Transportation Pooled Fund Program TPF-5(552) Quarterly Progress Report

Quarter 4, October – December 2025

prepared by
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TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): _FHWA___________________________________

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e., SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*	**Transportation Pooled Fund Program - Report Period:**
TPF-5(552)	☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☒Quarter 4 (October 1 – December 31)

Project Title:
High Performance Computational Fluid Dynamics (CFD) Modeling Services for Highway Hydraulics

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
James Pagenkopf	*(202) 493-7080*	*james.pagenkopf@dot.gov*
Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**

Project schedule status:

☒ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date

Project Description:

The Federal Highway Administration established an Inter-Agency Agreement (IAA) with the Department of Energy's (DOE) Argonne National Laboratory (ANL) Transportation Analysis Research Computing Center (TRACC) to get access and support for High Performance Computational Fluid Dynamics (CFD) modeling for highway hydraulics research conducted at the Turner-Fairbank Highway Research Center (TFHRC) Hydraulics Laboratory. TRACC was established in October 2006 to serve as a high-performance computing center for use by U.S. Department of Transportation (USDOT) research teams, including those from Argonne and their university partners. The objective of this cooperative project is to:

- Provide research and analysis for a variety of highway hydraulics projects managed or coordinated by State DOTs.
- Provide and maintain a high-performance Computational Fluid Dynamics (CFD) computing environment for application to highway hydraulics infrastructure and related projects.
- Support and seek to broaden the use of CFD among State Department of Transportation employees.

The work includes:

- Computational Mechanics Research on a Variety of Projects: The TRACC scientific staff in the computational mechanics focus area will perform research, analysis, and parametric computations as required for projects managed or coordinated by State DOTs.
- Computational Mechanics Research Support: The TRACC support team consisting of highly qualified engineers in the CFD focus areas will provide guidance to users of CFD software on an as needed or periodic basis determined by the State DOTs.
- Computing Support: The TRACC team will use the TRACC clusters for work done on projects; The TRACC system administrator will maintain the clusters and work closely with the Argonne system administrator's community; The TRACC system administrator will also install the latest versions of the STAR-CCM+ and OpenFOAM CFD software and other software that may be required for accomplishing projects.

Progress this Quarter:
(Includes meetings, work plan status, contract status, significant progress, etc.)

1: Computational Mechanics Research on a Variety of Projects

1.1. Noise Wall Drainage Window Modeling

The main goal of the project is to design an 81"-tall noise barrier with drainage window which is meant to be installed along Ohio highways in on-grade and sag conditions. The general parameters for the modeling of hydraulic efficiency, defined as the percentage of intercepted flow to the total flow for an on-grade scenario, are as follows:

- Shoulder section with a 2-inch depression at the face of the barrier,
- Roadway longitudinal profile grades at the following slopes: 0.25%, 0.5%, 1%, 3%, and 5%,
- Shoulder section width of 4' and 10' at a 4.0% shoulder cross slope and a 1.6% pavement cross slope
- For flow spreads: 2, 4, 6, 8, and 10 feet.

The hydraulic capacity of flow relative to the depth of ponding in a sump condition is analyzed for the following flow depths: 2, 4, 6, 12, and 18 inches.

The sensitivity study performed to obtain a geometry of the window which satisfies the design requirements resulted in a 10 to 12-foot-long, 6-inch-tall rectangular opening which tapers to the outside with a 0.08 slope. The selected geometry ensure the required hydraulic performance of the inlet and reduces the risk of clogging with roadside debris.

Figure 1 (left) shows the hydraulic performance curves obtained computationally for the inlet for a range of longitudinal slopes and flow rates, and a wide range of window lengths, from 10 ft to 20 ft. The inlet performance in sump conditions was also tested and the water depth vs. flow rate curves were plotted in the figure (right).

