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 #	**Transportation Pooled Fund Program - Report Period:**
TPF-5(248)	☐Quarter 1 (January 1 – March 31) 2012 √Quarter 2 (April 1 – June 30) 2012 ☐Quarter 3 (July 1 – September 30) 2012 ☐Quarter 4 (October 1 – December 31) 2012

Project Title:
Enhancements to the FHWA-FST2DH Model for Simulating Two-dimensional Depth-averaged Flow and Sediment Transport

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
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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:

FST2DH is FHWA's Two – Dimensional Hydraulic Model for modeling flows in floodplains and through complex bridge openings. The model was developed more than ten years ago and since that time many improvements have been made in computational capability. The program needs to be modified to take full advantage of these capabilities. Additionally, much advancement has been made to the computer hardware that is needed to solve the complex series of equations used by the program. Numeric algorithms for solving simultaneous series of equations have continued to evolve and computers with multiple cores that can speed up the solution times by a factor of ten are now the norm. From an engineering perspective, we are more frequently being asked to solve complex problems involving multiple bridge openings, different types of structures, multiple embankments that alter natural flow patterns, unsteady flows, sediment transport, and scour countermeasure design. Because of the increasingly more difficult types of problems that are routinely being encountered, the state-of–practice needs to continue to improve to keep pace.

The current version FST2DH is not suitable for modern computer standards and has to be improved. FST2DH is used by many sate DOT's to perform hydraulic modeling for bridge scour calculations. The objective of the study is to update the FHWA-FST2DH model for simulating two-dimensional depth-averaged flow and sediment transport.

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

Potential methods for the parallelization of the codes were investigated. One of the promising approaches was found to be the adoption of the Message passing Interface (MPI). The MPI standard was developed before multi-core processors existed, and it was developed to provide parallel processing on systems ranging from one dual processor PC or a few PCs networked together in a small organization to large high performance clusters. MPI works well on both shared memory systems and distributed memory systems. In a shared memory system, each process (core) simply has access only to the memory assigned to it. Preventing race conditions and deadlocks is not a significant issue with MPI because each process (core) only has access to its own assigned memory space on either shared or distributed memory systems. When processes do need to obtain variable values from other processes, for example the values of spatial or logical neighbors at a subdomain boundary that reside in the memory space of another process, these variable values are exchanged via the message passing paradigm using MPI. Thus instead of having critical code segments that must be locked allowing only one thread to execute the segment at a time to avoid race conditions that could corrupt shared memory that is read and written by more than one process, which can be bottlenecks with their own inefficiencies, when using MPI, the small amount of memory with values that need to be shared among processes is duplicated in the memory space of each process and kept up to date with message passing. The major CFD companies use MPI for their solvers, and for the cases where small problems are solved on single dual core PCs, the speed up in using both cores is nearly a factor of 2, which is excellent.
The development of hybrid algorithms that use both MPI with domain decomposition in what is sometimes referred to as coarse grained parallelism and multi-threading using OpenMP, pthreads, etc. for what may be termed fine grain parallelism is an area of active research that is still complex and challenging to get right. The major commercial CFD companies are still nearly universally using an MPI-everywhere approach because it works very well on everything from single dual or quad core PCs to large clusters.
To keep the parallelization of FST2DH software as simple, straightforward, and general as possible, and to keep the project within the current budget, an MPI only approach is requested. No effort need be spent on the implementation of multi-threading using OpenMP or equivalent. Using MPI to produce a parallel version of FST2DH that runs on a single multi-core machine, allows trivial extension in the future to, for example, run on 12 cores by using 3 quad core computers that are on a network in a small office.
The software requirements can be narrowed in scope as follows:

- Software code will be written in a standard, available software language and having compilers readily available to the Government (i.e., FORTRAN, BASIC, C++, etc).
- MPI will be used for inter-process communication and coordination among parallel processes running on different cores, and MPI versions of modern linear equation solvers, libraries, or packages will be used.
- MPICH, a freely available, portable implementation of MPI that works on both Microsoft Windows and most Linux and Mac OS X systems, will be used for parallel processing control and inter-process communication.
- Development, testing, and debugging of the parallel version of FST2DH will be done on a single multi-core computer.

- All software development tools used in producing the product will produce non- proprietary executable programs.
- The Government will be able to readily obtain these development tools and re-produce the software product.

Anticipated work next quarter:

- Finalizing the investigation on the approach for parallelization.
- Develop a multi-core processor version of the FST2DH software in accordance with the Software Requirements.

Significant Results:

Detailed description of all results will be included in the final documentation.

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).

No significant issue was identified.

Potential Implementation:

A parallel version of FST2DH that utilizes the computational power of modern high-performance computers.