps or other sources for many locations, $WSE_{99\%}$ is generally not available for the

same locations. This study investigates the correlation between $WSE_{99\%}$ and extreme flood elevations. A strong correlation between the two would allow estimating the $WSE_{99\%}$ for locations with known extreme flood elevations.

The updated values of $WSE_{99\%}$ and the extreme flood elevations for all NOAA stations were used to find equations to predict $WSE_{99\%}$ for three NOAA regions. The following summarizes the results for each region:

Northern Pacific Stations: using all stations in this region, a strong correlation was found between the 1-year and the 100-year WSE. A regression equation was developed allowing reliable prediction of $WSE_{99\%}$ using the known 100-year coastal flood elevation anywhere in this region.

Northern Atlantic Stations: using all stations in this region, a relatively strong correlation was found between the 1-year and the 10-year WSE. A regression equation was developed allowing prediction of $WSE_{99\%}$ using the known 10-year coastal flood elevation anywhere in this region.

Tropical & Gulf of Mexico Stations: no acceptable equations were found using all stations. Separate equations were developed for specific areas such as Hawaii and the East and the South coasts of Florida.

**BIO:** Dr. Kaveh Zomorodi is a Principal Engineer and a Senior Hydrologist at the Dewberry Companies. He received a Ph.D. in Civil and Environmental Engineering (Hydrology and Water Resources) from Utah State University in 1988. He has over 34 years of work experience in academic and consulting engineering work dealing with surface water, groundwater and water resources planning and management. Dr. Zomorodi has published or presented over 60 technical papers in various journals and conference proceedings and numerous R&D and project reports. His work has led to the development of new simplified approaches to several flood hazard analysis problems including frequency analysis of flood damage data and evaluation of average annual number of floods for evaluation of cost-effectiveness of flood mitigation projects. Dr. Zomorodi is the primary author of the computational procedures of the 2014 Federal Transit Administration HMCE tool and its Coastal Flooding Recurrence Interval Estimator which is used to assess cost-effectiveness of resiliency projects in areas impacted by super-storm Sandy. Recently, he has developed the equivalent risk method for integrating the impact of sea level rise in design coastal flood elevations. Other technology developments by Dr. Zomorodi include new methodology and equations for estimating design peak discharges impacted by climate change, post-fire peak flow rates, groundwater mounding, modified sheet flow travel time and prediction of levee breach geometry and probabilistic flood analysis.

## An investigation into future rainfall extremes within North Carolina for state transportation needs

**Abstract:** The North Carolina Department of Transportation is considering the best ways to adapt to climate change given a general knowledge that rainfall extremes will increase as the climate warms. Building a resilient highway system would benefit from a better understanding of how future rainfall extremes may change; however, this is a challenging applied climate problem because the data that supports relevant decisions have known limitations, such as the treatment of extreme rainfall associated with future hurricanes. Additionally, there are multiple methods that downscale the Global Climate Model (GCM) projections, including numerous statistical and dynamical datasets. Confidence increases for decisions when the regional to local changes in extreme rainfall are similar using different methods and considers additional methods/experiments that address known limitations. Here we show preliminary findings for several aspects of this study. The first is atmospheric numerical model experiments designed to circumvent known weaknesses related to rainfall extremes associated with future hurricanes. These experiments simulate a historical hurricane that created significant problems for NC DOT, here Hurricane Matthew in 2016 with localized precipitation amounts of 18.95 inches, and how Hurricane Matthew responds to future changes such as increases in the atmospheric moisture capacity and warmer sea surface temperatures. The simulations reveal localized rainfall totals may increase by as much as 150% for an end-century high greenhouse gas emission scenario. This study also calculates relative changes, scale factors, for daily (24hr) Intensity, Duration, Frequency (IDF) curves for the same period and greenhouse gas emission scenario using different statistical and dynamical downscaled projections. Preliminary analysis reveals that scaling the IDF curves may be more sensitive to the downscaling method than the GCM projections.

**BIO:** Dr. Jared Bowden is a Senior Research Scholar at North Carolina State University in Raleigh, NC. His expertise is the application of numerical weather and regional climate models, and has developed downscaled climate change projections using regional climate models for the Contiguous United States, US Caribbean, and Africa. His research has been used to inform many downstream climate change applications including ecology, air quality, and hydrology. His work has been used to help inform several US Global Change Research Program reports including the 4th National Climate Assessment and The Impacts of Climate Change on Human Health. Part of his ongoing research emphasizes characterizing uncertainty in changing precipitation regimes for air quality, ecological, and hydrological applications. Dr. Bowden is currently participating in the 5th National Climate Assessment.

## Watershed Modeling

### Two-dimensional Watershed Modeling with SRH-2D

**Abstract:** A new watershed module has been developed into the existing hydraulic model SRH-2D. This research and development effort makes SRH-2D a truly hydrological and hydraulic (H&H) model – resulting in a single unified model for a wide range of H&H applications. An immediate benefit to current SRH-2D users is that the same modeling process/step for river hydraulic modeling may now be adopted for watershed hydrological modeling without a steep learning curve.

In this talk, the theory and model structure are presented concerning the new watershed module; focus is on the new and salient features, as well as the difference from the river hydraulic solver. A field case is used to illustrate the typical input data required for watershed modeling. Application cases are presented to highlight various modeling performance such as accuracy, stability, calibration and challenges.

**BIO:** Yong Lai is a specialist hydraulic engineer at the Technical Service Center, U.S. Bureau of Reclamation, Denver, Colorado. Dr. Lai obtained his Ph.D. in 1990 and has since been involved in a wide range of research, development and engineering projects. His professional career includes working for a consulting company, a research institute, the University of Iowa, and the federal government. Dr. Lai has published more than 60 scientific journal papers in diverse engineering disciplines. He is the lead developer of SRH-2D, as well as the 3D CFD model U2RANS. Dr. Lai currently serves as an associate editor of the ASCE Journal of Hydraulic Engineering and a member of the Scientific Advisory Board for several conferences.

