AASHTO

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TECHNICAL COMMITTEE ON HYDROLOGY AND HYDRAULICS

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In This Issue

Letter from the TCHH Chair

Charlie Hebson - Maine Department of Transportation

Greetings,

It seems like only yesterday that we were preparing Hydrolink #23, published in December of last year – and here we are, at the threshold of summer and looking forward to the National Hydraulic Engineering Conference in August. Mississippi DOT has kindly offered to host NHEC 2024 in Biloxi. Speaking personally, I have never visited the Gulf Coast, so I am really looking forward to this – a nice change-up from the cold rock-bound coast of my home state of Maine. Make your plans now if you haven't started already. This gathering is the highlight for all things Hydrology and Hydraulics for practitioners in the Transportation arena. If you have never attended NHEC, make this your first. For those who have been fortunate to attend in the past, make this another one.

For the AASHTO Technical Committee on Hydrology and Hydraulics, NHEC is one of our in-person annual meetings (AASHTO Committee on Design being the other, in the off-year). Remote meeting capabilities have certainly improved our ability to do our work, but they are no substitute for in-person. I find them to be incredibly productive, and just as important, critical to maintaining the interest and energy in our efforts to advance and communicate H/H practice in Transportation.

The AASHTO Drainage Manual (ADM) update project is "this close" to completion as a National Cooperative Highway Research Program project (NCHRP 24-50) and we will hear from the project contractors at NHEC. Several of us at TCHH have been privileged to serve on the oversight panel and it has been gratifying to see the ADM come together. I can't wait for ADM to be officially published so that the wider practitioner community can tap into it as a direct technical reference as well as a source for the development of individual H/H manuals. Even with publication of the NCHRP research report, there is still AASHTO process to be followed before the updated manual can be released. But we have come a long way in three years and the end is in sight.

I invite you to explore the NHEC agenda. As always, there is a wealth of topical presentations. Modeling and scour will always be strongly represented, for the simple reason that scour will forever be a challenge for hydraulic engineers and modeling will be a standard tool for scour assessment. Modeling is also hugely important when DOTs have to address floodplain questions. The agenda includes sessions on 2-D modeling in general, as well sessions devoted to modeling for FEMA floodplains and higher-level FEMA programmatic considerations. Aquatic Organism Passage (AOP), a topic near and dear to my heart, has a prominent place on the agenda. MaineDOT sponsored NHEC in 2008 and we had a full-day AOP session. We featured it as a "conference within a conference" and had a huge turnout. I am looking forward to seeing how we have progressed in the intervening 16 (!) years. This is only a very incomplete overview of a great agenda, with additional sessions on hydrology, stormwater, coastal and resilience/climate change. So, look it over and make your own plans.

On a personal note, this marks my last Letter from the Chair. We are fortunate to have Julie Heilman from WashDOT stepping in as TCHH Chair at Biloxi. I have greatly enjoyed my term as Chair and look forward to Julie's leadership over the next few years. There is no shortage of challenges for TCHH to take on and I know we are in good hands. See you in Biloxi!

Index

State DOT Design, Construction and Monitoring Practices for Aquatic Organism Passage – NCHRP Project 20-05/Synthesis Topic 55-18

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Background

The National Cooperative Highway Research Program (NCHRP) Project 20-05/Topic 55-18 (NCHRP 55-18) is synthesis study on nationwide practice of aquatic organism passage (AOP) design, construction, and monitoring by state department of transportations (DOTs). The NCHRP 55-18 study is administered by the National Academy of Sciences (NAS) along with a collaborative panel of state DOT staff that have provided valuable direction and insight to the consultant team performing the study.

Aquatic Organism Passage (AOP) water crossing design is an evolving field at the nexus of the built environment and the natural world. When successful, AOP water crossings provide sustainable transportation infrastructure and environmental benefits focused on the connection of habitat for fish and other aquatic species. Transportation agencies have traditionally relied on the design of culvert structures to maximize the hydraulic efficiency of passing design flood flows and minimize capital expenditure costs. However, this design approach has, in many cases, resulted in unintended barriers to AOP. As these undesirable consequences are increasingly recognized, DOTs and others seek design methodologies that consider AOP while providing safe and effective transportation infrastructure. Such methods increase the focus on habitat connection by developing optimal low to moderate flow conditions throughout the structure for new water crossings, or for the replacement or retrofit of existing crossings.

Practices in the design, construction, and monitoring of AOP water crossing structures vary across the United States. While some DOTs have been developing and implementing AOP programs and projects for several years, many others are in early adoption stages and are seeking information on best practices.

Synthesis Objective and Methodology

The objective of this study is to document current practices of state DOTs in the design, construction, and monitoring of AOP water crossing structures. The synthesis investigates how state DOTs have implemented AOP structures and the strategies and practices that have been adopted or created. The following topics are being investigated to achieve this objective:

- The extent of state DOT adoption of AOP practices.
- Types of aquatic organisms typically considered in AOP design.
- Current state DOT guidance documents for AOP.
- Design methodologies employed for sizing and designing AOP structures.
- Programmatic approaches to AOP project implementation.
- Use and approaches to culvert rehabilitation and retrofits for AOP.
- Impacts to project costs for AOP implementation.
- Prioritization basis for replacement of current structures with AOP structures.
- Construction practices for AOP structure installation.
- Specifications for streambed materials.
- Considerations for sizing and selection of AOP water crossing structures.
- Project delivery methods.
- Internal state DOT structure, staffing, and training for AOP programs.
- State DOT practices in monitoring of AOP installations.
- State DOT practices in asset management for AOP installations.
- Secondary benefits realized by DOTs from AOP practices.

A literature review was the first step to achieve the objectives of this synthesis study. The literature review was followed by an online survey, and follow-up case example interviews with select state DOTs. The literature review focused on current state and federal publications documenting practices in AOP water crossing design, construction, and monitoring. The online survey was disseminated to the 50 state DOTs, Puerto Rico, and the District of Columbia. Responses were received from 42 of the 52 survey recipients (81% response rate), with 36 of the 42 respondents (86%) acknowledging that they have AOP water crossing projects. The online survey consisted of 30 questions, with questions targeted at each of the synthesis study objectives.

Five DOTs were selected for a follow-up case example interview which represent a cross-section of geographic and ecological conditions in the United States and thus potential AOP water crossing treatments.

Preliminary and Final Findings

Preliminary findings of this study will be presented at the 2024 National Hydraulic Engineering Conference in Biloxi, Mississippi. Formal and final findings are expected be published by the NAS in early 2025.

Index

What is a Watershed Approach to Meeting Stormwater Requirements?

Roger Kilgore,
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The typical approach for mitigating stormwater quantity impacts caused by road and bridge projects is to provide onsite stormwater management. This is feasible in many cases, but requires sufficient area in the project right-of-way, can be costly, and requires ongoing maintenance by the DOT. NCHRP 25-60 developed a watershed approach to meeting stormwater requirements that provides additional tools for meeting stormwater requirements by considering mitigation outside of the right-of-way that not only meets stormwater requirements, but usually avoids the need for ongoing maintenance responsibilities for the DOT. NCHRP 25-60 emphasized landscape mitigation techniques that typically also provide other benefits of value beyond stormwater mitigation (these are called co-benefits). The landscape techniques included in the research were:

- Wetland restoration and creation.
- Forest restoration and creation.
- Stream restoration and improvement.
- Uplands restoration.
- Agricultural practices modification and land conversion.

