Suspended Sediment Transport model in Urban Drainage structure

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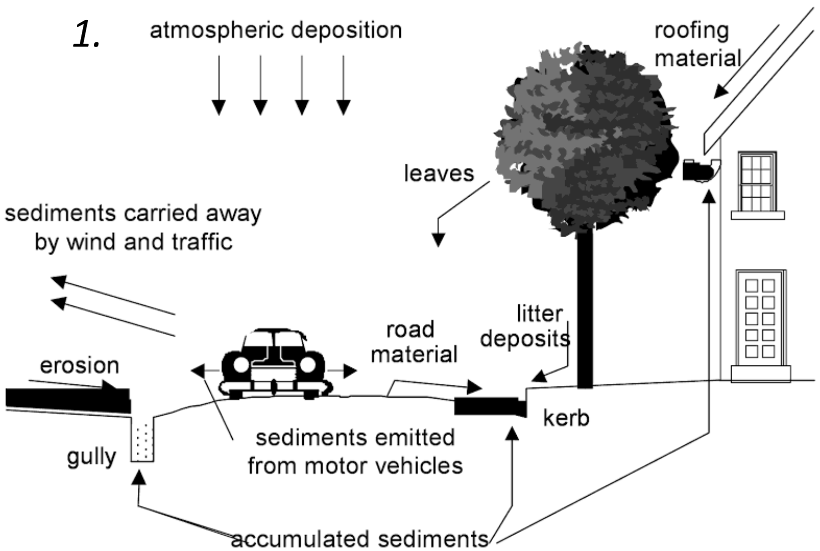
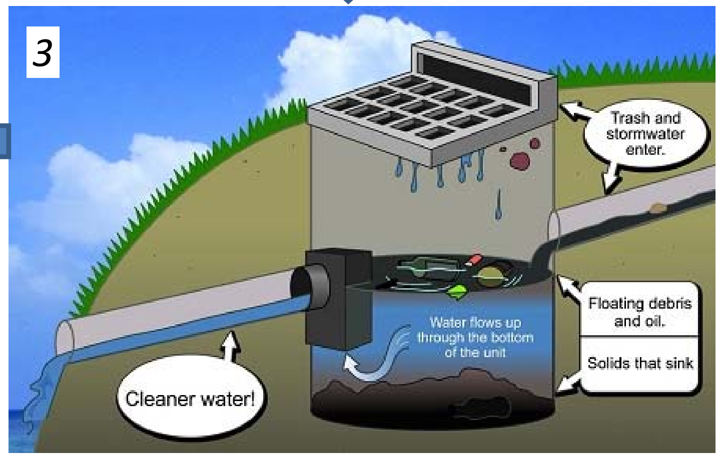
Motivation





1. *(Ashley et al. 2004)*
2. https://www.satelytics.com/
3. *https://silt-barriers.com/stormdrainfilters.html*
4. *rpitt.eng.ua.edu*
5. http://ucnfanews.ucanr.edu/Articles/Get_Cultured/GET_CULTURED__Drainage_channels_and_vegetated_filter_strips_in_nurseries/

Water Quality Modelling

Aim

- Robust and accurate particulate transport modelling
- Calculation of sediment concentration
- Calculation of residence time of sediment in hydraulic structures
- Calculation of sediment storage efficiency in manholes

Literature review of sediment transport CFD modelling

Three different approaches are mainly considered

1. **Euler-Euler approach**:
   - Sediment is considered as a concentration within the continuous fluid
   - Ahmad et al. (2015) used in Reef3D, Liu and García (2008) used in OpenFoam, Stovin and Saul (1996; 2000) used in Fluent
2. **Lagrangian particle tracking**:
   - Discrete particle trajectories in a Lagrangian reference frame using well established buoyancy and drag laws
   - Isenmann et al. (2017) used in OpenFoam,
3. **Considering a new phase for sediment layer**:
   - This approach considers the sediment as a new phase
   - Some examples consider 2 phase flow (sediment and water) and some consider three phase flow (sediment, water and air)
   - Cheng et al., (2017) used sedFoam in OpenFOAM, Bohorquez (2008) used three phased model