## Assessing the state of the practice of hydrologic modeling in the context of roadway design

**Abstract:** Hydrologic modeling tools can be applied in transportation engineering to provide insights and design guidance to manage water-related stressors such as flooding and stormwater runoff. These tools are applicable in the context of roadway design to improve their resiliency against ware-related stressors. Distributed rainfall-runoff models (DRRMs) are hydrologic models that represent a range of watershed processes using rainfall data as input. DRRMs divide watersheds into smaller elements (e.g., grid cells, sub-catchments, hydrological response units), and hydrologic processes are calculated for each of these smaller elements. This work summarizes the findings of an NCHRP-sponsored synthesis to assess the state of practice of hydrologic modeling within state transportation agencies, focusing on DRRMs. A review of published design guidelines, questionnaire responses, and follow-up interviews have enabled a better understanding of the models currently being used across the US. Data analysis on the gathered information indicated the most common applications of DRRMs in the context of roadway analysis and design. Some applications included the design of drainage structures and the management of stormwater runoff quantity and quality. Other applications included the assessment of the roadway infrastructure exposed to stressors such as flooding, scouring, aggradation. In some cases, DRRMs were used along with hydraulic modeling tools to achieve the study or design goals. Despite the wide range of DRRMs applications, only 31% of the state transportation agencies reported that these tools are commonly adopted. This presentation also discusses some of these

barriers and presents conclusions and suggestions that could lead to broader adoption of DRRMs in roadway infrastructure design.

**BIO:** Dr. Xing Fang is the co-PI for NCHRP synthesis project 5311 "Resilient design with distributed rainfall-runoff modeling". He is Arthur H. Feagin Chair professor in civil engineering at Auburn University since 2014 and worked at Auburn since 2007. He was a faculty in the Department of Civil and Environmental Engineering at Lamar University, Texas for 12 years from 1995. He is an accomplished researcher in the areas of surface hydrology, hydraulic analysis and modeling. Dr. Fang has worked on 22 funded projects related to hydrology and hydraulics from three DOTs (Texas, Alabama, and Iowa) as leading PI or Co-PI. He also worked on other 32 funded projects from various funding agencies. He has published 126 journal papers and authored 62 project reports for funding agencies. He served as an Associate Editor in surface hydrology for the Journal of the American Water Resources Association and Hydrological Science Journal.

## Watershed Approach to Mitigating Hydrologic Impacts of Highway Projects

**Abstract:** This presentation describes the multi-disciplinary approach for development of a watershed based approach for mitigating stormwater quantity impacts off-site elsewhere in the watershed. This research and development effort is part of the National Cooperative Highway Research Program dedicated to applied research (Project NCHRP 25-60). The objectives of the project were to: "Develop guidance for state DOTs for developing and implementing watershed-based strategies and techniques for mitigating hydrologic impacts of transportation facilities." This research is focused on meeting needs and constraints of state DOTs facing increasing stringent requirements for stormwater quantity and quality while looking for opportunities to collaborate with regulatory agencies, stakeholders, and other potential collaborators for solutions where the whole is greater than the sum of its parts. the intended result of the research is guidance on how to: • Identify opportunities in a watershed to conserve, restore, enhance, or create landscape features for hydrologic mitigation. • Plan, site, and design features for hydrologic mitigation. • Quantify the hydrologic outcomes from selected features. • Develop strategies for implementing a watershed-based approach to hydrologic mitigation. Information on the rationale for using a watershed-level approach is important background and contextual information that will be provided. This context will provide important incentives and justification for state DOTs to test and apply the concepts and approaches developed in this research. This research builds on previous and ongoing NCHRP research efforts addressed primarily to water quality issues. The project developed screening and detailed analysis tools and methods for assessing the hydrologic and co-benefits of "out-of-kind" off-site mitigation measures. While not limited to out-of-kind off site mitigation, the research focused on landscape measures including stream restoration, wetlands creation/restoration, forest creation/restoration, and uplands creation/restoration. The role and benefits of collaborating stakeholders is also emphasized.

**BIO:** Roger Kilgore (Kilgore Consulting and Management) is a Professional Engineer and board certified in water resources engineering. Based in Denver Colorado he has over 30 years of experience in hydrology and hydraulics, stormwater management, water quality, and flood mitigation. He has written several design manuals for the Federal Highway Administration including Highways in the River Environment - Floodplains, Extreme Events, Risk, and Resilience (HEC-17) and Highway Hydrology (HDS-2). He also served as the Principal Investigator of NCHRP 15-61 “Applying Climate Change Information to Hydrologic and Hydraulic Design of Transportation Infrastructure” and NCHRP 25-60 “Watershed Approach to Mitigating Hydrologic Impacts of Transportation Projects.”

## Missouri River Modeling for Resiliency

**Abstract:** In March 2019, widespread flooding impacted western Iowa, greatly exceeding the Missouri River levee system’s design capacity, resulting in 51 breaches, levee and roadway overtopping including I-680 and I-29, and significant flooding. Ultimately, system failure resulted in nearly 60,000 acres of flooding. During the event, the Iowa Department of Transportation asked HDR to develop a model of the flooding to assist with operational questions. HDR developed a 2D model extending along the Missouri River from near Blair, NE to just downstream of Hamburg, IA (about 110 River Miles). The model included 21 breaches, 150 culverts, and thousands of roadway miles used as breaklines. As breaches were repaired and the water receded, HDR updated the model to reflect changing conditions. In the following months, subsets of the model were used to evaluate and inform designs for resiliency measures along the corridor including evaluation of new levees, roadway armoring with Flexamat, new culverts, and elevating roadways. In addition to the 2D modeling, CFD models informed the location and designs of the Flexamat roadway armoring. Some resiliency options have been completed, others are in planning or construction, and others will not be pursued at this time.

**BIOs:** Rusty Jones (PE, HDR) worked for HDR for about 10 years and recently joined the BMT Group. He has over 20 years of experience with 2D modeling. At HDR, Rusty worked on a variety of models in TUFLOW, SRH-2D, HEC-RAS, and others. He especially enjoys working on large but detailed combined 1D and 2D models. Some of these models have included a wide variety of structures including operational controls, levee breaches and repairs, custom post-processing using python, and models simulating durations up to 10 months. In addition to high-end modeling, Rusty enjoys automating work flows and solving problems using python.

Andy McCoy (PhD, PE, HDR) is a senior water resources engineer with 23 years of experience using computational hydraulics to complete complex evaluations involving flood inundation, river hydraulics, transportation facilities, channel restoration, channel stability, fish-passage facilities, water/wastewater facilities and habitat suitability. He has created simulations to support infrastructure design, demonstrate regulatory compliance, and for decision support.

Iris Brenner has worked at HDR for three years as a Water Resources EIT. Her Master's degree is from the University of Iowa where she did her thesis work studying the effect of storm transposition on flood volume using the 2008 flood of Cedar Rapids, Iowa. She began work at HDR during the early aftermath of the 2019 Missouri River flood and has since participated in the modeling efforts for many Tuflow projects to improve flood resiliency along the Missouri River in western Iowa.