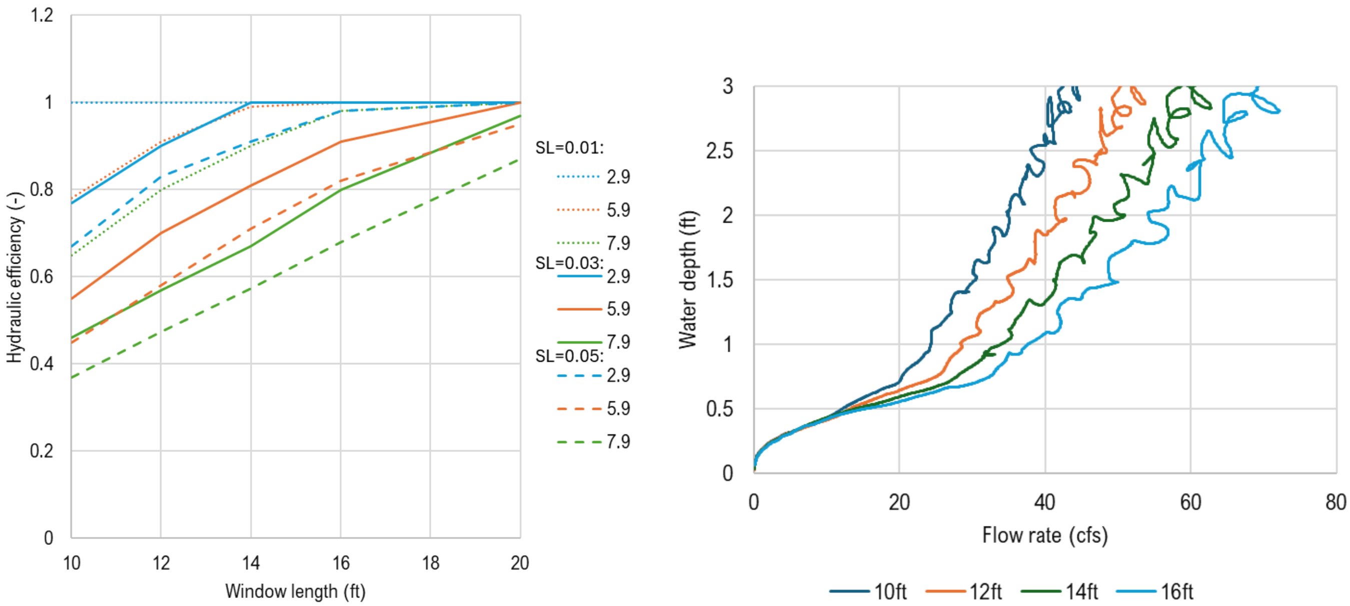

Figure 1. Hydraulic efficiency curves for the new design on a grade (left) and hydraulic capacity in sump (right).

1.2. Internal Culvert Energy Dissipators

Site retrofits are becoming a common approach to extend culvert performance life. These typically include full circumference lining of an existing conduit, typically with HDPE although other materials can be used, or partially treating the invert. Both approaches may lead to changes in hydraulic performance of the culvert, due to a decrease in the cross-sectional area of the pipe, reduction of the internal hydraulic roughness, etc. The potential increase in flow velocities may be countered by introducing baffles or ripraps, which act as internal energy dissipators in culverts operating in inlet control.

Conduit design includes using Manning's roughness coefficients to compute cross section averaged flow parameters. However, the hydraulic parameters of retrofits under varying conditions including composite Manning values are not well known. Varying conditions include but may not be limited to:

- headwater to culvert depth (HW/D) ratios (0.1-1.50),
- culvert slope (0.5% - 10%),
- culvert size and shape,
- obstruction configuration

Colorado DOT reached out to ANL researchers to perform a computational analysis of various scenarios of culverts and energy dissipators in order to compare the difference in the outlet flow depth, velocity for the retrofit with and without the baffle configurations. Also, CDOT is interested in the best estimation of the composite Manning roughness coefficient inside the barrel for each configuration tested.

