Transportation Pooled Fund Program TPF-5(446) Quarterly Progress Report

Quarter 2, April - June 2020

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 current 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)* *TPF-5(446)*	**Transportation Pooled Fund Program - Report Period:** ☐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): *Kornel Kerenyi*	**Phone Number:** *(202) 493-3142*	**E-Mail** *kornel.kerenyi@fhwa.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+ 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: Computational Fluid Dynamics Modelling of Hydraulic Capacity of Drainage Structures

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 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 two state Departments of Transportation: South Carolina, SCDOT, and Ohio, ODOT, to perform an evaluation of drainage used on highways. SCDOT catch basin types CB16 and CB17 are curb opening inlets, which are 4-feet and 8-feet long, respectively. Inlets CB3 and CB3A are a combination of a grate inlet and window, the first one installed as single, and the other as a double grate.

The project is ongoing and computational models of cases from the test case matrix are being developed and analyzed. Example results will be presented in the following sections.

1.1.1. SCDOT catch basin study.

The purpose of the catch basin is to intercept water from one direction of the road, i.e. from the road crown to the median, which covers a 12-feet wide travel lane and a 1.5-feet wide gutter. The test case matrix includes simulations for: two cross-slopes, 0.5% and 2%, nine longitudinal slopes, from 0.3% to 16%, and initially 5 flow rate values for each case set. Figure 1 presents computational results for CB16. The efficiency of the curb opening was established for varying geometry of the road and flow rate. For small grades and lower flow rates the efficiency of the drain exceeds 50%, but drops to approximately 15% for the highest considered flow rates and road grades.

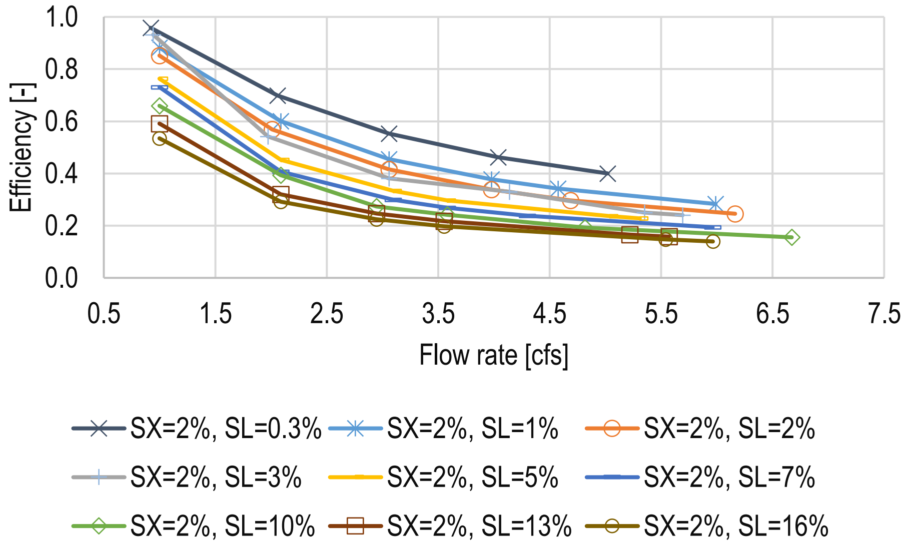

Figure 1. Computational (CFD) efficiency curves for CB16 for a road with 2% cross-slope and varying longitudinal slope and flow rate.

1.1.2. ODOT catch basin study.

CFD simulations of flow on a road (1.6% cross slope) with a 2-foot gutter (8.33% cross slope) and varying longitudinal slope (0.25% - 8%) in on-grade conditions were performed for spread range from 2 feet to 8 feet. The computationally obtained hydraulic efficiency of the drain vs. flow rate was presented in Figure 2. Separate efficiency curves are plotted for different longitudinal slope. The efficiency of the grade for smaller flow rates is close to 100%. As expected, it drops for increasing grade and flow. In the tested range of parameters, the efficiency does not fall below 62%, which means that most of the flow on the road is intercepted by the drain. Figure 3 shows the percentage of the flow flowing through the front and side of the grate, vs. longitudinal slope. Most of the flow enters the grate through the front. The most flow enters through the side surface for a combination of relatively small grades with small pool spread (flow rate) values. The highest fraction of side flow is just above 20%.

