

Numerical Investigation of the Flow Field inside a Manhole-Pipe Drainage System

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Introduction

One of the busiest city in Dhaka, due to 46mm of rainfall in one and a half hour; on afternoon of September 1, 2015.
Photo Credit: The Daily Star on September 2, 2015.

Pluvial flooding at City centre of Coimbra on May 2006
Photo Source: http://www.raingain.eu/en/actualite/flood-solutions-north-south-europe

Chertsey, UK on February 11, 2014
Photo source: The Guardian on 11 February, 2014

Introduction

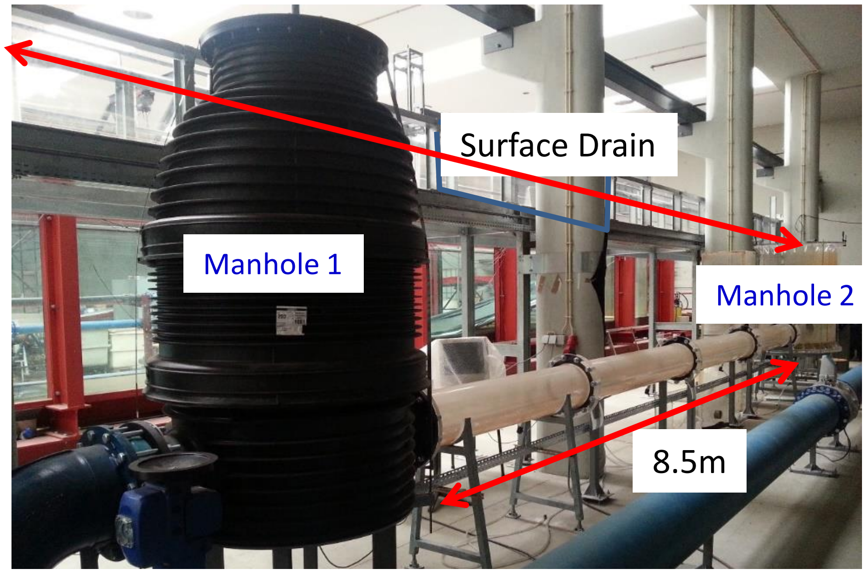
- Flooding is one the of biggest threats for a busy urban city
- The urban drainage system is responsible for safe routing of flood water; hence an efficient drainage is mandatory
- Drainage system efficiency is dependent on the individual efficiency of each element
- Manhole is one of the most common feature of an urban drainage system
- Analysis of flow characteristics inside a manhole can give a better understanding of the flow efficiency

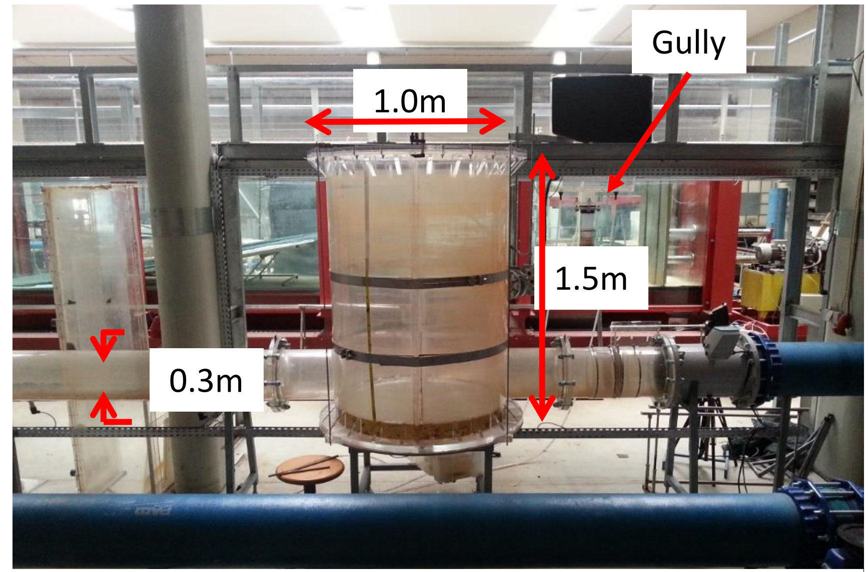
Objective

- To validate CFD model with experimental measurement at the laboratory
- To analyse the different flow behaviour inside a manhole

