Quarterly Progress Report

In-situ Scour Testing Device

TPF-5(210)

July 1, 2011 to September 30, 2011

The research work was initiated with a series of brainstorming sessions to harvest potential concepts that potentially produce the desirable flow conditions in the field and provide erosion rate measurement for undisturbed bed material.

A few concepts were suggested for further consideration:

1. Idea (1) Embedded nozzle direct shear approach

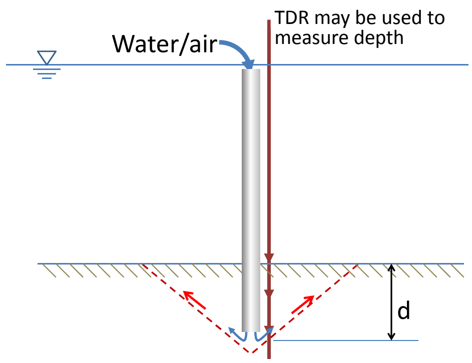

Figure 1 Idea (1) Embedded nozzle direct shear approach

Pros: Force is parallel to the failure surface
Cons: Soil may block the jet at the beginning. The water directly pushes soil away—not an erosion.

2. Idea (2) Surface nozzle impact/shear approach

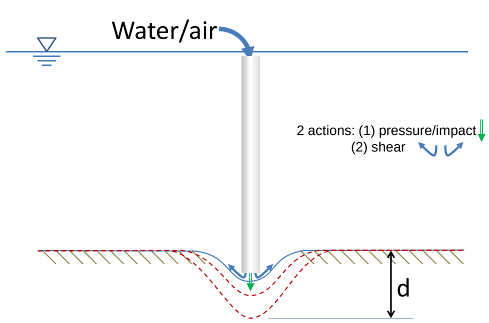

Figure 2 Idea (2) Surface nozzle impact/shear approach

Pros: More representative in shear stress.

Cons: Energy and shear aspect is not clear.