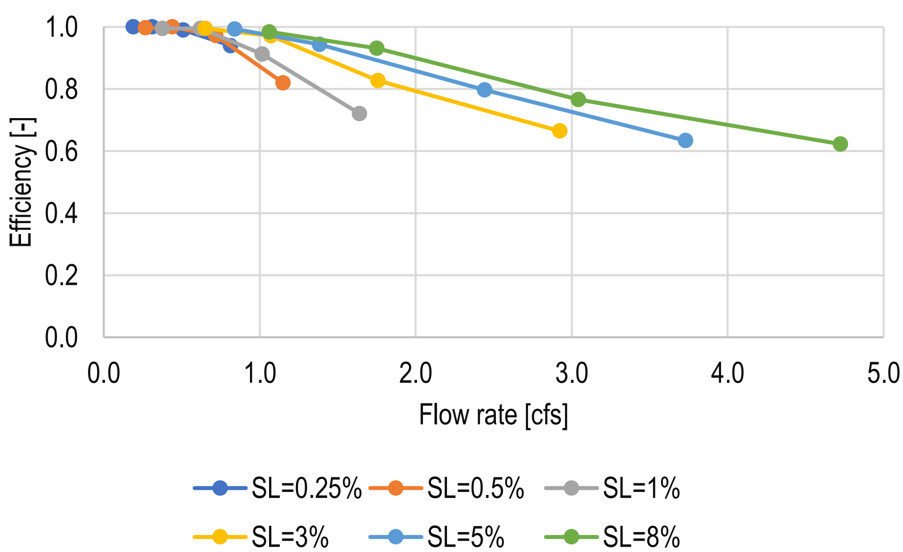

Figure 2. Computational (CFD) efficiency curves for CB3A for varying longitudinal slope and flow rate.

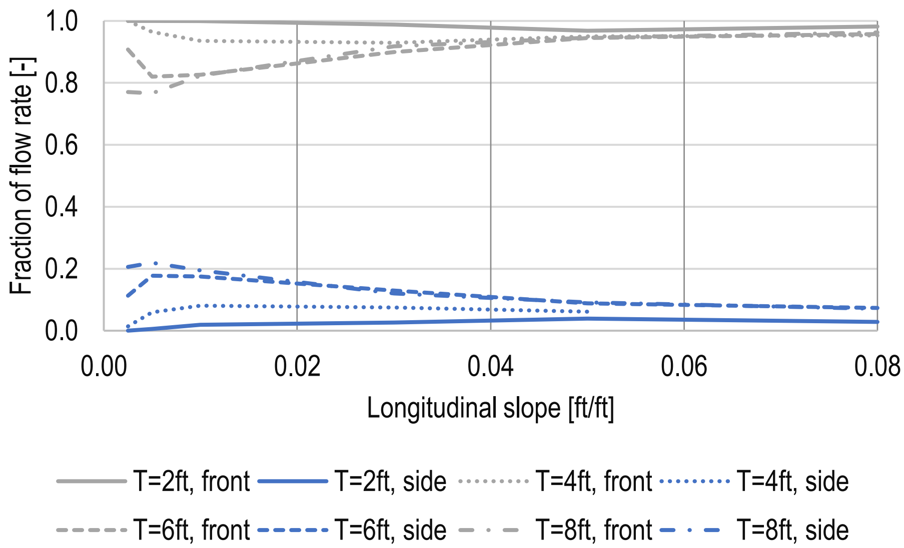

Figure 3. Percentage of flow flowing through the front and side of the grate obtained in the simulations.

2: Computational Mechanics Research Support

Argonne Transportation Research and Analysis Computing Center (TRACC) computational mechanics staff ran nationwide videoconferences every other Thursday that were open to state Department of Transportation staff and university researchers supported by the Federal Highway Administration or state DOTs. The videoconferences provide a venue to discuss approaches and issues related to hydraulics modeling projects. Topics during this reporting period included, but were not limited to:

- new methodologies of scour modeling,
- approaches to modeling and mitigating hydroplaning risk,
- hydraulic analysis of catch basins,

3: Computing Support

Routine cluster maintenance including software and hardware upgrades, security patching against cyber threats, and development of custom tools to increase users' productivity. Currently working on upgrading the TRACC clusters to support the latest scientific and engineering software utilizing industry's best practice guidelines in Open-Source software and virtualization.

Anticipated work next quarter:

1: Computational Mechanics Research on a Variety of Projects

- development of a new methodology for riverbed scour
- hydraulic analysis of a catch basins
- analysis of water film thickness 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, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.