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

Quarter 2, April – June 2026

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. Internal Culvert Energy Dissipators

This research evaluates internal energy dissipation measures for retrofitted culverts, with a focus on how baffles can offset the hydraulic impacts of smooth culvert liners. When older corrugated culverts are lined with smoother materials such as HDPE, the culvert often conveys flow more efficiently, which can unintentionally increase outlet velocities and create poor downstream conditions, including challenges for fish passage. The study investigates whether adding internal baffles can restore resistance and reduce these adverse effects.

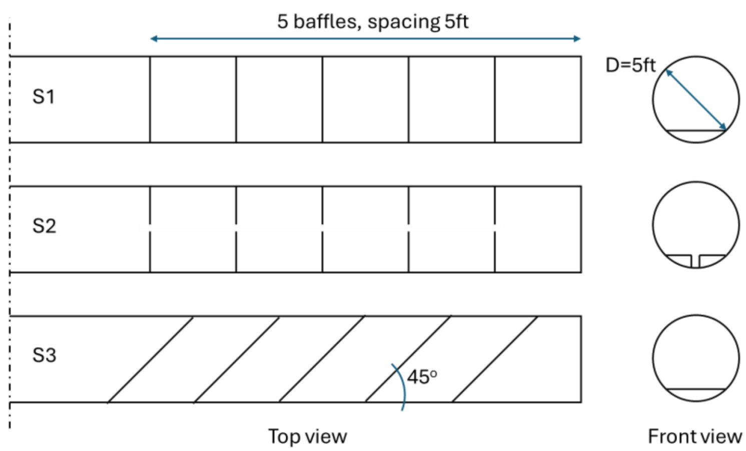

Figure 1. Downstream culvert section with considered baffle configurations (5 baffles). S1 - perpendicular baffles, S2 - perpendicular baffles with a thalweg gap, S3 - baffles at 45 deg.

The reduced screening matrix includes:

- slopes: 0.005, 0.05, and 0.10 ft/ft,
- headwater ratios: HW/D = 0.10, 0.75, and 1.50,
- baffle counts: 5 and 15 for the baffle-based scenarios,
- scenarios: baseline plus 3 internal treatment configurations.

which gives 72 CFD simulations to establish the dominant sensitivities and identify the effective operating envelope. Stage 2 is a refinement campaign which fills the interpolation gaps identified by the screening results and resolves transition behavior.

In this work, a combination of standard culvert inlet-control equations and three-dimensional computational fluid dynamics (CFD) simulations to assess hydraulic performance, is used. The study examines a 100-ft-long, 60-in-diameter HDPE-lined culvert under multiple slopes, headwater-to-diameter ratios, and internal treatment configurations. Four cases were considered: a baseline culvert with no dissipation features, perpendicular baffles, perpendicular baffles with a thalweg gap, and 45-degree skewed baffles (see Figure 1).

The main finding is that baffles can significantly reduce outlet velocity, but their effectiveness depends strongly on hydraulic conditions. They perform best in steeper culverts and under low to moderate headwater conditions, where they can reduce outlet velocity by roughly 16% to 47% and substantially increase hydraulic resistance. Under mild slopes or highly submerged conditions, their benefit is much smaller (see Table 1).

Table 1. Percentage reduction of outlet velocity from baseline (%).

Slope	HW/D	S1-5	S1-15	S2-5	S2-15	S3-5	S3-15
0.05	0.10	36.4	36.1	36.4	35.7	40.3	40.3
0.05	0.75	16.4	21.7	16.4	20.2	29.6	31.7
0.05	1.50	-0.2	0.9	-0.9	1.1	0.4	3.9
0.10	0.10	43.9	43.4	43.9	43.4	46.2	46.9
0.10	0.75	24.7	27.7	24.7	27.7	34.4	38.3
0.10	1.50	2.8	6.6	2.8	6.6	5.3	9.8

Among the configurations studied, 45-degree skewed baffles consistently performed best. They generated the greatest velocity reductions, the largest increases in effective resistance, and the strongest reductions in outlet Froude number. In contrast, the perpendicular baffles with and without a thalweg gap behaved almost identically from a bulk hydraulic standpoint, suggesting that the thalweg gap may matter more for sediment, debris, or constructability considerations than for overall flow resistance.

A key contribution of the study is the development of effective Manning's roughness coefficients derived from CFD results. Because the hydraulic effects of baffles are localized and flow-dependent, these values are not true material roughnesses but rather equivalent resistance parameters that reproduce the overall hydraulic response. This makes the results more useful for engineering practice, since they can support simpler one-dimensional culvert analyses and screening calculations.

Overall, the research shows that internal dissipation retrofits can be an effective strategy for managing increased velocities in lined culverts, especially where full culvert replacement is impractical. However, the study also concludes that baffles alone are generally not enough to make outlet flow subcritical in steep culverts, so additional design measures may still be needed where fish passage or downstream stability is a priority.

1.2. CFD Modeling of DI 36×36, DI 112, DI 125, CB 9, and CB 18 Roadway Drainage Inlets

An Excel design-aid workbook, which helps a user select an inlet type and scenario, then automatically matches that choice to the correct CFD case and fills in the related data, is being developed for South Carolina DOT. The spreadsheet pulls information from a case library, builds dropdown menus for user selection, and organizes the results into user-facing and technical tabs. The workbook then uses the selected case's depth–flow data to interpolate two key design checks: the depth required for a given design flow and the flow capacity available at a given allowable depth. Finally, it summarizes those results in a design-check sheet.

The spreadsheet acts as a structured decision-support and design-check tool that allows engineers to screen inlet options, retrieve the correct CFD-based hydraulic response for each case, and evaluate performance without manually sorting through raw model outputs. However, this workbook is still a work in progress and not yet in its final form. Further refinement, testing, formatting improvements, and possible changes to workflow, inputs, and outputs are expected as development continues. Additional work will be performed to ensure the tool is aligned with and ultimately meets the sponsor's expectations and project needs.

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.