3. Idea (2-a) Surface nozzle impact/shear approach with a needle guide

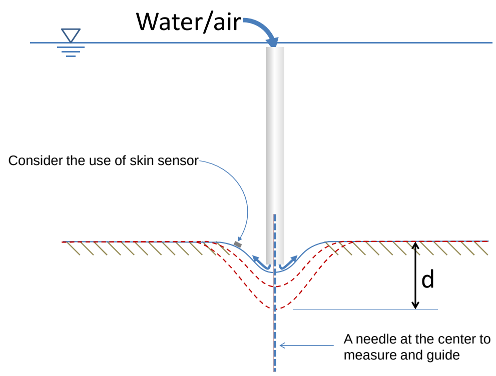

Figure 3 Idea (2-a) Surface nozzle impact/shear approach with a needle guide

4. Idea (3) Tent/bottomless pipe approach

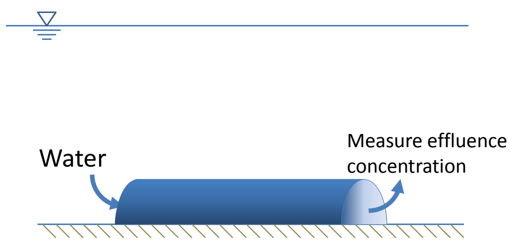

Figure 4 Idea (3) Tent/bottomless pipe approach

5. Idea (4) Panel division approach

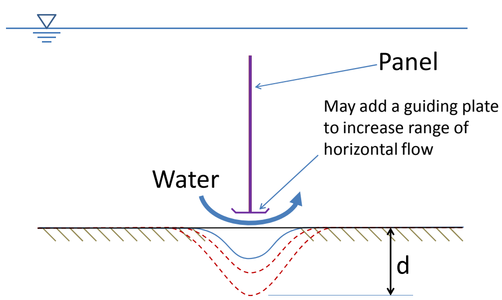

Figure 5 Idea (4) Panel division approach

6. Idea (5) Fully-encased mini flume

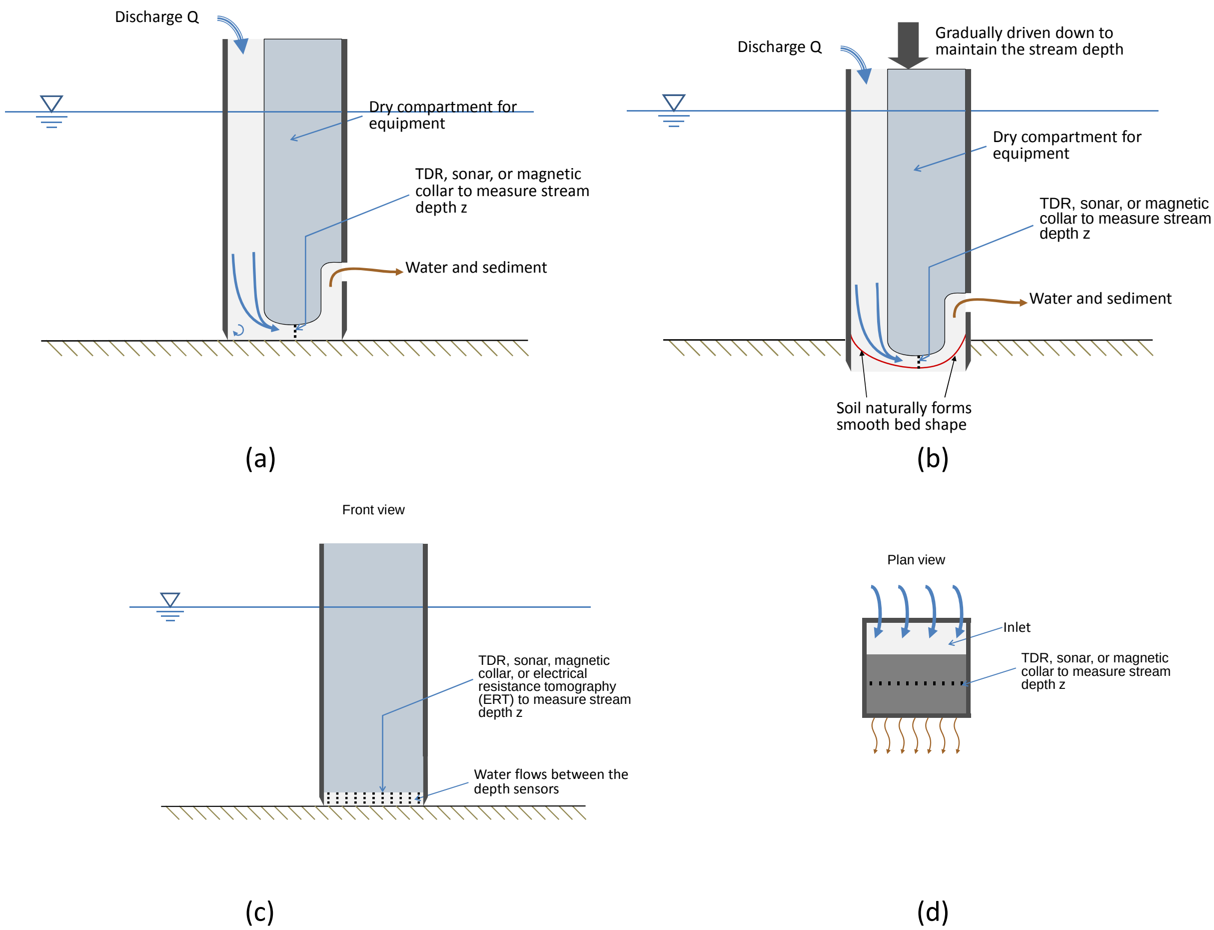

Figure 6 Idea (5) Fully-encased mini flume

7. Idea (6) Worm erosion device: Compact, mobile, resilient, and capable of deep probing.

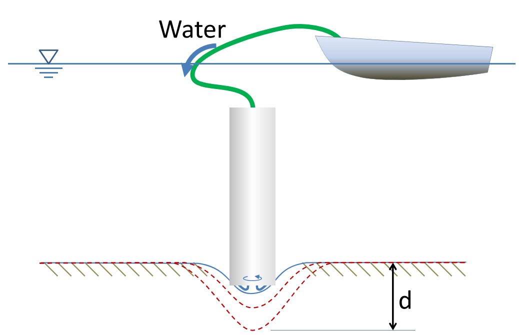

Figure 7 Idea (6) Worm erosion device

Literature and feasibility study was conducted for each potential concept and the better options were identified. CAD models were constructed for the best contenders for further investigation by analytical study, physical prototyping, and CFD simulation.