NCHRP 25-60 produced a project final report and design guidebook. The Guidebook describes procedures and resources for analyzing the hydrologic impacts of transportation projects, as well as the hydrologic benefits and co-benefits of landscape mitigation techniques. Co-benefits are benefits of stormwater mitigation in addition to the primary hydrologic objectives, e.g., improvements to recreation opportunities or enhancement of climate resilience of water supplies. Co-benefits are created by the provision of ecosystem services that contribute to human health, wealth, and well-being provided by natural ecosystems. The Guidebook provides information on how to:

- Implement a watershed-based approach to hydrologic mitigation.
- Identify opportunities in a watershed to restore, enhance, or create landscape features for hydrologic mitigation.
- Plan and locate hydrologic mitigation strategies.
- Quantify the hydrologic outcomes from selected features.
- Estimate co-benefits of hydrologic mitigation techniques.

Case Example

Figure 1 displays a watershed within which new roadway projects are planned over the next 20 years (indicated by gray lines). The figure shows the watershed boundary as well as the existing land use in the watershed. **Figure 1**

also identifies two "assessment points" where the stormwater increases caused by the road projects will be assessed and also where the effectiveness of landscape mitigation techniques will be assessed. AP1 is immediately downstream of the roadway projects and AP2 is at the outlet of the watershed.

NCHRP 25-60 developed ***mitigation ratios*** for reforestation, uplands restoration, wetlands restoration, and stream restoration. These mitigation ratios describe how much mitigation is required to compensate for a unit area of impervious impact from the roadway.

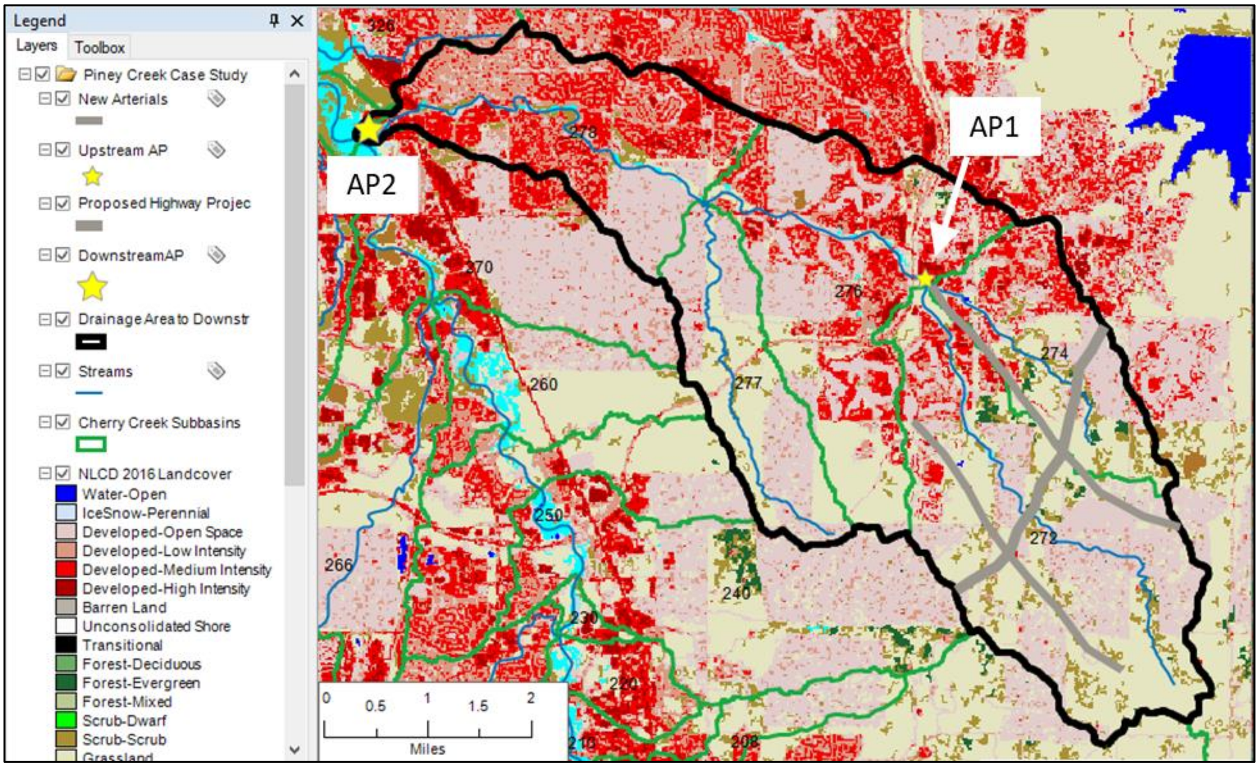

Figure 1. The hypothetical proposed highway project in Colorado.

Table 1 provides example mitigation ratios at AP1 for the 100-year and 2-year peak flows as well as the 100-year and 2-year event volumes. For example, it takes 7.1 acres of uplands restoration to mitigate the increases in the 100-year peak flow caused by 1 acre of new impervious highway. **Table 2** provides analogous information for assessment point 2 (AP2). With these two tables we can now develop mitigation strategies anywhere in the watershed to mitigate our highway stormwater impacts using these landscape mitigation techniques.

Table 1. Mitigation ratios for AP1 (area of mitigation per unit area of new impervious highway impact).

Mitigation Type	100-yr Peak Flow	2-yr Peak Flow	100-yr Event Volume	2-yr Event Volume
Forest Restoration	1.4	1.6	1.4	N/A
Uplands (Grassland) Restoration	7.1	2.0	2.5	1.4
Wetland Restoration	2.0	1.6	1.6	1.1

Table 2. Mitigation ratios for AP2 with mitigation upstream of project (area of mitigation per unit area of new impervious highway impact).

Mitigation Type	100-yr Peak Flow	2-yr Peak Flow	100-yr Event Volume	2-yr Event Volume
Forest Restoration	1.4	1.4	1.5	N/A
Uplands (Grassland) Restoration	2.2	1.6	1.9	N/A
Wetland Restoration	1.4	1.4	2.0	1.1

In addition to the stormwater mitigation benefits, these landscape mitigation techniques also bring co-benefits including in this case, better public open spaces, better water quality, and improved habitat. And depending on the restoration sites, overall maintenance is reduced and generally not the responsibility of the DOT. Once implemented, the DOT can continue to focus on its transportation mission.

Limitations and Challenges

Using the watershed approach with offsite landscape mitigation techniques is not needed for all projects or all situations. But, for larger projects, projects developed over longer time periods, or projects with challenging onsite limitations, the watershed approach adds tools to the DOT toolbox for meeting stormwater management requirements.

The two greatest challenges are identifying appropriate sites for offsite mitigation and working with stakeholders to develop an acceptable mitigation plan. However, because offsite landscape mitigation often brings co-benefits of value to stakeholders, stakeholders have additional incentives to collaborate in bringing mitigation plans to reality.

We are currently developing an implementation proposal through NCHRP to provide further examples of successful landscape mitigation approaches. If you are interested in participating or have examples of offsite mitigation, please let me know.