Governing Equations

- ✓ Flow model uses three dimensional incompressible Navier-Stokes equation
- ✓ Solver interFoam within CFD tool box OpenFOAM® v5.0 was used

$$\nabla . \boldsymbol{u} = 0$$

$$\frac{\partial \rho \boldsymbol{u}}{\partial t} + \nabla . (\rho \boldsymbol{u} \boldsymbol{u}) = -\nabla p^{*} + \nabla . \boldsymbol{\tau} + \boldsymbol{g} . \boldsymbol{x} \nabla \rho + \boldsymbol{f}_{\boldsymbol{\sigma}}$$

New solver

- ✓ Standard convection diffusion equation
- ✓ Sediment must be fine enough to ignore particle inertial effect

$$\frac{\partial c}{\partial t} + \nabla . \left(\boldsymbol{u} - \boldsymbol{v}_{\boldsymbol{s}} \frac{\boldsymbol{g}}{|\boldsymbol{g}|} \right) c = \nabla . (\nu_t \nabla c)$$

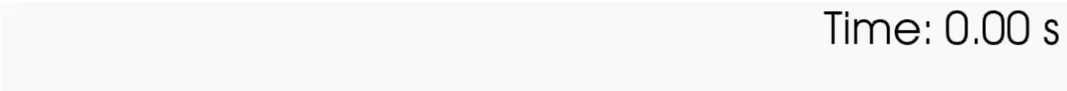
c is the volumetric concentration [m^3/m^3]

$\boldsymbol{v}_{\boldsymbol{s}}$ is the settling velocity

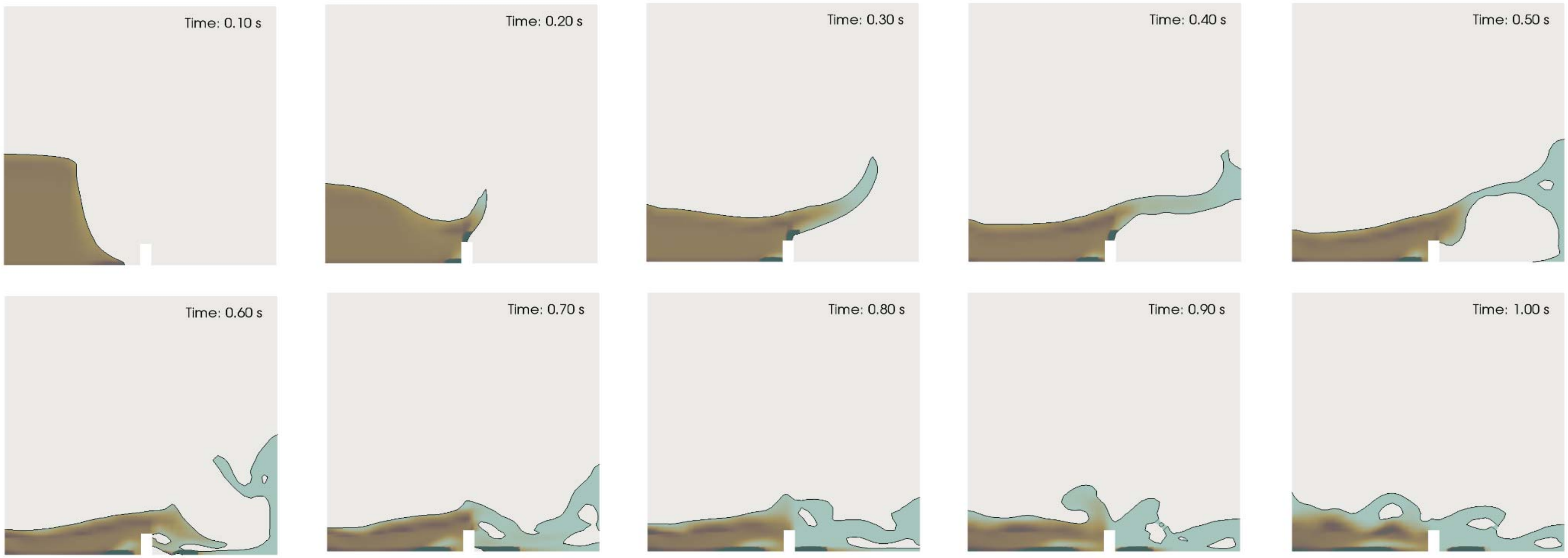
- ✓ Uses VOF method
- ✓ One way coupling
- ✓ Calculates flow velocity at a time step and then updates sediment concentration of the same time step