Methodology

Physical Model set up



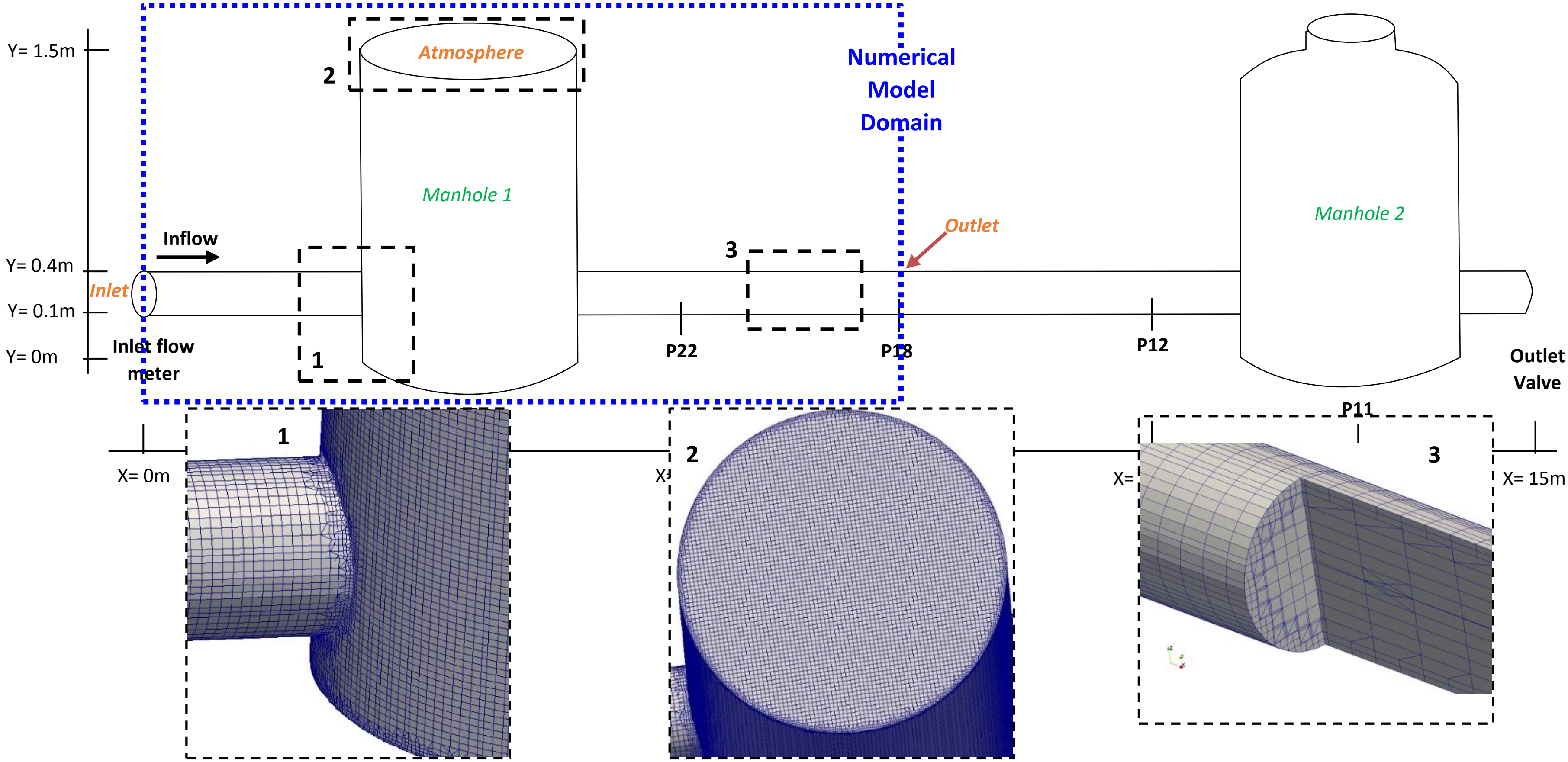


The physical model facility is installed at the Department of Civil Engineering, University of Coimbra. The Physical model is consists of:

- Two manholes
- Connected by a Ø300 sewer pipe
- 10 m long and 0.6 m wide and 1% slopped surface channel
- Two gullies (only one is in the picture)
- It has the ability to simulate simultaneously the surface and the transparent sewer system

Methodology

Numerical Model set up



- *SnappyHexMesh*
- Mesh size 2.5cm at manhole and 2.5-10cm at the pipe
- 1.75 cm at the walls
- 210,000 computational meshes