Index

Physical and CFD Modeling for ODOT Barrier Inlets

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Sediment, trash, large debris, and other pollutants resulting from environmental deposition and vehicular traffic are prevalent on Ohio Department of Transportation (ODOT) roads. Everything from fine soil particles, leaves and grass clippings to tree branches, hubcaps, tires, and large pieces of wood inevitably end up being swept into roadside drainage structures potentially blocking flow and causing serious disruption to stormwater collection systems. ODOT's *Benefit Analysis of Barrier Inlet Screens* research project studied the effectiveness of screening devices at preventing debris from entering stormwater inlets along highway barrier walls, while considering motorist safety, hydraulic performance, operation/maintenance requirements, durability, and costs.

This collaborative effort between ms consultants, inc., IIHR - Hydroscience and Engineering at the University of Iowa (IIHR), and Ohio State University evaluated the performance of a variety of commercially available and in-house fabricated screening devices, through a combination of full-scale laboratory physical modeling and field testing along active ODOT roadways. IIHR performed full scale (1:1) physical modeling by constructing a 12-foot wide, 50-foot-long test channel to mimic a typical ODOT roadway (**Figure 1**) and simulate stormwater flow along a standard highway barrier inlet adjacent to a paved shoulder (**Figure 2**).

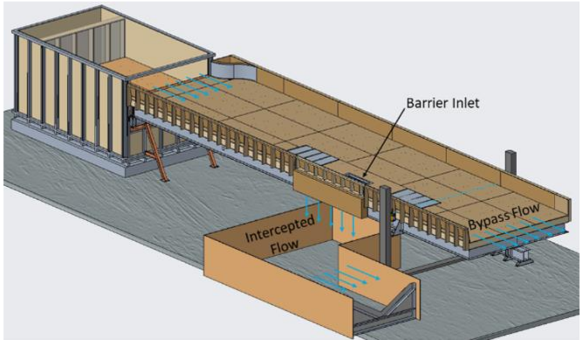

Figure 1. Three-dimensional rendering of the full-scale roadway test deck designed by IIHR.

Figure 2. Constructed full-scale test deck during flow testing at IIHR's hydraulics laboratory.

The test channel featured adjustable longitudinal and cross slopes to test each product over a range of simulated roadway grade and hydraulic conditions. Additionally, a variety of inlet configurations were tested, such as those on-grade and in sag conditions, as well as inlets with and without accompanying inlet grates and catch basins. Simulated debris and trash were incorporated into the test channel to evaluate the debris removal efficiency of screening devices and the subsequent impacts on hydraulic capacity at the inlet (**Figure 3 and Figure 4**). Inflows tested in the physical model ranged from 2.4 to 7.9 cfs. The inflows were derived based on Ohio intensity-duration-frequency (IDF) curves for 10-year to 1000-year rainfall events for drainage areas of 0.5 to 1 acre, which are typical based on current ODOT inlet spacing standards.

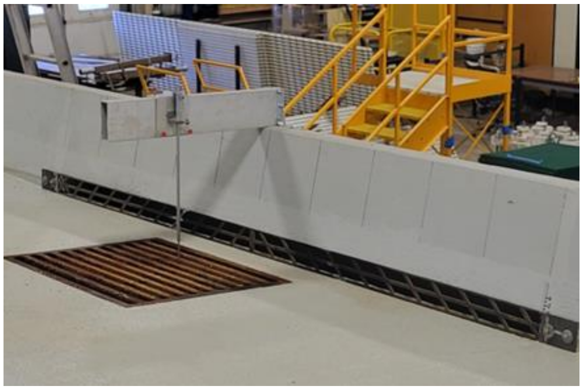

Figure 3. In-house fabricated barrier screen installed on test channel prior to simulated debris testing.

Figure 4. Debris accumulated on barrier screens following simulated debris testing.

Based on the findings from field and laboratory study, the research team developed a custom fabricated barrier inlet screen design and recommended its implementation along existing ODOT roadways where trash and debris are a known concern. The expected benefits from barrier inlet screens include cost savings from reduced inlet and sewer cleaning, safer working conditions for ODOT maintenance personnel, and less debris entering receiving waterways. To access copies of the final report, visit: https://www.transportation.ohio.gov/programs/research-program/research-program.

The barrier inlet screen research effort led to additional collaboration between Argonne National Laboratory and IIHR. The researchers from Argonne National Laboratory developed three-dimensional Computational Fluid Dynamics simulations of a representative set of the baseline physical tests with no screens at the inlet, and the barrier window and grate open. The test case matrix covered flow rates up to 7.9 cfs and longitudinal grades up to 0.05 ft/ft with a constant cross-grade of 0.04 ft/ft.

The computational model was set up in Simcenter STAR-CCM+ v.17.06 using the unsteady Reynolds-averaged Navier-Stokes solver with k-ω turbulence model to model the turbulent open-channel flow of water and air, which were modeled with the Eulerian two-phase model combined with the Volume of Fluid model to account for the free surface. The simulation is initialized with the model filled with air. At time zero, the flow is introduced to the model through the inlet boundary defined at the headbox (top right corner of **Figure 5**) with a specified flow rate.

The pavement is tilted by a specified longitudinal grade and the water flows from the headbox towards the window and grate inlet. Water exits the model either through the outlets underneath the barrier window and grate or bypasses the inlet and exits through the outlet on the downstream end of the model. The simulation is run until a steady state is reached and the inflowing and outflowing mass is balanced.

The results of the computational simulations correspond well to the hydraulics observed in the physical tests. As an example, **Figure 5** presents the results of a case with longitudinal grade of 0.01 ft/ft and flow rate of 7.9 cfs. The details of the flow on the pavement match very well between the physical and computational models. The flow spread upstream of the inlet is ~ 10 ft, there are standing waves at the pavement section close to the head box and at the downstream edge of the barrier inlet, the water depth at the upstream edge of the barrier inlet matches, and a similar fraction of the grate is overtopped. During the physical tests, blue dye was injected into the flowing water to show the flow streamlines. **Figure 6** shows the injection at a point three feet away from the barrier. In the computational model, the streamlines are generated for the entire flow field. The two red points on the right side of the figure represent two dye injection locations (three and six feet from the barrier) and the black curves are the velocity streamlines which originate from those points. Again, there is good agreement between the physical and computational results.

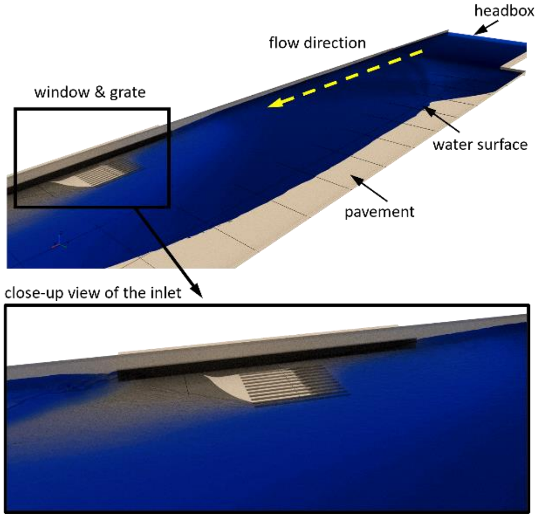

Figure 5. Computational model of water flow on the pavement, and over the grate and barrier inlet.