Test Case

- Checking at 2D dambreak case



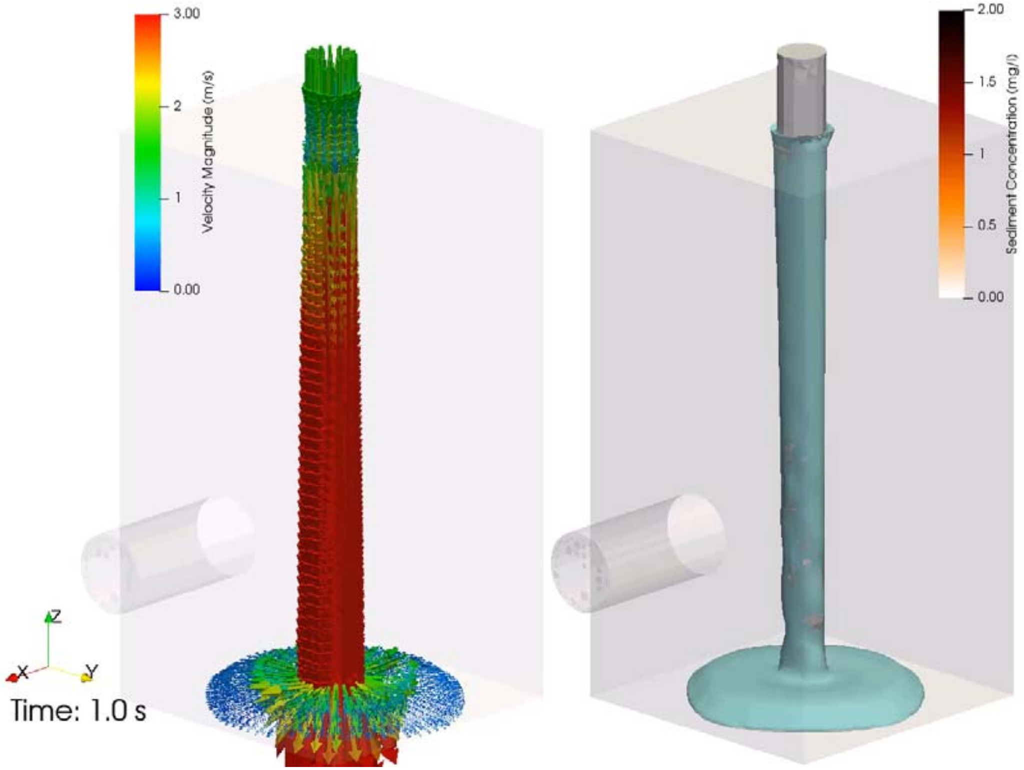
Initial case: well mixed sediment



Test Case

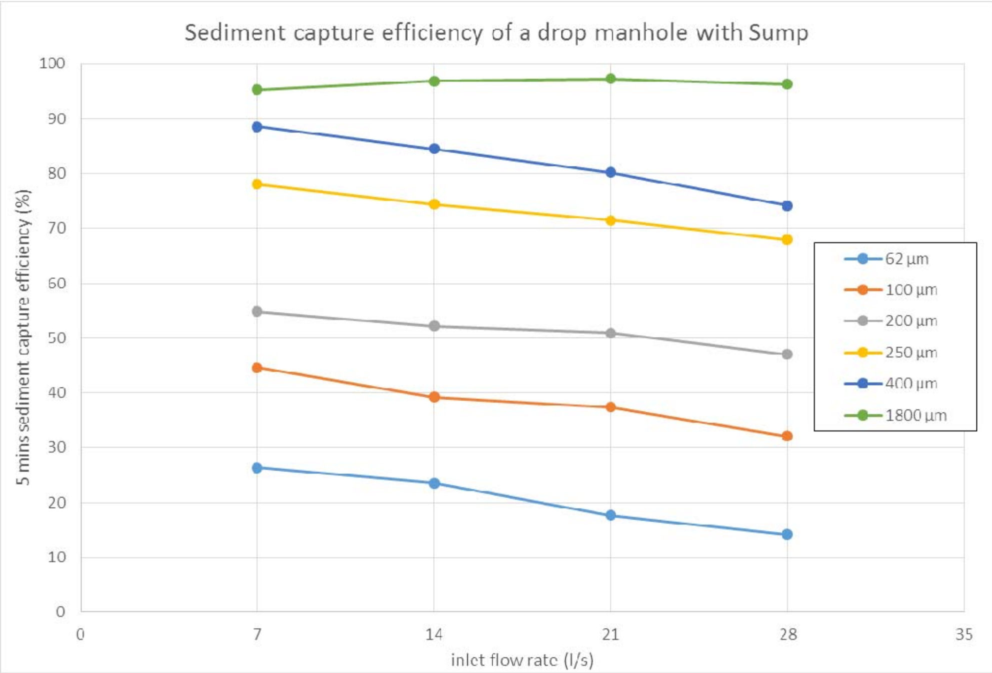
Comparison with Tang et al. (2016)

- Square drop manhole (with and without sump)
- 0.9m x 0.9m x 1.5m