The study started with developing models of pipes with hydraulically smooth surfaces, without any baffles and with uniformly spaced baffles. Figure 2 shows the flow in a culvert without baffles (left) and with baffles (right) at the same geometry and upstream flow conditions. The addition of baffles significantly slow down the flow velocity and increases the depth along the culvert. The impact of baffles on the flow was visualized by introducing a few spheres with the characteristics of ping pong balls at the upstream end of the pipe. Their residence time, the time needed to travel the entire length of the culvert, increased about five times when the baffles were introduced.

Figure 3 shows the velocity vectors and magnitude on a vertical plane along the centerline of the culvert (flow from left to right). Each of the baffles is an obstruction to the flow which creates a large eddy (flow recirculation) immediately downstream of the baffle and therefore reduces the bulk flow velocity.

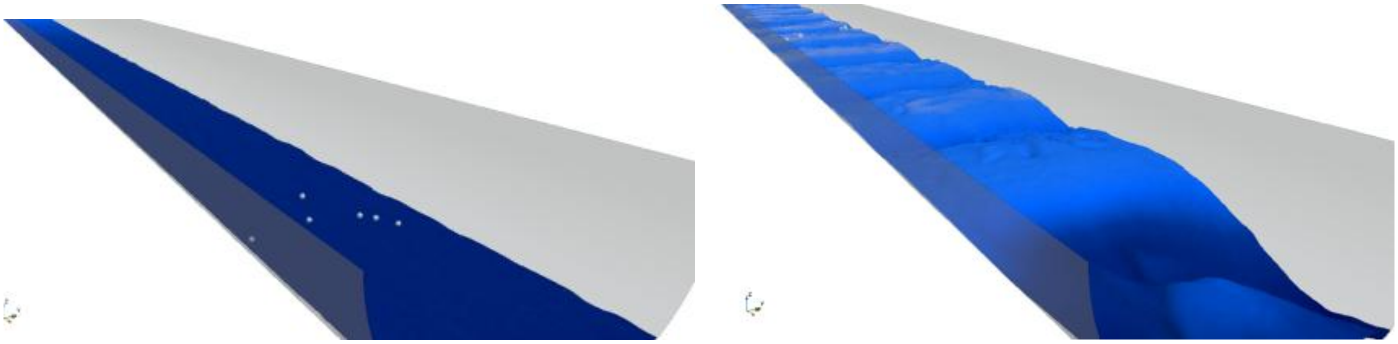

Figure 2. Flow in a culvert without baffles (left) and with baffles (right) at the same geometry and upstream flow conditions.

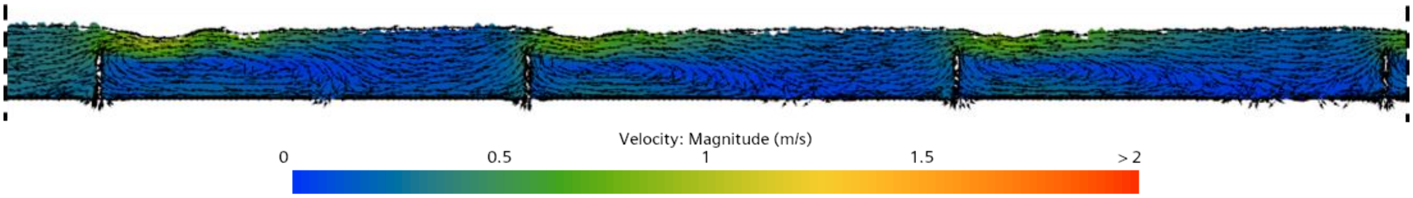

Figure 3. Velocity vectors on a cross-section along the culvert.

The study will continue with a more detailed analysis of the impact of varying baffle configurations at different flow rates and culvert slopes.

Anticipated work in the next quarter:

1: Computational Mechanics Research on a Variety of Projects

- hydraulic analysis of catch basins on grade and in sump
- culvert hydraulics
- modeling of water film on pavements

2: Computational Mechanics Research Support

This work will continue.

Task 3: Computing Support

This work will continue.

Circumstance affecting project or budget.

(Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.