

EEMS Demonstration Model Description

DM_Tidal_Channel_Culvert_Flow

1 Objective

This demonstration model uses EFDC+ Explorer (EE) and EFDC+ to simulate tidally-driven flow through a culvert connecting two water bodies. The model is designed to demonstrate how a hydraulic structure boundary condition is configured in EFDC+ and how dye tracing can be used to visualize the transport of water through the culvert under oscillating tidal forcing. The culvert acts as a constriction between an upstream basin and a downstream channel. As the tidal water surface alternately rises and falls on either side of the structure, the head difference across the culvert drives bi-directional pipe flow, and the resulting dye breakthrough curves at cells upstream and downstream of the structure quantify the timing and magnitude of this exchange.

2 Model Description

The model configuration is summarized in Table 1 and the model domain is shown in Figure 1. The domain represents a 1D channel system with a culvert embedded at a mid-reach constriction. Bottom elevations range from -0.5 m to 2.0 m, with the raised bottom elevation in the middle representing the embankment through which the culvert passes.

Table 1 Model configuration summary

Run Period (Julian Days)	Horizontal Cells	Vertical Layers	Activated Modules
0–1.5	90 cells	5 layers	- Hydrodynamics - Dye

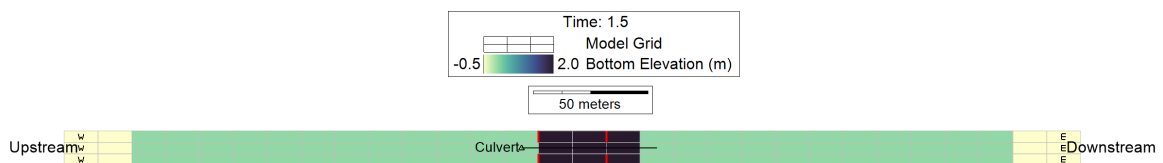


Figure 1 Model domain and bottom elevation, red lines show the masks configured

2.1 Tidal Forcing

The model is driven by a single M2 tidal constituent (period = 44,714.2 s $\approx$ 12.4 hours) applied as a harmonic surface elevation boundary condition at both the upstream (west) and downstream (east) open boundaries. Three west boundary cells ($I = 3$, $J = 3,4,5$) are assigned forcing harmonic 2 (amplitude 0.5 m, phase 21,500 s) and three east boundary cells ($I = 32$, $J = 3,4,5$) are assigned forcing harmonic 1 (amplitude 0.5 m, phase 0 s). The phase offset between the two ends drives an oscillating head difference across the culvert, producing alternating flood and ebb flows through the pipe over the 1.5-day simulation period (approximately 3 tidal cycles).

2.2 Culvert Configuration

A single hydraulic structure of type Culvert is configured between the upstream cell (Cell 45, $I = 16$, $J = 4$) and the downstream cell (Cell 49, $I = 20$, $J = 4$), using the CULVERT – PIPE equation. The culvert parameters are summarized in Table 2.

Table 2 Culvert hydraulic structure parameters

Parameter	Value
Structure Type	Culvert (Pipe)
Cross-Section Shape	Circle
Diameter (Width)	0.25 m
Upstream Invert Elevation	0.250 m
Downstream Invert Elevation	0.250 m
Length	30.0 m
Manning's n	0.025
Flow Control	Uncontrolled (no gates)
Flow Direction	Upstream-to-downstream (default masks)

The upstream cell has an initial water surface elevation (WSE) of 1.5 m and a depth of 1.5 m; the downstream cell has an initial WSE of 0.25 m, confirming that flow is driven entirely by the tidal head difference rather than a static imposed gradient.

2.3 Dye Configuration

One dye class is simulated ($NDYE = 1$) to track water originating from the upstream basin. The upstream open boundaries are assigned a constant inflow dye concentration of 1 mg/L, while the downstream open boundaries carry zero dye concentration. This allows the arrival and dilution of upstream water at the downstream side of the culvert to be directly observed in the model output.

3 Model Results

Figure 2 shows the depth-averaged dye concentration time series at two monitoring cells over the 1.5-day simulation: the upstream cell (Cell 36, $I = 7$, $J = 4$) and the downstream cell (Cell 51, $I = 22$, $J = 4$), located on opposite sides of the culvert.

At the upstream cell, dye rises sharply from zero to about 1 mg/L by day 0.35, consistent with the arrival of the first tide carrying dye from upstream. The concentration then drops during ebb before rising again on the second flood cycle, demonstrating the tidally-oscillating exchange pattern.