- Different inlet flow from top
- Different sediment size used
- C = 0.15mg/l at inlet
- Sediment remaining was weighte after 5 mins of measurement
- Sediment capture efficiency was recorded



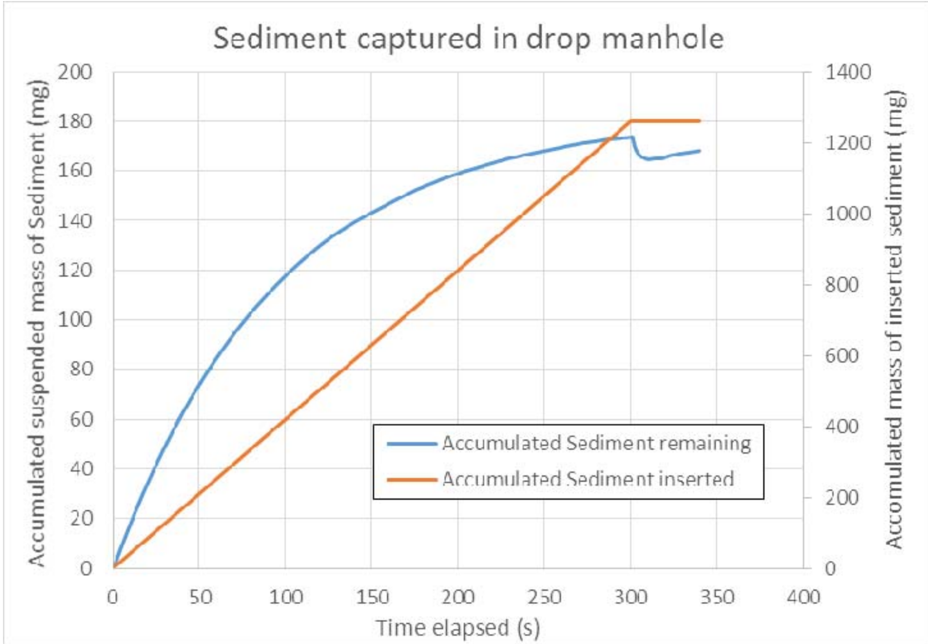
Test Case

- Comparison with Tang et al. (2016)