## AOP/ Water Quality Modeling

### Update on Monitoring Protocol for Assessing Aquatic Organism Passage at Water Crossings

**Abstract:** At the 2020 NHEC, the project team presented on the initial development (Phase I) of an aquatic organism passage (AOP)success monitoring protocol. This presentation will provide an update on the new technologies, lessons learned, and updated data collection findings as the project has progressed. AOP water crossing design is an evolving field that combines the built environment with the natural world to produce resilient infrastructure while also providing environmental benefits, specifically related to the passage of fish. The design and construction of AOP water crossings is gaining popularity across the US, as environmental agencies, tribal entities, and infrastructure owners seek improved approaches to road-stream crossing designs. Providing effective AOP at water crossings represents a significant investment and management priority for various agencies across the country. As billions of additional dollars are made available to replace our aging infrastructure, monitoring the effectiveness and sustainability of water crossings over time becomes increasingly more important in ensuring passage goals are achieved and maintained. With design approaches varying across the world, a consistent protocol for monitoring and assessment of performance data becomes essential in helping environmental agencies, infrastructure owners, and tribal entities understand failures and successes. This information can then be used to develop effective guidance on varied design or maintenance approaches across unique habitats and geomorphic conditions nationally. Recognizing the implications of various design approaches, lack of performance data and need for a standardized monitoring protocol, the Western Federal Lands Highway Division (WFLHD) team, with support of WSP and Natural Waters, conducted a two phase research study focused on assessing AOP water crossing design and preservation best practices. Phase 1 (completed in 2019) involved development of a multi-stage monitoring protocol focused on assessing constructed AOP water crossings using a data driven success criteria that can be applied to all types of AOP crossings, across varying regions with different hydrology, geomorphology and species of interests. Phase 2 (on-going) has involved further refinement to the protocol, the development of a mobile application for data collection and collection of field data from a larger statistically significant number of sites across the country. The protocol was field tested in Alaska, California, Georgia, North Carolina, Maine, Minnesota, Oregon, Vermont, Washington and Wisconsin. The project team envisions the results of the research study to be

utilized nationwide for improving AOP water crossing design and preservation best practices. Our updated presentation focuses on new lessons learned as the project has progressed, common observations of AOP water crossings across the states visited, feedback from state DOTs and permitting agencies, other beneficial applications of the protocol, and database challenges. The presentation will conclude with discussions on next steps, including but not limited to, integration of advanced geomorphic and biological assessment protocols, long-term research goals, and opportunities for partner agencies to become involved in the project.

**BIOs:** Justin Lennon is a Vice President and Technical Fellow with WSP USA's Water National Business Line. He specializes in river engineering, complex hydraulics, aquatic organism passage, stream & ecosystem restoration design, and climate change adaptation. He has been supporting the Western Federal Lands program on aquatic organism passage research for the past four years.

Casey Kramer, PE, has over 20 years of experience working in both the public and private sectors in the fields of hydrology, hydraulics, river engineering, and fish passage while specializing in hydraulic design of transportation infrastructure. Casey has been involved with over 400 water and transportation projects and has a thorough understanding of project delivery of hydraulics and restoration projects. Casey was formerly the State Hydraulic Engineer for the Washington State Department of Transportation where he also served as a member of the AASHTO TCHH.

## Bedform Evolution and Bank Importance in Aquatic Organism Passage (AOP) Culverts

**Abstract:** Aquatic Organism Passage (AOP) culverts are increasingly becoming a priority for state and federal agencies to meet Clean Water and Endangered Species Act mandates. Current culvert design methods utilize constructed interior banks, or extensive fixed structures that necessitate larger span culverts, with the goal of achieving stream simulation. Field observations of culverts installed using these design methods found that often banks are washed out after a few regular flood events, contributing to a plane bed morphology and shallow expanded flow condition in the structure, as compared to the natural stream. These conditions lead to a decline in the quality and effectiveness of aquatic organism passage within structures. Similarly, rigid structures, such as rock weirs often used as grade controls, were observed to transform into potential barriers to passage, due to jump height, as bedforms naturally evolve around large rigid features. FHWA is studying how constructed interior banks, culvert walls, and bedforms affect the flow and transport of streambed material, and their subsequent influence on AOP. Western Federal Lands Highway Division (WFLHD) and Turner-Fairbank Highway Research Center (TFHRC) Hydraulics Laboratory have designed and fabricated an experimental culvert flume to demonstrate the evolution of bedforms inside culverts and the effect of constructed interior banks and rigid features on the effectiveness of aquatic organism passage. The culvert flume design will incorporate adjustable culvert walls to study varying design methods, from bankfull to twice

the bankfull width, consistent with current design practice. Ongoing laboratory physical studies will use typical streambed gradation, extreme bimodal gradation, and uniform gradation. Constructed interior features will include banks, no banks, rock wiers, and no rock weirs. Flow conditions will range, from low flow, through bankfull, up to 75% of maximum culvert capacity. Bedforms that evolve from culvert flume experiments will be laser scanned for Computational Fluid Dynamics (CFD) modeling and analysis. Numerical model analysis will study how flow is distributed around bed features, banks, and culverts, along with wall shear stress, turbulence, and flow velocity variations within bedforms. Surface particle image velocimetry (SPIV) will be used to collect surface velocity fields and used to validate CFD models. The presentation will cover design considerations of the culvert flume, reproduction of gradations used in the tests, preliminary numerical simulation results, and preliminary bedform evolution and devolution inside culverts for various streambed gradations and flows.

**BIO:** Jenn Mora is a Hydraulics Engineer for (FHWA) Federal Highway Administration, (WFLHD) Western Federal Lands Highway Division Office based out of Vancouver, WA. She worked with the Oregon Department of Transportation (ODOT) before joining WFLHD, eager to investigate, support, and promote bioengineered solutions and effective fish passage design and best practices.

## Minebank Run Restoration and Water Quality Improvements

**Abstract:** Minebank Run Restoration and Water Quality Improvement project constructed by the Maryland Department of Transportation MDOT is an example of holistic approach and creative integration of transportation infrastructure safety improvements and resiliency upgrades with ecological restoration and environmental enhancement of natural resources within our communities. The design team has implemented innovative strategies, science, and the latest technology to develop sustainable and resilient design solutions for restoring the lost hydrologic/hydraulic, geomorphic, and ecological functions of a stream corridor within a highly urbanized watershed.