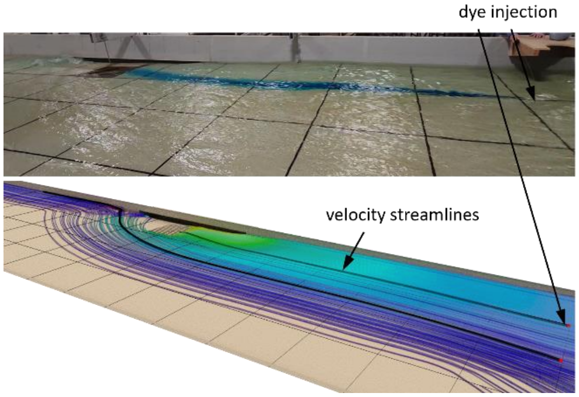

Figure 6. Dye injection shows the flow streamlines in the physical test. Streamlines plotted in the computational model show a very good match.

Acknowledgements

The funding for Argonne National Laboratory came from Ohio Department of Transportation through the Transportation Pooled Fund Program TPF-5(446) “High Performance Computational Fluid Dynamics Modeling Services for Highway Hydraulics”, managed by the Turner-Fairbank Highway Research Center through the Interagency Agreement between DOT and DOE.

The funding for ms consultants, inc., IIHR - Hydroscience and Engineering, and Ohio State University’s efforts came from Ohio Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration through the “Benefit Analysis of Barrier Inlet Screens” research project.

Index

Flow Features and Resulting Scour Hole Geometry Around Cylindrical Piers Subject to Wave and Current

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Background and Motivation

Scour is a significant contributing factor to bridge failure. In the U.S., from 1980 to 2012, scouring accounted for 20% of the bridge failures [1]. Currently over 20,000 of the 580,000 U.S. bridges are classified as scour critical [2]. The primary type of scour at bridge piers is local scour, caused by flow features such as eddies and vortices. While unidirectional flow typically causes scour in riverine environments, in coastal areas and lakes, scour is driven by multidirectional flows and wave action, with vortex shedding being a prominent factor [3]. There has been substantial research on predicting scour depth around bridge piers, especially in riverine conditions, with less focus on coastal and lacustrine environments.

Since the geometry of the scour hole is determined by the flow dynamics around the pier, the main objective of this study was to investigate the flow characteristics and patterns around cylindrical piers and the resulting scour hole geometry under wave-current conditions. To achieve this objective, 38 experiments were conducted in the laboratory under clear-water conditions. Particle Image Velocimetry (PIV) was used to visualize and investigate the flow structure around piers in the streamwise horizontal plane. Flow patterns around the pier were compared with the size and shape of the scour hole to demonstrate that the scour hole is the footprint of the horizontal eddies formed around piers.

Experimental Setup and Test Conditions

The 38 experiments were divided into two sets of 19 tests: Set 1 featured a movable sediment bed, while Set 2 utilized a fixed bed with a Particle Image Velocimetry (PIV) setup. Both sets included six wave-alone, six current-alone, and seven combined wave-current experiments with consistent test parameters to facilitate comparison. The experimental setup is depicted in **Figure 1**. The movable bed was a 1.2 m long, 0.3 m wide, and 0.5 m deep sandbox with ramps for smooth transitions. Two piers with diameters of 19 mm and 50 mm were tested. The PIV setup employed a laser, a lens to form a laser sheet, a GoPro Hero 5 action video camera, and silver-colored particles as seeding material. A flap-type wave generator created regular waves that propagated in the opposite direction to the current.

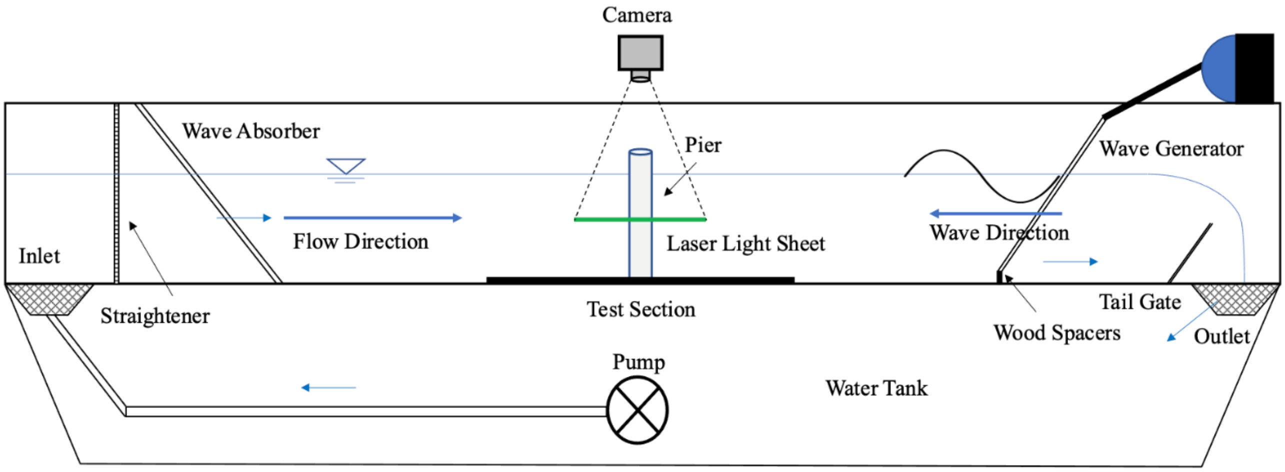


Figure 1. Schematic of the experimental flume and PIV setup (not to scale).

The details of the test conditions in each experiment are outlined in **Table 1**. In this table, the Keulegan-Carpenter (*KC*) number is a dimensionless parameter that is used to express the relative magnitude of the flow and structure length scales. The value of *KC* is used for predicting the geometry of scour holes in coastal and lacustrine environments. When $KC < 1$, the wave field and pier interactions dominate the scour process, and when $6 < KC <$

1000, the vortex shedding is the only governing factor of the scour process. For *KC* >1000, the scour process reaches an equilibrium value due to the quasi-steady nature of the flow relative to the size of the pier [4].

Table 1. Test conditions and flow parameters.

Test No.	Pier Dia. (mm)	Flow Condition	Water Depth, d (cm)	Wave Height, H (cm)	Wave Period, T (s)	Wavelength, L (cm)	KC	Flow Rate, Q (lit/s)	Flow Velocity, v (m/s)	Test Duration (min)
1	50	Current-alone	10.2	-	-	-	-	4.8	0.157	120
2			12.7	-	-	-	-	6.6	0.174	12[a]
3			15.2	-	-	-	-	12.4	0.272	3[a]
4		Waves-alone	15.2	7.6	0.7	70.5	2.31	-	-	600
5			17.8	8.4	0.7	72.5	2.16	-	-	600
6			20.3	9.1	0.7	73.8	1.96	-	-	600
7		Wave-current combined	15.2	6.4	0.68	67.3	1.81	7	0.153	120
8			17.8	7	0.72	75.9	1.91	8.6	0.161	120
9			20.3	7.6	0.7	73.8	1.65	9.7	0.158	120
10			25.6	8.2	0.7	75.4	1.24	12.4	0.161	120
11	19	Current-alone	10.2	-	-	-	-	4.9	0.159	120
12			12.7	-	-	-	-	6.7	0.174	120
13			15.2	-	-	-	-	12.4	0.272	120
14		Wave-alone	15.2	7.6	0.72	73.6	6.39	-	-	600
15			17.8	8.4	0.72	75.9	6.07	-	-	600
16			20.3	9.1	0.72	77.5	5.56	-	-	600
17		Wave-current combined	15.2	5.8	0.69	68.9	4.53	7	0.153	120
18			17.8	7	0.72	75.9	5.04	8.6	0.161	120
19			20.3	7.6	0.72	77.5	4.68	9.7	0.159	120

[a] 12 min and 3 min durations are for the experiments with the 50 mm pier when the tests were stopped because the scour hole reached the bottom of the sediment bed before reaching the test duration target of 120 min.