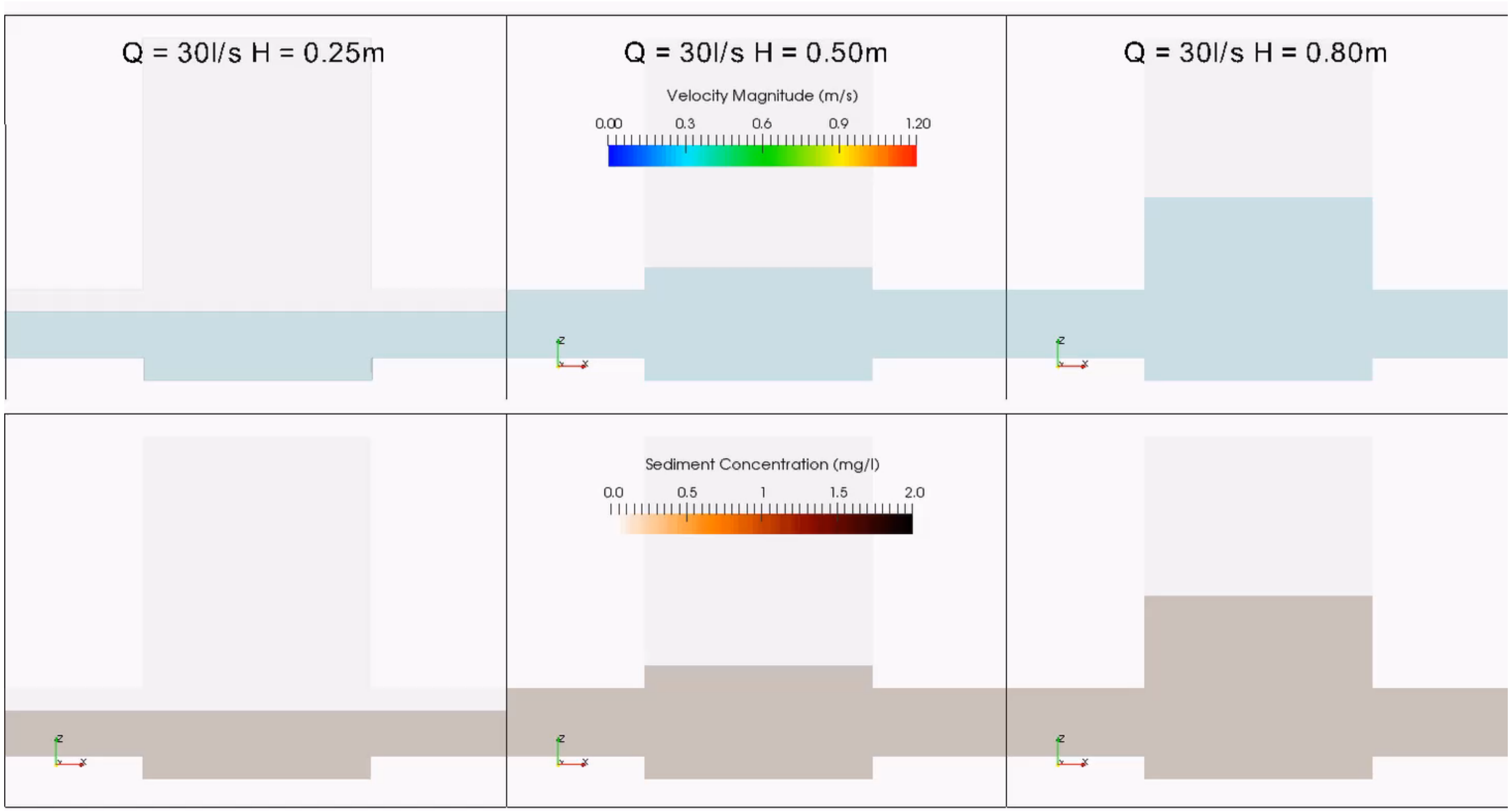
Tang, Y., Zhu, D.Z., Rajaratnam, N., van Duin, B., 2016. Experimental study of hydraulics and sediment capture efficiency in catchbasins. Water Sci. Technol. 74, 2717–2726. doi:10.2166/wst.2016.448