**BIO:** Dana Havlik is a Division Chief of Highway Hydraulics Division (HHD) at the Maryland Department of Transportation State Highway Administration. She has 28 years' experience in water resources and environmental engineering. Dana leads engineering teams to support development and delivery of MDOT capital improvement and system preservation projects while assuring environmental compliance. She oversees the Stormwater Systems Assets Program to assure safety and proper functionality of highway drainage and stormwater management infrastructure as well as compliance with the National Pollutant Discharge Elimination System (NPDES) MS4 Permit requirements. She is responsible for fund management of roadway drainage improvements and water quality projects including system preservation, remediation and capacity upgrades, restoration, and functional enhancements along with other environmental stewardship initiatives.

## Approaches for Simulating Large Woody Material (LWM) in Two-Dimensional (2D) Models

**Abstract:** Large Woody Material (LWM) is an integral component in river restoration and aquatic organism passage (AOP) projects, and is widely used for enhancing aquatic organism habitat. A key mechanism for this enhancement is the variability introduced by LWM into the surrounding hydraulics, which is manifested by zones of velocity acceleration and deceleration, variable bed shear stress and flow depth, as well as backwater and the formation of pools. Since these altered hydraulics affect the design of projects that utilize LWM, it is necessary that these LWM effects are accounted for in the hydraulic models used for design. Because two-dimensional (2D) models are gaining popularity in engineering practice, it is important to evaluate how LWM can be simulated within these models. This work summarizes a suite of methods utilized in AOP projects for representing the effects of LWM in the Sedimentation and River Hydraulics - Two-Dimension (SRH-2D), a commonly used 2D, depth-averaged hydraulic model. These methods included representing LWM through: 1) an educated adjustment of the Manning's roughness coefficient, n, either locally for the 2D model elements within the LWM footprint, or globally, outside the general vicinity of the LWM; 2) use of the blocked obstruction feature built-in SRH-2D, which assigns a drag force through a user-defined drag coefficient and the obstruction geometry; 3) incorporation of the LWM in the geometry of the computational mesh; and 4) combinations of these methods. No benchmark measurements were available to provide an absolute performance measure of the four methods considered. However, the comparison of the hydraulics from the various methods highlighted the limitations and assumptions of each method. More importantly, this comparison provided ranges of applicability, where each method could provide satisfactory results relative to the anticipated computational cost.

# Drainage & Erosion Control

## Three-Dimensional Computational Fluid Dynamics Modeling of Hydraulic Efficiency of Road Drainage Structures

**Abstract:** Highway drainage systems need to handle higher volumes of runoff during rain events than they have in the past. To handle higher volumes of traffic, modern roads are being built, and old roads are being expanded with more lanes giving a larger rainfall collection area. In addition, more frequent and extreme rain events can overwhelm existing drainage systems and new systems need to be designed to handle the higher rates of runoff. State Departments of Transportation are developing new designs of drainage structures including more accurate functions of efficiency under a variety of conditions. They are also assessing old designs to determine if they are sufficient to drain higher flow rates off of the roads. Three-dimensional computational fluid dynamics analysis can determine flow and efficiency through drains with complex

geometry and catch basins at field scale over a broad range of conditions. Argonne researchers were approached by state DOTs to perform an evaluation of new and existing inlets with the use of computational fluid dynamics on a high-performance computing cluster. The studies were done under the Hydraulics Research Program at the Turner-Fairbank Highway Research Center, through an Interagency Agreement between DOT and DOE. Geometric parameters in the test case matrix include varying cross-slopes and longitudinal slopes of the road surface, shoulder/gutter width, as well as a range of flow rates. On-grade and sump conditions are accounted for in the study. The computational analysis resulted in finding the hydraulic efficiency of the inlets, the split of the flow rate between front, side and backflow of the grate, flow through the curb opening when present, as well as the bypass flow. The results were incorporated into a spreadsheet-based design tool to guide determination of catch basin inlet spacing along the roadway. The presentation will cover the modeling approach, results, and application of the results to drainage system design.

**BIO:** Dr. Marta Sitek graduated and later worked as an assistant professor at the Faculty of Civil Engineering, Warsaw University of Technology, in Warsaw, Poland. Currently works as a Principal Mechanical Engineer at Argonne National Laboratory, in Lemont, Illinois.

Expertise in Computational Structural Mechanics and Computational Fluid Dynamics modeling and analysis. Contributes to the work for Hydraulics Research Program at the FHWA's Turner-Fairbank Highway Research Center. Performs research, analysis, and computations for projects managed or coordinated by State DOTs.

## New NCDOT Hydroplaning Policy, Analytical Tool Development, and Mitigation Strategies

**Abstract:** Wider roadway sections, either through new designs or widening existing roadways present hydroplaning concerns. Understanding these concerns and providing mitigation efforts early in the design process is imperative to efficient project delivery and risk mitigation.

The NCDOT Hydraulics Unit is renovating their approach to managing hydroplaning risk with robust, new policy language to identify concerns early in the project design process, identify mitigation strategies, and a new hydroplaning assessment computer program to better predict hydroplaning potential. Program improvements include a computationally averaged water film thickness approach, regionally specific pavement texture depths, an adjustment for modern tire pressure, a factor to assess the maximum water film thickness in superelevation transitions, and a modified application of the PAVDRN hydroplaning speed formula that adjusts to the specific mean texture depth and eliminates the effects of a formula computational discontinuity. These policy improvements allow designers to better quantify the risk associated with wide section roadways and decide when it would be beneficial to implement a mitigation strategy to decrease risk.

NCDOT is also developing a Mitigation Selection Guide to assist designers in selecting the mitigation techniques most suitable for different design or rehabilitation projects. This guide navigates designers through hydroplaning risk considerations, projects constraints, pavement type, life-cycle costs, and the effectiveness of various strategies to reduce risk.

Identification of NCDOT process improvements, on-going research efforts, and mitigation strategies will be discussed and complemented by a demonstration of the new hydroplaning tool and sample problem discussion.

**BIOs:** Matthew York joined the North Carolina Department of Transportation in 2013 after graduating from North Carolina State University. Matthew has nearly a decade of experience involving transportation drainage, H&H modeling, drainage design, permitting, and drainage design guidance. In 2019, Matt began efforts to bring hydroplaning analysis up to date with the latest research and tools available and created a multi-discipline Hydroplaning Technical Advisory Group for the department. Through these efforts and the partnership of Atkins Global, the Hydroplaning analysis tool and guidance is ready to address safety and resiliency of major transportation facilities throughout the state.

Katey Earp joined Atkins in 2020, bringing 17 years of water resource engineering experience involving transportation drainage, H&H modeling, floodplain mapping, drainage design and permitting efforts. Katey served for seven years in Florida Department of Transportation's Central Office Drainage Group. She's worked on many innovative water policy projects while at Atkins, including NCDOT's hydroplaning program, FDOT resiliency efforts and regional watershed management policy.