Results and Discussions

Current-alone Cases: Twelve current-alone experiments were conducted: six experiments with movable bed and six with fixed bed. In these experiments, a distinct inverted truncated cone-shaped scour hole was consistently observed around the piers. As an example, **Figure 2a** shows the scour hole around the 50-mm pier under Test 2 condition with movable bed. The PIV results for these cases produced fully formed vortices downstream of the pier. In **Figure 2b**, the flow field around the 50-mm pier under Test 2 condition with fixed bed is shown, as an example. In this figure, the red half-circle is half of the pier, and the yellow lines surrounding it represent streamlines around the pier. The strength of vortices increased with flow velocity, and the stronger these vortices became, the further they carried sediment downstream.

The time-averaged velocity distribution around the 19-mm pier for the current-alone case (Test 13) shows that the flow velocity was close to zero immediately upstream of the pier and negative downstream of the pier (**Figure 3**). The stagnation point where the flow meets the pier justifies the velocity close to zero, and the swirling motion of the vortices resulted in negative velocity downstream of the pier. The sediment deposition downstream of the pier (shown in **Figure 2a**) was the result of the swirling motion in this area.

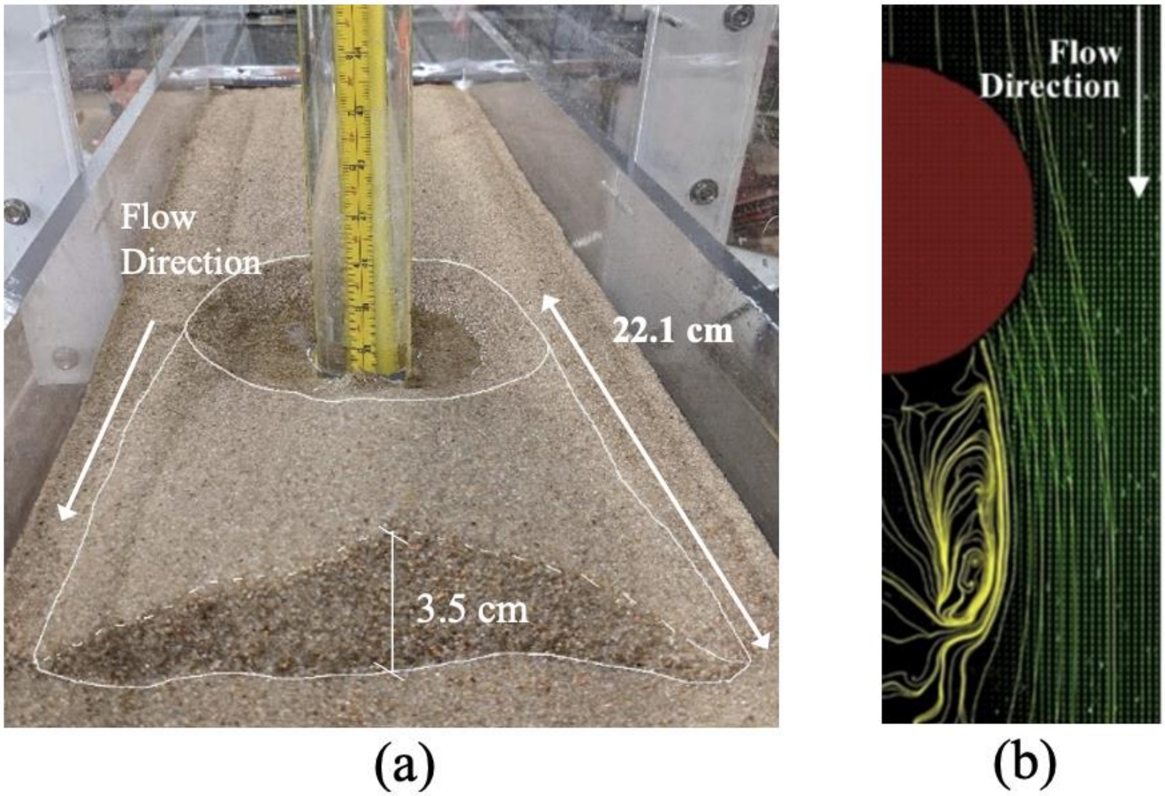


Figure 2. Current-alone experiments: Test 2 results with 50-mm pier: (a) Scour hole geometry (movable bed), (b) Flow pattern around the pier (fixed bed).