- Prediction shows 2.5% difference with experimental
- Sediment residence time is also checked



Case study

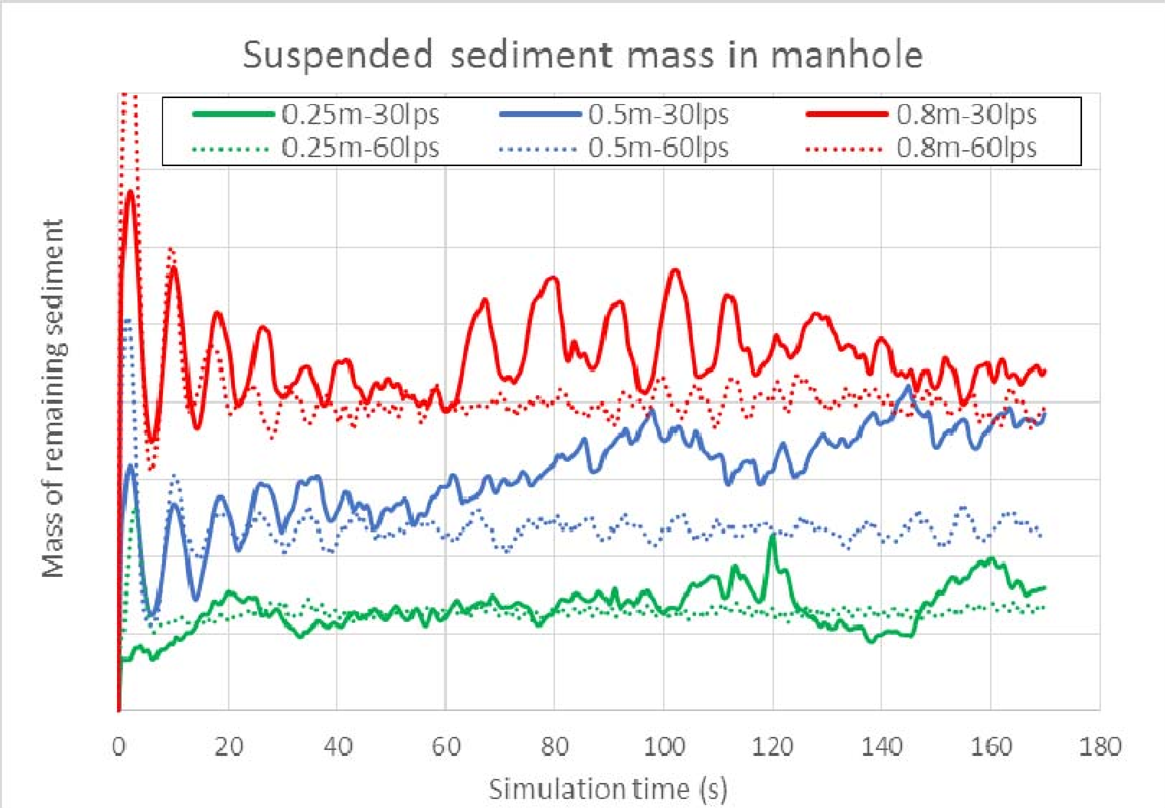
- Application in a real scale inline manhole



- All inlet contains 0.15mg/l of sediment
- Normal sediment concentration in sewer (Ghani, A. 1993)
- Used 100µm sediment

Case study

- Application in a real scale inline manhole



- Only one sediment type is checked
- Increasing manhole surcharge captured more sediment
- With increased flow rate, sediment mass remaining decreases slightly

Future Work

The solver is still under development.

The following options are planned to be added:

- Adding bed-load transport
- Add instability based on slope
- Add variable sediment properties (more than one type of sediment, Flocculation etc)
- Both way coupling at high sediment concentration
- Implementation of morphological changes

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Thank you for your attention

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