Rick Renna was born and raised in Key West, FL, moving later to the Ft. Lauderdale area where he joined the Florida Department of Transportation (FDOT) in 1974. He served in Construction from 1974 - 1986 as an estimates engineer, segmental bridge inspector, and a construction project engineer; he managed bridge scour research from 1988 - 2010, including the development of FDOT's bridge scour equations. Rick served as the FDOT District 4 Drainage Engineer from September 1995 – late 1998, the FDOT State Drainage Engineer from 2001-2016, and joined Akins in 2016 as a senior water resources engineer. Both at Atkins and FDOT, Rick has focused on stormwater management process and BMP development, bridge scour, pipe service life, coastal engineering, major highway and regional drainage design, bridge hydraulics, and hydroplaning analysis.

## Urban Drainage Design (HEC-22) Fourth Edition Manual Update and Curb Opening Inlet Equations

**Abstract:** The Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22 (HEC-22), provides a comprehensive and practical guide for designing storm drainage systems associated with transportation facilities. Design guidance is provided to design storm drainage systems that collect, convey, and discharge stormwater flowing within and along the highway right-of-way. The manual was updated to better align with current industry practice, regulations, and technology. This presentation will briefly review some of the methods, procedures, and updates presented in the fourth edition of this manual.

In conjunction with the manual update, revised curb inlet equations to better estimate the full capture of the approaching gutter flow on grade from the roadway. FHWA researchers reviewed the inspection methodology and conducted a series of numerical experiment using computational fluid dynamics (CFD). The researchers performed CFD simulations for various curb opening lengths (5, 10, and 15 ft), cross slopes (0.002, 0.04, and 0.06 ft/ft), and longitudinal slopes (ranging from 0.001 to 0.05 ft/ft). FHWA researchers developed new equations for 100 percent curb opening inlet interception capacity with lower RMSE errors based on the CFD simulations. This presentation will review the additional research performed in developing and applying these new curb opening inlet equations.

**BIO:** Ryan Lizewski is a hydraulic engineer with FHWA's Resource Center having 15 years of experience in the field of hydraulic engineering. Ryan was hired into the Resource Center last year with his prior experience in the private sector providing consulting services in the Northeast. Ryan specializes in many areas of hydraulic engineering including urban drainage, stormwater management, floodplains analysis, and hydraulic modeling. Ryan is currently the technical lead for the HEC-22 Urban Drainage Design manual update and several of FHWA's National Highway Institute courses. He graduated from Worcester Polytechnic Institute with a bachelor's degree in Civil Engineering.

James Pagenkopf is a hydraulics research engineer in the FHWA's Office of Infrastructure R&D, providing support for hydraulic and hydrological research activities conducted at TFHRC Hydraulics Research Laboratory. He was previously a research engineer providing over 12 years of contracting support at TFHRC for both the Hydraulics and Aerodynamics Laboratories. Mr. Pagenkopf holds M.E. and B.S. degrees in Mechanical Engineering from the University of Virginia.

## Effects of Bridge Construction on Overland Erosion and Downstream Sediment Regime

**Abstract:** Bridge construction activities can directly affect aquatic habitats. The impacts may include changes in stream hydraulics, suspended sediment concentration, and stream substrate composition. These impacts could be temporary and during bridge construction or permanent. They can be avoided or minimized if areas of potential impact are predicted. A GIS-based Predictive Sediment Toolbar is developed to estimate overland erosion and determine the potential depositional area and suspended sediment concentration downstream of

bridge construction sites. The performance of the GIS-toolbar is assessed in a bridge construction site. This paper presents the results of the field monitoring program in the Wilson Creek bridge construction site (McKinney, Texas) and the evaluation of the developed GIS-toolbar in predicting the effect of the bridge construction on the creek sediment regime.

**BIO:** Habib Ahmari is an assistant professor in the Department of Civil Engineering at the University of Texas at Arlington (UTA) and a licensed professional engineer in Texas and Ontario, Canada. He has more than twenty years of industry, research, and teaching experience in the area of water resources, environmental hydraulics, and river morphology. Before joining UTA, he worked for ten years in Canada, where he led several environmental impact assessment studies of hydroelectric dam construction projects.

## Programmatic Resilience

### Traffic Must Flow: NCDOT's Steps to Prepare for Future Flood Hazards with Digital Solutions

**Abstract:** In the wake of Hurricanes Florence and Matthew, the NCDOT was left with the major task of preparing our state's infrastructure for the future, one where flood events will be more severe, with greater frequency and less predictability. Fortunately, North Carolina is a data rich state, with access to high-resolution statewide flood datasets, LiDAR and hydraulic modeling. To aid this effort and leverage the assets available, NCDOT partnered with Wood to perform multiple analyses on the state road network, leveraging data from both NCDOT and the NC Division of Emergency Management (NCEM), to produce proof-of-concept digital products that will aid transportation stakeholders in preparing for and implementing a resilience-focused strategy that will ensure that traffic and commerce continue to flow in spite of flood waters rather then be overtaken by them.

**BIO:** Kenneth Ashe is a Principal Engineer with Wood Environment and Infrastructure Inc. where he serves as Wood's Deputy Risk Map Program Lead and Carolinas Water Lead. His background is a combination of program management, H&H modeling, flood studies, the NFIP, hazard mitigation and emergency management including positions in State government and the private sector. He has supported the NCDOT Hydraulics Unit since 2006, including providing H&H, disaster response and recent resiliency initiatives. Ken is a Professional Engineer, Project Management Professional, and Certified Floodplain Manager. He currently serves a Chair of the NC Association of Floodplain Managers, as an Advisory Board Member for the NC Department of Environmental Quality Natural Infrastructure Flood Mitigation Advisory Board and serves on the UNCW Coastal Engineering Advisory Board. He has a BS and MS in Engineering from the University of Central Florida.