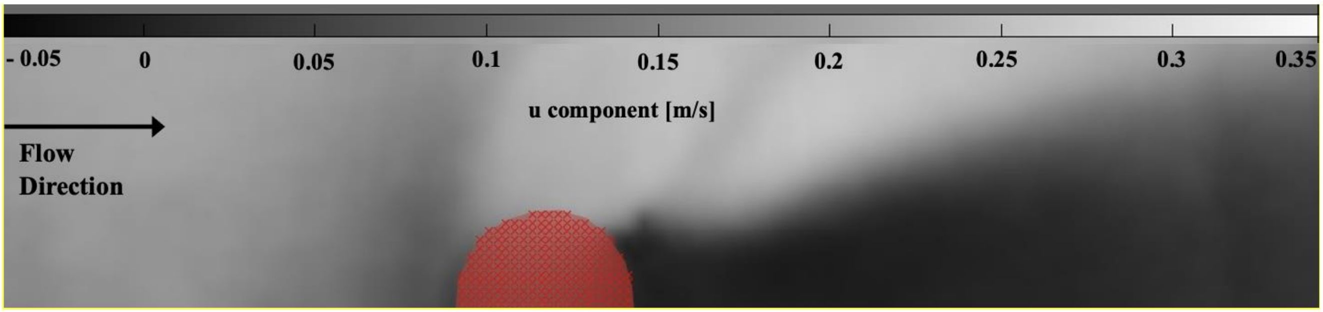
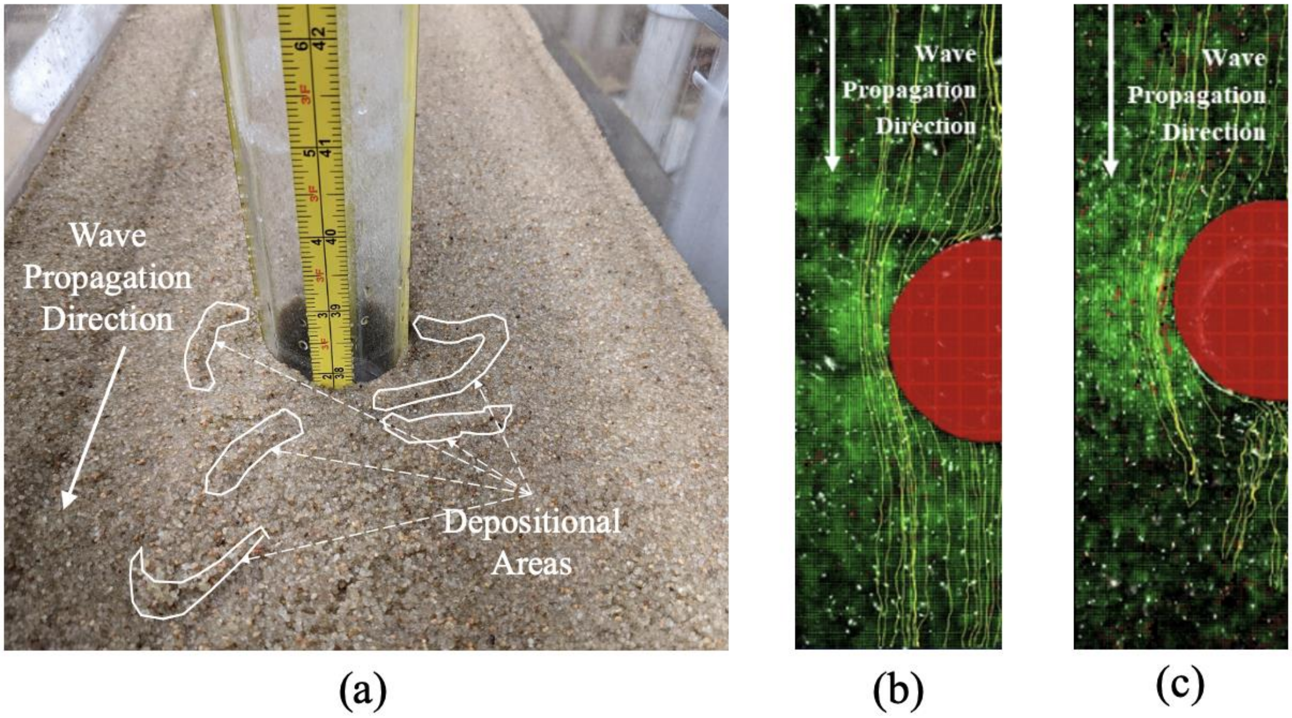


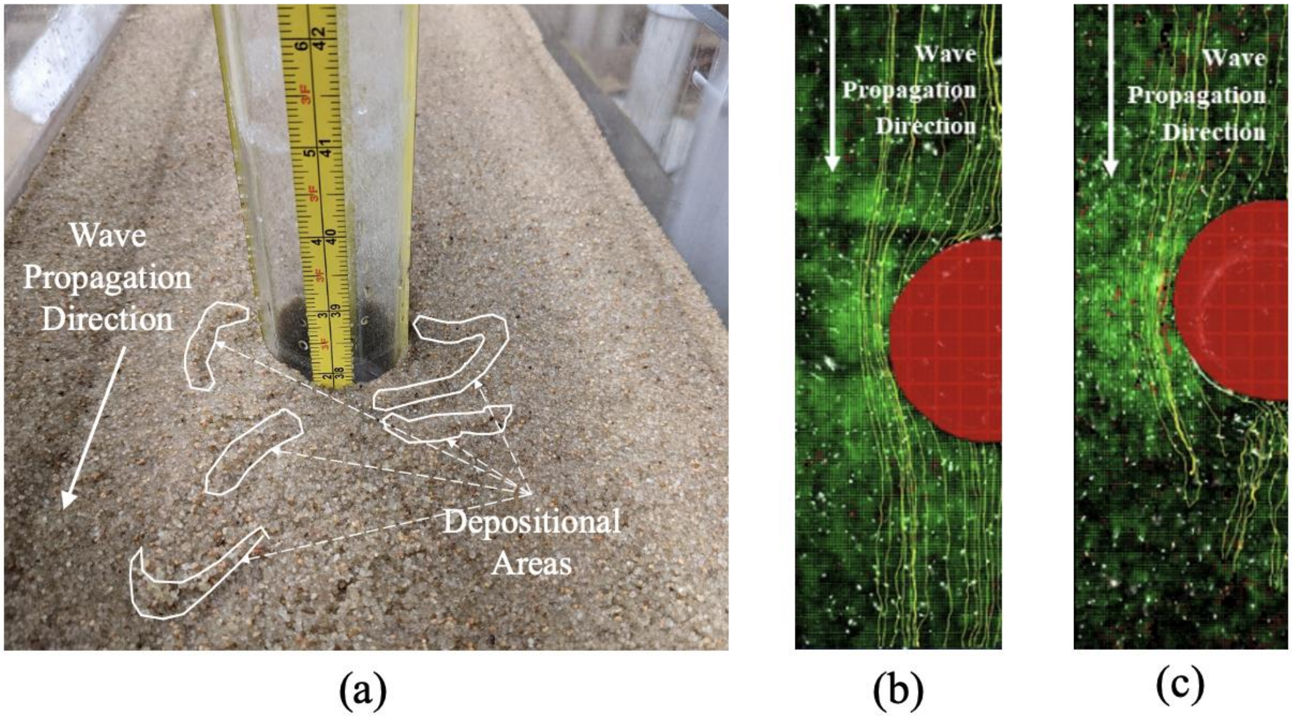
Figure 3. Time-averaged velocity distribution around the 19-mm circular pier (Test 13). The u-component represents the velocity along the flow direction.

Wave-alone Cases: Twelve wave-alone experiments were conducted. In the six movable bed tests, sand transport around the pier was minimal, but the maximum scour depth, which increased with higher *KC* numbers, was primarily noted on the sides of the pier. However, no consistent scour pattern emerged in experiments using the 50-mm pier (**Figure 4a**). The findings of Sumer and Fredsøe (2006) [5], which detailed the expected flow structures around cylinders in oscillatory flows with increasing *KC* numbers, were largely confirmed by the PIV results. At lower *KC* values (1.96 to 2.31), only flow separation occurred downstream of the pier without vortex formation (**Figures 4b and 4c**). At higher *KC* values (5.56 to 6.39), the flow field showed partially formed pairs of asymmetric vortices (**Figures 5b and 5c**). In **Figure 5a**, although less prominent than expected, a scour pattern resembling the twin-horn shape described by Kobayashi and Oda (2015) [6] was observed on the sediment bed.



(a) (b) (c)

Figure 4. Wave-alone experiments: Test 7 results with 50-mm pier (*KC* < 6): (a) Scour hole geometry (movable bed), (b) Flow pattern around the pier when wave crest crossing the pier (fixed bed), and (c) Flow pattern around the pier when wave trough crossing the pier (fixed bed).



(a) (b) (c)

Figure 5. Wave-alone experiments: Test 11 results with 19-mm pier (*KC* > 6): (a) Scour hole geometry (movable bed); (b) Flow pattern around the pier when wave crest crossing the pier (fixed bed), and (c) Flow pattern around the pier when wave trough crossing the pier (fixed bed).