While the idea number 5, fully-encased mini flume, showed great potential in producing desired flow conditions, there could be a broad range of variation in geometry and detailing. It was unclear how each geometric parameter affected the flow conditions and which combination was the best. A conceptual computer model was built and tested in CFD simulation (Figure 8).

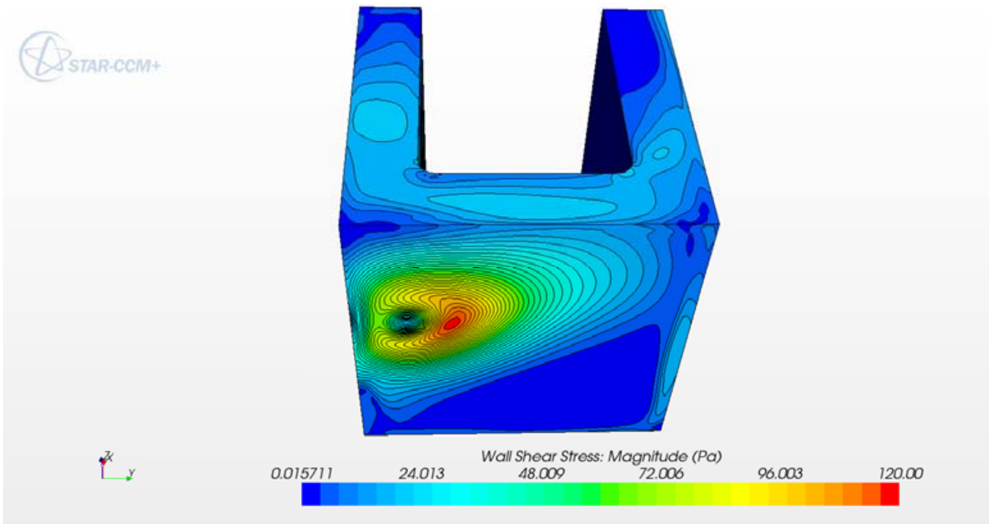

Figure 8 Conceptual model for CFD simulation

The result of CFD was shown in Figure 8. It was observed that the inlet pipe had a significant impact on the flow conditions in the test section. The jet from the high speed flow in the water supply pipe extended through a great distance in the device and produced a concentrated high-stress area near the test section. This jet must be avoided to get a uniform flow condition and consequently a uniform shear stress. A modified model was produced with a horizontal pipe input to smooth the water flow by creating a 90 degree change of the flow direction. The discharge of the pump was set to create a 0.5m/s velocity in the test section. The results of the CFD simulation showed nice velocity distribution without an impact of a jet:

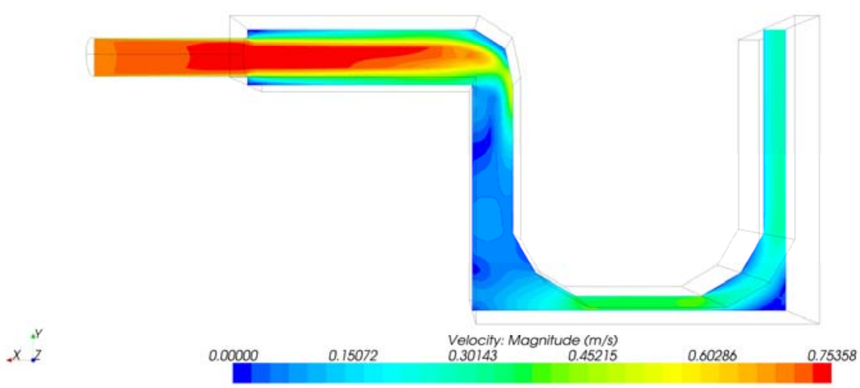

Figure 9 Modified model for reduced jet impact

Because of the good results from CFD simulation, a physical model was constructed with Plexiglas to conduct proof-of-concept testing.