### Colorado Department of Transportation 2D Quick Check Statewide Initiative

**Abstract:** State Highway 14 spans the Cache la Poudre River on the east side of Fort Collins, CO. The Poudre River at this location underwent a substantial realignment in 1949 to accommodate the SH 14 bridge structure, shifting the channel via an engineered meandering section. Design of the replacement bridge began in 2013 and culminated in construction of the replacement bridge in 2015-16, along with a substantial change to the vertical alignment of SH 14 and associated river grading. A tall, largely stable vegetated bank was present on the right overbank area prior to the recent bridge replacement. Only one year after construction, a significant gravel bar with cobble top layer began rapidly developing upstream of, and under, the new bridge footprint. This bar continues to expand into the active channel and bridge opening. A morphodynamic model of the fluvial system upstream and downstream of the bridge has been constructed using SRH-2D. Taking advantage of topographic data and employing SRH-2D's sediment transport capabilities, we have experimented with the predictability of the observed gravel bar formation using this hydraulic model. Towards that end, we have utilized a nearby USGS gaging station to run actual flow data through the simulated fluvial system. Our preliminary findings suggest that the initial stages of the gravel bar formation may be expected within a single year of post-construction runoff, which matches observation of the site. Further, the morphodynamic model is able to demonstrate approximately correct lateral and vertical location of the bar's formation. In addition to these findings, we propose to also address the difficulties inherent in such a model during the pre-construction design phase for a DOT engineer: calibration of the model and sufficient understanding of the geomorphic response of the larger system to the disruption caused by the new bridge and associated grading. An important take-away for hydraulic engineering practitioners, as demonstrated by this study, is that design using only large magnitude (small recurrence) peak flows, and assuming a static non-moveable bed, may not provide adequate understanding of the fluvial system when arriving at a proposed condition grading plan for infrastructure improvements. This could lead to diminished hydraulic capacity and performance at a bridge crossing, as well as larger floodplain encroachments than initially expected.

**BIOs:** Kalli Wegren has been with the Colorado Department of Transportation since April 2020. She is passionate about hydrologic and hydraulic modeling, stormwater design, conservation, and GIS. Water is also a passion of hers outside of work as you can usually find her skiing, visiting Lake Tahoe, or floating the river!

Sara is a Project Manager and Water Resource Engineer with Muller Engineering in Lakewood, Colorado. She has 14 years of consulting experience with MS4 regulations and policy, hydrologic and hydraulic studies, stream restoration and stabilization, and flood risk mapping.

## Mississippi's Advancing the State of Practice for Hydraulic Engineers, Designing with Depth and Breadth: A Deep Dive into the Evolution of the Bridge Hydraulic Design Process featuring Best Practices in Mississippi including the use of SRH-2D

## National Hydraulic Engineering Conference 2022

## Advancing Hydraulic Engineering For Infrastructure Resiliency

**Abstract:** Mississippi Department of Transportation (MDOT) bridge hydraulic design procedures have evolved significantly over the past ten years advancing hydraulic engineering for Mississippi's infrastructure resiliency and best practices for the State: • Design Process Evolution, Improving Communication: Improving the design process, deliverables, and coordination within the DOT throughout a projects life cycle to ensure that new bridge designs consider environmental impacts, cost, constructability, and maintainability by bringing key personnel to the table. • Hydraulic Analysis and Design Evolution, Embracing CHANGE and the Big Picture: Advancing the hydraulic analysis and design process by: o Embracing the CHANGE of hydraulic modeling techniques which has evolved FROM using WSPRO TO now SRH-2D models which provides more accurate representations of flow conditions, including water surface elevations, depths, velocities, and shear stress across channels and floodplains. o Evaluating, the BIG PICTURE, all aspects that factor into the hydraulic design of safe bridges in Mississippi that has evolved FROM simply checking regulatory requirements TO considering stream stability and geomorphic assessments, backwater, flow distributions, stream velocities, and scour potential using the latest and greatest FHWA guidance to ensure that bridges are designed as safely as possible while optimizing costs and limiting impacts to property and the environment. • Hydraulic Submittal Evolution, Final Results for Resilient Hydraulic Structures: Developing specific requirements and documentation for hydraulic submittals to include pertinent information for management to quickly review hydraulic bridge recommendations including design alternatives comparing proposed bridge lengths to respective backwater and roadway impacts/improvements. Using advanced tools such as 2D hydraulic modeling is providing MDOT with more accurate results to inform the location and size of structures and determine depths of bridge foundations. Due to the complexity of Mississippi's floodplains and highway crossings, MDOT is saving tax payers by utilizing 2D models for designs which have shown a reduction in required openings and foundation depths when compared to utilizing 1D models. Once the hydraulic analysis and designs are complete, the results from the 2D hydraulic models is providing enhanced collaboration via 3D visualization and intuitive and visually rich graphical output to aid in communicating design results to a variety of stakeholders within MDOT and to other agencies. Rachel currently serves as lead Drainage Engineer for Gresham Smith across the Transportation Market, and has been with Gresham Smith for two years, and has been in the private sector for five years total. She started her career at the Mississippi Dept. of Transportation in Bridge Division in 2003, and served as the State Hydraulic Engineer for seven years before moving into the private sector. Rachel has completed hydraulic design in Mississippi, Georgia, Tennessee, and Kentucky and continues to sharpen her knowledge and experience as the hydraulic engineering field is continually expanding and changing. She has experience in bridge hydraulic analysis and design, federal regulatory compliance, bridge hydraulic modeling, risk and impact assessments, stream stability, and scour analysis. Rachel possesses extensive knowledge and practice in FHWA Hydraulic Engineering Circulars and Publications thanks to the National Highway Institute, time served at MDOT and in

the private sector. Rachel previously served on the AASHTO Technical Committee on Hydrology and Hydraulics from 2012 to 2017.

**BIO:** Rachel Westerfield (PE, CFM) currently serves as lead Drainage Engineer for Gresham Smith across the Transportation Market, and has been with Gresham Smith for two years, and has been in the private sector for five years total. She started her career at the Mississippi Dept. of Transportation in Bridge Division in 2003, and served as the State Hydraulic Engineer for seven years before moving into the private sector.

Rachel has completed hydraulic design in Mississippi, Georgia, Tennessee, and Kentucky and continues to sharpen her knowledge and experience as the hydraulic engineering field is continually expanding and changing. She has experience in bridge hydraulic analysis and design, federal regulatory compliance, bridge hydraulic modeling, risk and impact assessments, stream stability, and scour analysis. Rachel possesses extensive knowledge and practice in FHWA Hydraulic Engineering Circulars and Publications thanks to the National Highway Institute, time served at MDOT and in the private sector. Rachel previously served on the AASHTO Technical Committee on Hydrology and Hydraulics from 2012 to 2017.