Combined Wave-current Cases: In combined wave-current scenarios, the interaction between wave and current is more complex compared to wave-alone or current-alone cases. The U_{cw} parameter, calculated using Equation 1, represents the ratio of wave and current components in combined wave-current flows:

$$U_{cw} = \frac{U_c}{U_c + U_m} \qquad (1)$$

In this equation, U_c is the undisturbed current velocity at the distance $D/2$ from the bed representing the near-bed current velocity (D = pier diameter), and U_m is the maximum value of the undisturbed orbital velocity at the bottom, just above the wave boundary layer. The value of U_{cw} varies between 0 and 1, with $U_{cw} = 0$ and 1 representing the wave-alone and current-alone conditions, respectively. At $U_{cw} \geq 0.7$, only the current component is significant [3].

In the 14 combined wave-current experiments (seven with movable bed and seven with fixed bed), U_{cw} values ranged from 0.53 to 0.63, indicating a predominance of current in the flow. Despite the opposing wave propagation, streamlines in PIV images depicted water movement primarily in the current direction (**Figure 6**). The scour hole observed was typically an inverted truncated cone, similar to those in the current-alone cases. The presence of waves significantly influenced the flow dynamics by disrupting the formation of current-induced vortices which was evident from the PIV results. **Figure 7a** illustrates negative velocities caused by the wave half-cycle moving opposite to the current, indicating the significant effect of waves in these scenarios. Conversely, **Figure 7b**, where wave and current directions are aligned, shows higher local velocities. Since the wave effect could somewhat neutralize the current effect, it led to shallower scour depths than those caused solely by current. The scour depth in these cases increased with the increasing U_{cw} values. The downstream deposition was much more gradual and smoother than in the current-alone cases. When the water depth was low and the wave trough was closer to the flume bottom, it stirred up the bed materials easily and the current carried them downstream. In deeper waters, however, wave-induced local velocity could not stir up the bed material as easily, reducing sediment transport downstream.

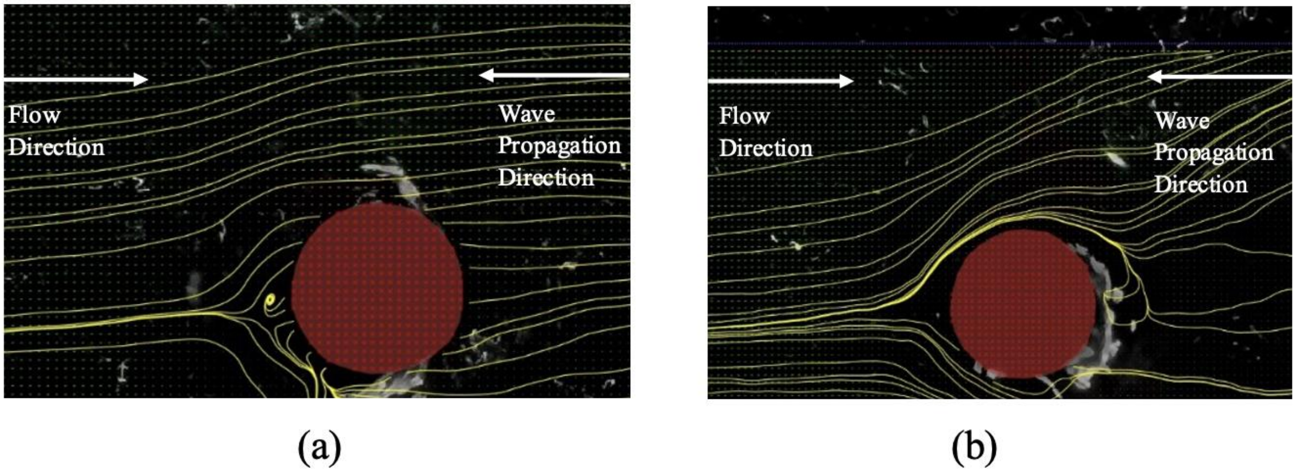


Figure 6. Wave-current combined experiments: Flow field around the 19-mm pier in Test 17 with $KC = 4.5$: (a) Wave crest area crossing the pier, (b) Wave trough area crossing the pier.

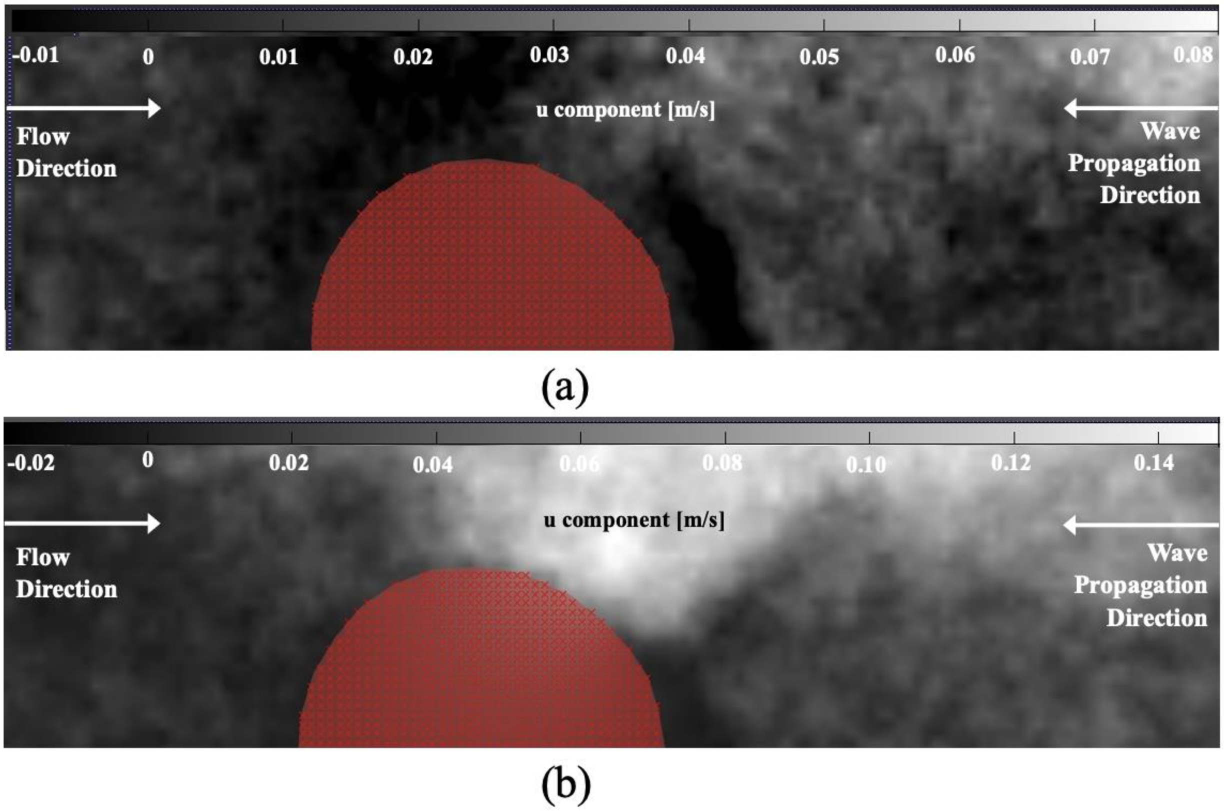


Figure 7. Typical mean velocity field around the 50-mm pier for combined wave-current cases (Tests 13 to 16: (a) Wave-induced local flow direction opposite to the current direction, (b) Wave-induced local flow in the same direction as the current. The *u*-component represents the velocity along the flow direction.