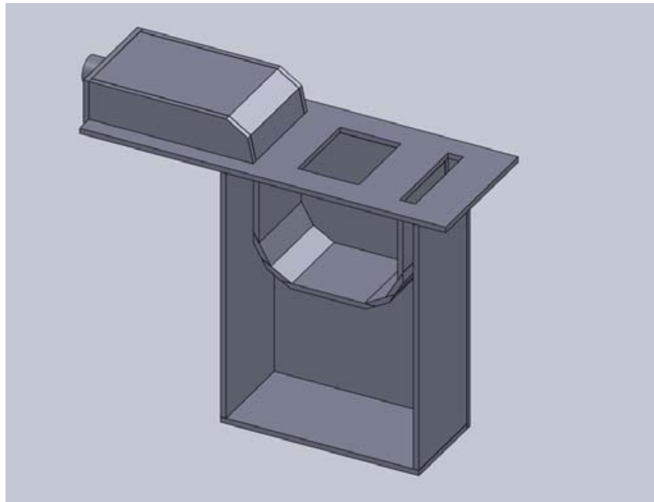

Figure 10 Proof-of-concept testing module

The bottom of the outer box was filled with sand (D_{50} = 1mm) that had an initial distance of 3cm between bottom of the U-shape and the sand. Because of the big dimensions the test device could not be used completely submerged. Because of this and because of leaking the device cannot be filled completely with water before starting the pump. As a result the horizontal inlet box has always some air left. After starting the pump the sediment was eroded in an unexpected way.

A few factors needed to be carefully managed to have maintain a well-controlled flow condition that satisfied the needs in the test section. This included the pump power, inlet channel size, test section size, outlet sizes, and the initiation sequence that filled the device with water and let eliminating air. When a good combination was selected, the controlled erosion would be accomplished as shown in Figure 11. An example of unsuccessful choice of the parameters/sequence resulting in uncontrolled erosion outside the test section was shown in Figure 12. In this case, a high flow velocity changed about 90 degree and created a huge scour hole at the toe of the inlet channel.

After testing different pump discharge values the research team found that a large ratio between the cross section of inlet and test section (e.g. approximately 10:1) decreases the impact of the jet to a manageable level. Another advantage of having a small test section was a nearly complete elimination of the jet impact because the required pump discharge was very small so that the velocity in the device was just created by a static pressure from the difference of water level of about 3cm.

The results are showing erosion in the form of a bathtub. This shape creates a nice transition in and out of the test section in the U-channel testing device. This concept has been proven a valid idea for an in-situ scour testing device and will be used as a model for further development/improvement.

Before After

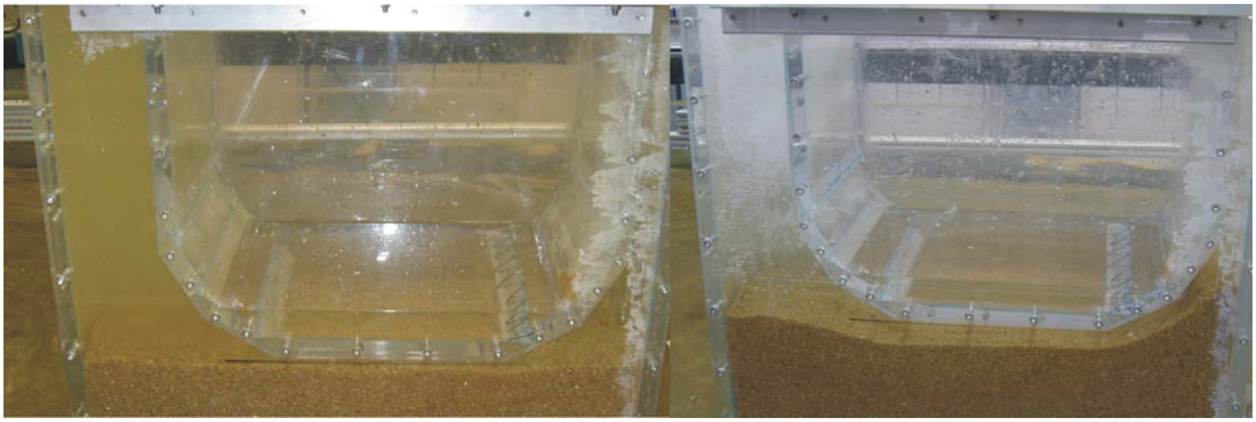

Figure 11 Controlled erosion in test section

Figure 12 Unsuccessful combination of testing parameters