## The Benefits of Compiling and Analyzing Hydraulic-Design Data for Bridges

**Abstract:** It is typical to see design engineers grow in their knowledge and judgement with increasing years of experience. In the case of bridge hydraulic engineers, design experience develops their knowledge of regional stream characteristics, such as stream slopes, channel and floodplain widths, and soils. Additionally, design experience develops their understanding of the typical range of bridge-design characteristics, such as bridge length, flow velocities, and backwater, informing them of the range of acceptable design values for a given project. In general, this practical knowledge is acquired one bridge at a time, and developing a strong measure of expertise is a lengthy process. A supplemental tool that can promote the development of engineering knowledge and judgement is to compile, analyze, and graphically present data associated with stream and bridge-design characteristics determined from previous bridge-hydraulic studies. If the data set is sufficiently large, graphs developed from such an effort can provide engineers with a more comprehensive picture of the range and trend of selected stream and bridge-design characteristics, providing tools to assist in their professional development. Additionally, these graphs can provide simple, but useful tools for scoping future projects and for reviewing new design projects. With respect to scoping future projects, the graphs can provide understanding of the typical range of hydraulic design variables at previously designed bridges (such as, length, flow velocities, and backwater), giving insight to probable values at the site of interest, prior to doing a detailed hydraulic study. With respect to reviewing detailed bridge designs, the graphs can help the engineer evaluate if the hydraulic design variables for a proposed bridge, fall within the range of previously designed bridges, helping the engineer discern if the proposed bridge design is reasonable. While such graphs cannot serve as primary design tools, they can promote engineering knowledge and judgment, and provide an

added measure of insight and quality control to the bridge-hydraulic design process. There are several sources of stream and bridge-hydraulic data for South Carolina bridge sites that can be used to develop these supplemental tools, including the U.S. Geological Survey (USGS) South Carolina bridge-scour envelope curve investigation (1), and the South Carolina Department of Transportation (SCDOT) bridge-design database (unpublished). The USGS and SCDOT databases include bridge-hydraulic data for approximately 300 and 200 bridges, respectively, and provide a valuable resource for understanding general trends of stream characteristics and hydraulic bridge-design variables in South Carolina. This presentation will review the results of the graphical analysis of the hydraulic data associated with stream and bridge-design characteristics in South Carolina (2), and discuss how these tools can help develop engineering knowledge and judgement, and assist in scoping future projects and reviewing proposed designs for bridges in South Carolina. While the tools presented in this paper are specific to South Carolina, they demonstrate how other states can use hydraulic data from previously designed bridges within their state to develop similar tools. NOTE: The title and content of this abstract and proposed presentation are based on the recently published paper by Benedict and Knight (2021), as cited below. REFERENCES 1. Benedict, S. T., T .D. Feaster, and A. W. Caldwell. The South Carolina Bridge-Scour Envelope Curves. U.S. Geological Survey Scientific Investigations Report 2016-5121, United States Department of the Interior, 2016 (revised 2018). https://doi.org/10.3133/sir20165121. 2.

**BIO:** Stephen Benedict, PE is a hydraulic engineer with 39 years of experience, and currently serves as a Senior Hydraulic Engineer with the AECOM Greenville office. Prior to working with AECOM, Stephen spent 11 years with the SC Department of Transportation, and 25 years with the US Geological Survey. His work experience includes the areas of bridge scour, bridge hydraulics, surface-water models, flood documentation and monitoring, data collection and analysis, practical field research, report writing, bridge-hydraulic design policy, and training instructor.

While at the SCDOT, Stephen focused on the hydraulic design of bridges, review and revision of design policy, and the development of staff training classes for bridge scour, hydraulic bridge design, and Level I geomorphic assessments. Stephen also helped develop flood monitoring tools using historical flood data in conjunction with real-time USGS gage data. These tools helped identify potential flood threats from the 4 hurricanes that passed through South Carolina between 2016 and 2018 and he received the SCDOT 2019 Engineering Excellence Award for his efforts in flood-monitoring during Hurricane Florence.

Stephen's career with the USGS included numerous projects related to the collection and/or compilation of various field data, analysis of the data, and documentation of the findings. These data projects included bridge-scour, floods, river models, Florida Everglades water-levels, and water-quality data.

A prominent focus of his career has been in field investigations of bridge scour that led to the development of the South Carolina bridge-scour envelope curves (https://pubs.er.usgs.gov/ publication/sir20165121), an assessment method now adopted by the SCDOT. Stephen received the Superior Service Award from the US Department of the Interior for recognition of his research contributions to the discipline of bridge scour. Stephen has authored or coauthored 14 technical reports, 8 professional papers and 44 conference presentations.

## Stream Morphology & Sediment Transport

### Morphodynamic Modeling of Gravel Bar Formation at a Bridge Replacement

**Abstract:** State Highway 14 spans the Cache la Poudre River on the east side of Fort Collins, CO. The Poudre River at this location underwent a substantial realignment in 1949 to accommodate the SH 14 bridge structure, shifting the channel via an engineered meandering section. Design of the replacement bridge began in 2013 and culminated in construction of the replacement bridge in 2015-16, along with a substantial change to the vertical alignment of SH 14 and associated river grading. A tall, largely stable vegetated bank was present on the right overbank area prior to the recent bridge replacement. Only one year after construction, a significant gravel bar with cobble top layer began rapidly developing upstream of, and under, the new bridge footprint. This bar continues to expand into the active channel and bridge opening. A morphodynamic model of the fluvial system upstream and downstream of the bridge has been constructed using SRH-2D. Taking advantage of topographic data and employing SRH-2D's sediment transport capabilities, we have experimented with the predictability of the observed gravel bar formation using this hydraulic model. Towards that end, we have utilized a nearby USGS gaging station to run actual flow data through the simulated fluvial system. Our preliminary findings suggest that the initial stages of the gravel bar formation may be expected within a single year of post-construction runoff, which matches observation of the site. Further, the morphodynamic model is able to demonstrate approximately correct lateral and vertical location of the bar's formation. In addition to these findings, we propose to also address the difficulties inherent in such a model during the pre-construction design phase for a DOT engineer: calibration of the model and sufficient understanding of the geomorphic response of the larger system to the disruption caused by the new bridge and associated grading. An important take-away for hydraulic engineering practitioners, as demonstrated by this study, is that design using only large magnitude (small recurrence) peak flows, and assuming a static non-moveable bed, may not provide adequate understanding of the fluvial system when arriving at a proposed condition grading plan for infrastructure improvements. This could lead to diminished hydraulic capacity and performance at a bridge crossing, as well as larger floodplain encroachments than initially expected.

**BIO:** Steven Griffin is the Hydraulic Engineer covering Northern and Eastern Colorado, and has served 14 years with the Colorado Department of Transportation. He holds a Masters degree in Hydraulics from Colorado State University and is currently pursuing his PhD, hoping to research post-wildfire hydrology and recovery from a DOT perspective.