Conclusions

In this study, the relationship between flow patterns and the geometry of the scour hole around bridge piers under different flow conditions was examined. For current-alone cases, fully developed wake vortices were noted, with the vortex characteristics (size and strength) changing with the flow velocity. This led to an inverted truncated cone-shaped scour hole and a trapezoidal deposition pattern downstream. Wake vortices observed in the PIV images justified the geometry of the scour hole and depositional areas downstream of the pier.

In the wave-alone cases, flow separation was the only flow feature observed in experiments with lower *KC* values, whereas vortices formed around the pier in experiments with higher *KC* values. In experiments with lower *KC* values, no definite scour pattern was detectable. For the higher *KC* values, a partially developed twin-horn shape was observed, with maximum scour occurring on the sides of the pier. The wave-induced local flow velocity was too small to create horseshoe vortices; therefore, no scour was observed on the upstream and downstream sides of the pier.

In the wave-current combined cases, the relative flow in the current direction justified the shape of the scour, and the depositional pattern was similar to those observed in current-alone cases. The depth of scour in these scenarios was smaller than that caused solely by the current-alone but larger than that created by the wave-alone, underscoring the significant impact of wave action in these mixed conditions. The waves caused scoured materials to be transported further downstream and resulted in smooth rounded edges at the tail of the deposition area.

Based on the findings of this study, future research is recommended to provide a revised formula or construct a new relationship suitable for combined wave-current flow conditions. The flow structure around a group of piles with different arrangements should also be investigated. Future research may cover the effect of a wider range of relative flow velocity (U_{cw}) and wave height on the flow parameters. Future studies are required to investigate different angles of wave propagation concerning the direction of the current. Investigating the effect of the relative angle between the current and wave and the structure is another scope for future work. It is suggested to explore the effect of irregular waves around piers and the resulting scour as well. Flow hydrodynamics affect not just the bridge substructure but also the superstructures. Therefore, along with the substructure (piers), future studies should investigate the flow patterns around other components of transportation systems in different flow conditions. Further work on the above-mentioned areas would be very helpful in understanding the effects of flow structure around piers under different flow conditions.

More details on this study, experimental setup, and results are accessible using the following link: https://ascelibrary.org/doi/abs/10.1061/JWPED5.WWENG-2022.

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Index

Virtual Training

Mark Bailey,
Indiana Department of Transportation

Need to train a new grad or summer intern? Looking to brush up on something that you have not done in a while? Virtual Training may be the way to go!

When it comes to virtual training there are a few major categories where knowledge can be found. The traditional NHI courses, training sessions offered by various States, and the FHWA YouTube videos are all great sources of information. The classic google search should not be overlooked either, as several universities share their research on the topics and software that we need to do our engineering designs and keep the public “flowing” along the highways of our country.

The NHI offers several classes for free as well as virtual instructor led classes and web-conference training courses. Visit NHI’s website and type “hydraulics” in Search for a Course to see all their offerings.

I facilitated the creation of online training courses at the Indiana DOT to educate new employees and our consultants on the intricacies of completing hydraulic designs for Indiana. An additional goal was to improve the quality and consistency of consultant submittals, which reduced the number of resubmittals as well as decreased the review time creating a win-win for the DOT and our consultant partners. Our courses cover non-INDOT projects which drain to State right-of-way and require a permit, small structure (culvert) hydraulic design, storm sewer and detention, as well as bridge hydraulic design and are required under the prequalification process to submit a permit application or respond to a request for proposal for a project whose scope includes a hydraulics related work type. If you would like to explore INDOT’s courses, here is a link to the instructions for registering for an account as well as the course descriptions.

Some universities also share presentations given at their conferences such as the Road School Transportation Conference and Expo hosted by my alma mater Purdue University. Additionally, the University of New Hampshire has partnered with the Infrastructure & Climate Network to offer a series of webinars focused on climate science and transportation engineering research.

While working on this article, I was surprised to find that there are hundreds of videos on YouTube covering HEC-RAS and dozens of videos on HY-8.

Some Useful Websites/Weblinks

Mark Bailey, Indiana DOT
Roberto Ruiz, South Carolina DOT
Charles Hebson, Maine DOT

Many of us keep a list of useful websites for our work. See below for many of our go-to's.

- FHWA
  - Hydraulics: Hydraulics - Bridges & Structures - Federal Highway Administration (dot.gov)
  - Resilience: Resilience - Sustainability - Environment - FHWA (dot.gov)
- Topographic Maps
  - USGS National Map
  - USGS Historic Topo Maps
  - Tools for Google Earth: https://www.earthpoint.us/topomap.aspx
- USDA soils data
  - Online soils map viewer
  - Digital geographic databases
  - Web Soil Survey
- Flood History Data
  - NOAA
    - Atlas 14 Rainfall Data
    - NOAA Local Climatological Data:
      - https://www.ncei.noaa.gov/products/land-based-station/local-climatological-data
  - USGS
    - USGS Flood Event Viewer
    - USGS gage rating curves
    - USGS StreamStats
    - USGS National Water Information System Mapper
    - USGS PeakFQ program for computing flood frequency for gage data
    - USGS National Map Viewer
  - FEMA FIRM and FIS information
    - FEMA Flood Map Service Center
  - Dam Information
    - USACE National Inventory of Dams
  - Manning's n-values
    - Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains
    - Roughness Characteristics of Natural Channels
    - USGS Verified Roughness Characteristics of Natural channels
  - Tidal / Coastal Design
    - NOAA Center for Operational Oceanographic Products and Services (CO-OPS)
    - NOAA Data Access Viewer: https://www.coast.noaa.gov/dataviewer/#/
    - NOAA VDATUM: https://vdatum.noaa.gov/vdatumweb/
    - NOAA Tidal Datum Calculator: https://access.co-ops.nos.noaa.gov/datumcalc/
    - NOAA Inundation Dashboard
    - Coastal LiDAR data from NOAA's Coastal Services Center
    - National Data Buoy Center (NDBC)
    - NOAA Historical Hurricanes
    - ASCE Standard 7-16 Windspeeds
    - Sea-Level Change Curve Calculator
    - Sea-Level Rise Viewer
    - Coastal Hazards System, V2.0
    - Coastal Emergency Risks Assessment (CERA)
    - North Atlantic Coast Comprehensive Study
    - USGS Vector Shorelines for US Southeast Atlantic Coast

River WebCams of the South Atlantic Water Science Center (Georgia, North and South Carolina)

Index

Calendar of Events

2024 National Hydraulic Engineering Conference

AUGUST 27-30, 2024
BEAU RIVAGE | BILOXI, MS
2024 NHEC (ms.gov)

2025 TRB Annual Meeting

January 5-9, 2025
Washington D.C.
nationalacademies.org/event/885_01-2025_2025-trb-annual-meeting

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Mike Hogan at: michael.hogan@ct.gov

For more information on the Technical Committee on Hydrology and Hydraulics, see:

https://transportation.org/design/technical-committees/hydrology-and-hydraulics/

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