At the downstream cell, the dye signal is delayed relative to the upstream cell, reaching a peak of approximately 0.4 mg/L around day 1.05. This lag reflects the travel time of dye through the culvert and its dilution by the dye-free downstream water. The lower peak concentration at the downstream cell confirms that the 0.25 m diameter pipe acts as a significant hydraulic constriction, limiting the volume of upstream water reaching the downstream basin during each tidal cycle.

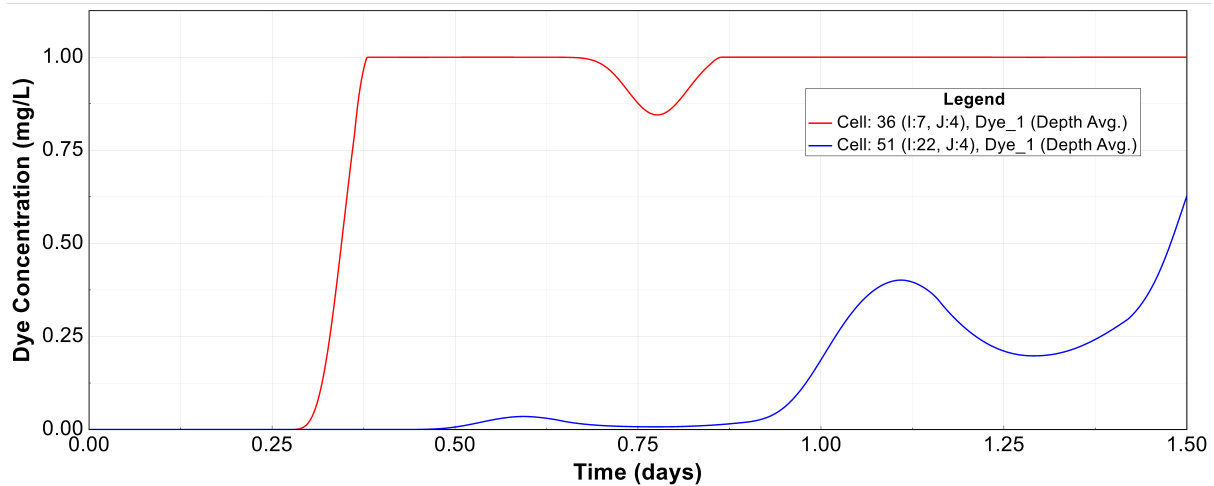


Figure 2 Depth-averaged dye concentration (mg/L) at the upstream cell (Cell 36, I = 7, J = 4) and downstream cell (Cell 51, I = 22, J = 4) over the 1.5-day simulation

Figure 3 shows the 2DH spatial distribution of depth-averaged dye at the end of the simulation. The upstream basin (left) retains a near-uniform concentration of 1 mg/L, confirming that the upstream open boundary continuously supplies dye throughout the run. The culvert location is visible as the mid-reach. Immediately downstream of the culvert, dye concentrations are elevated, reflecting water that has passed through the pipe and mixed into the downstream channel. Concentrations decrease progressively toward the downstream open boundary, illustrating the dilution of upstream water as it disperses through the downstream reach over successive tidal cycles.

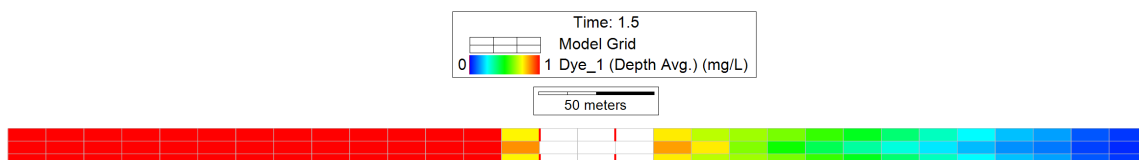


Figure 3 2DH plan view of depth-averaged dye concentration (Dye_1; mg/L) at day 1.5

4 Notes

4.1 Disclaimer

This model is provided to demonstrate that EFDC+ Explorer and EFDC+ can be used to build and analyze this type of models. The simulation results are consistent with expected behavior; however, the model should not be considered a final or validated product. Users are encouraged to review, modify, and refine model parameters to obtain results appropriate for their specific application.

4.2 EEMS Demo Mode

In Demo mode, the model is validated against a set of predefined signatures, including grid size, domain area, center coordinates, transport count, and module configuration. While certain parameter values may be adjusted, the grid cannot be modified, transports cannot be added,

and the prescribed module setup cannot be altered. Any deviation from these conditions results in the model no longer being considered a valid demo model.

4.3 Support

For technical support, additional documentation, or to obtain the latest version of EFDC+ Explorer, please visit: www.eemodelingsystem.com