## Coupling Hydro-Morphodynamic Numerical Modeling and Fiber-Optic Distributed Temperature Sensing to Improve Bridge Scour Prediction

**Abstract:** Despite major engineering efforts, most prediction methods struggle with accurate predictions of scour depths. The objective of this study was to critically assess the performance of hydro-morphodynamic numerical models by using high spatiotemporal resolution bridge scour data. The data were collected through a fiber-optic distributed temperature sensing (FO-DTS) approach, which used temperature and heat transfer methods to determine if a section of the FO-DTS device was either exposed to water or buried within the channel-bed material. Herein, modeling predictions from HEC-RAS 1D and SRH-2D were compared against field measurements collected with a FO-DTS device deployed in a sand-bed river in North Carolina, USA. Numerical simulations focused on: (1) examining the relative performance between the models when predicting stage, flow velocity, and applied boundary shear stress for the 10-yr, 25-yr, 50-yr, and 100-yr events; and (2) on comparing modeling predictions with FO-DTS measurements for a series of events measured in-situ. Ultimately, this study aims to provide new insights on the dynamics of scour hole development, which in turn can improve the predictive capabilities of numerical models used for bridge scour prediction.

**BIO:** Dr. Celso Castro-Bolinaga is an assistant professor in the Department of Biological and Agricultural Engineering at North Carolina State University. He received his Ph.D. and M.S. in Civil Engineering from Virginia Tech, and he completed his undergraduate studies in Civil Engineering at Universidad Católica Andrés Bello (UCAB) in Caracas, Venezuela. Dr. Castro-Bolinaga's areas of expertise include sediment transport, environmental fluid mechanics, and numerical modeling, with research interests covering topics such as river resilience, dam removal, stream restoration, and soil erodibility.

## Application of Incised Channel Evolution Theory and Engineering Geomorphology to Roadway Erosion Mitigation Design

**Abstract:** The New Mexico Department of Transportation (NMDOT) has identified numerous sites throughout the state of New Mexico that are experiencing severe erosion and are putting road infrastructure at risk. Two of these sites, located within District 6 (D6), are representative of some of the more common erosion related issues that require mitigation by the NMDOT. The first site is located along NM Highway 124 at Milepost 15,

where bank erosion in an unnamed arroyo is impinging on the roadway in multiple locations. The erosion has reached the ROW fence at the primary erosion risk area, where there is a headcut (vertical drop) of approximately 15 feet from the ROW fence to the bottom of the channel. The second site is located at NM Highway 197 at Milepost 24.5, where the sharp channel bend in Torreon Wash is actively migrating toward the highway, scouring the channel banks to the ROW fencing and threatening the highway. Bohannan Huston, Inc. (BHI) worked with the NMDOT to develop recommendations and prepare conceptual designs for erosion mitigation at the two sites. As part of this work, BHI conducted site investigations, hydrologic and hydraulic analyses, sediment-transport calculations and geomorphic desktop evaluations to inform the recommendations. The incised channel evolutionary stage (Schumm et al., 1984) was determined for each site based on observations during the site investigations. The NM 124 site represents a system with a channel that is evolving to account for the upstream water and sediment supply. The project reach represents several different stages of channel evolution, with the most dynamic reach demonstrating tendencies that would be expected during its current state of evolution. This site presents signs of vertical instability that are a primary factor in the bank erosion. The ongoing incision and widening has left the roadway culverts perched, resulting in plunging flow conditions that exacerbate erosion at the outfalls. Because of the vertical instabilities, grade control was recommended to reduce the downcutting that will likely result in future bank instabilities and to protect the recommended bank protection. Gabion-type grade control structures appears to be a viable method for controlling the downcutting and protecting the proposed bank stabilization measures. In contrast to the NM 124 site, the NM 197 site represents a system with a channel that is in a state of dynamic equilibrium with the upstream supply of water and sediment. The presence of bedrock in the channel bed indicates the channel is vertically stable. Thus, dynamic equilibrium is achieved primarily through planform adjustments. The eroding bank is occurring through a very sharp bend that, based on results from 2D hydraulic modeling, will be difficult to stabilize using traditional methods, so channel realignment was recommended. The recommendations also included a series of gabion-bound terraces to protect the outside bank of the realigned channel. Contact Information: Stuart Trabant, Bohannan Huston, Inc, Albuquerque, NM 87109 USA, Phone: 505-823-1000, Fax: 505-798-7988, Email: strabant@bhinc.com

**BIO:** Caroline Ogg is a Surface Water Engineer working at Bohannan Huston, Inc. in the Denver office. Ms. Ogg has 6 years of experience in the private and public sectors with a focus on hydrologic and hydraulic analysis, erosion mitigation, flood mitigation, and drainage system design and analysis for both small and large-scale applications throughout the southwest. Ms. Ogg has significant experience with two-dimensional hydraulic modeling, scour analyses, and drainage infrastructure design. She holds bachelor's degrees in engineering science and interdisciplinary liberal arts from Colorado State University, and is an advisor for the CSU chapter of Tau Beta Pi. She is a registered professional engineer in Colorado.

## Making Mississippi's bridges more resilient to lateral migration

**Abstract:** The Mississippi Department of Transportation (MDOT) has identified channel migration as a major concern at multiple locations throughout the state. In addition to investigating the individual bridge locations, the Department has expended significant effort to consider the channels from a system-wide approach. MDOT's approach includes consideration of channel morphology and the changes over time which could possibly impact Mississippi's bridge infrastructure in the future and MDOT is taking a proactive stance on addressing future potential concerns. One-dimensional and two-dimensional hydraulic modeling has been used with Federal Highway Administration guidance to develop and construct different countermeasures throughout the state. The range of countermeasure designs reflect the uniqueness of each site and the individual challenges they bring. MDOT has been documenting the performance and resilience of its countermeasure designs addressing lateral migration challenges in multiple case studies.

**BIO:** Blake Mendrop, PE, PLS, is a civil engineer with over 30 years of experience in hydraulic and hydrologic design, civil design, surveying, project management, construction management, and economic development. Prior to founding Mendrop Engineering Resources (MER), Mr. Mendrop developed a broad technical background in planning, engineering, and project management, including experience working at the U.S. Army Corps of Engineers – Vicksburg District.

Mr. Mendrop is recognized for his expertise in the area of Water Resources with advanced studies being obtained at Colorado State University. Over the past 30 years, he has provided all aspects of project support for site development and water resource projects throughout the southeast United States. Mr. Mendrop has been involved in the development of technical work plans for many watersheds in North Mississippi, including drainage basin planning and construction plans. As the founder of MER, his responsibilities have ranged from business and client development, as well as, technical design and engineering management of all technical aspects on a wide range of projects.

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