Methodology

OpenFOAM simulation

- OpenFOAM v. 2.3.0
- *interFOAM* solver: considering isothermal, incompressible and immiscible two-phase flow (air and water for this case)
- Mass and Momentum conservation

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \boldsymbol{u}) = 0$$

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

- Uses Volume of Fluid (VOF) method (Hirt and Nichols 1981) to track the free surface or interface location
- RAS k-ε turbulent model was used
- PISO algorithm was used

Methodology

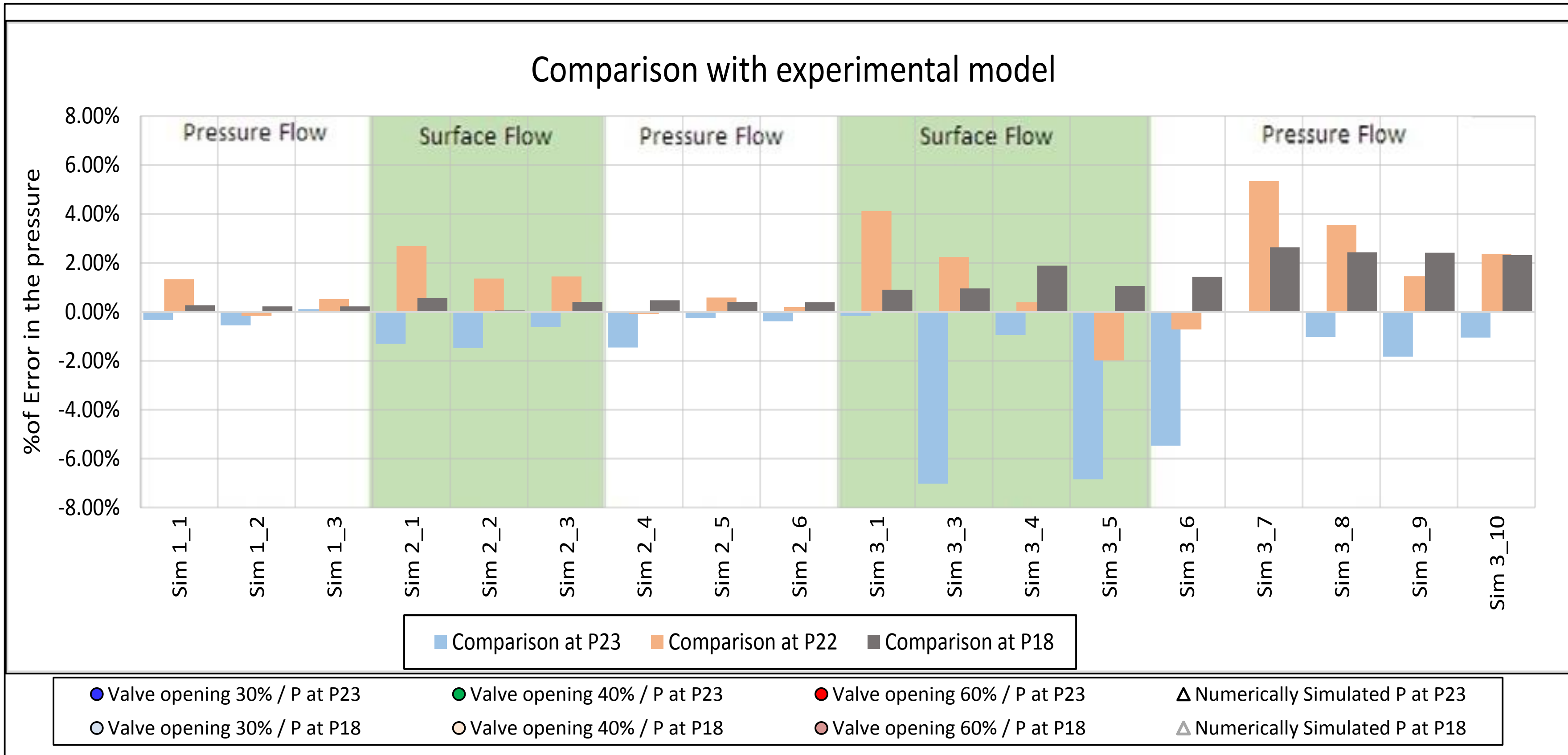
Tests performed

- Combinations of different inflows and surcharge level in the manhole
- 18 different scenarios:
  - both high and low flow (using upstream valves)
  - high pressure and low pressure conditions (using downstream valves)
  - Both free surface and pressure flow in the pipe

Results

Comparison with experimental tests performed

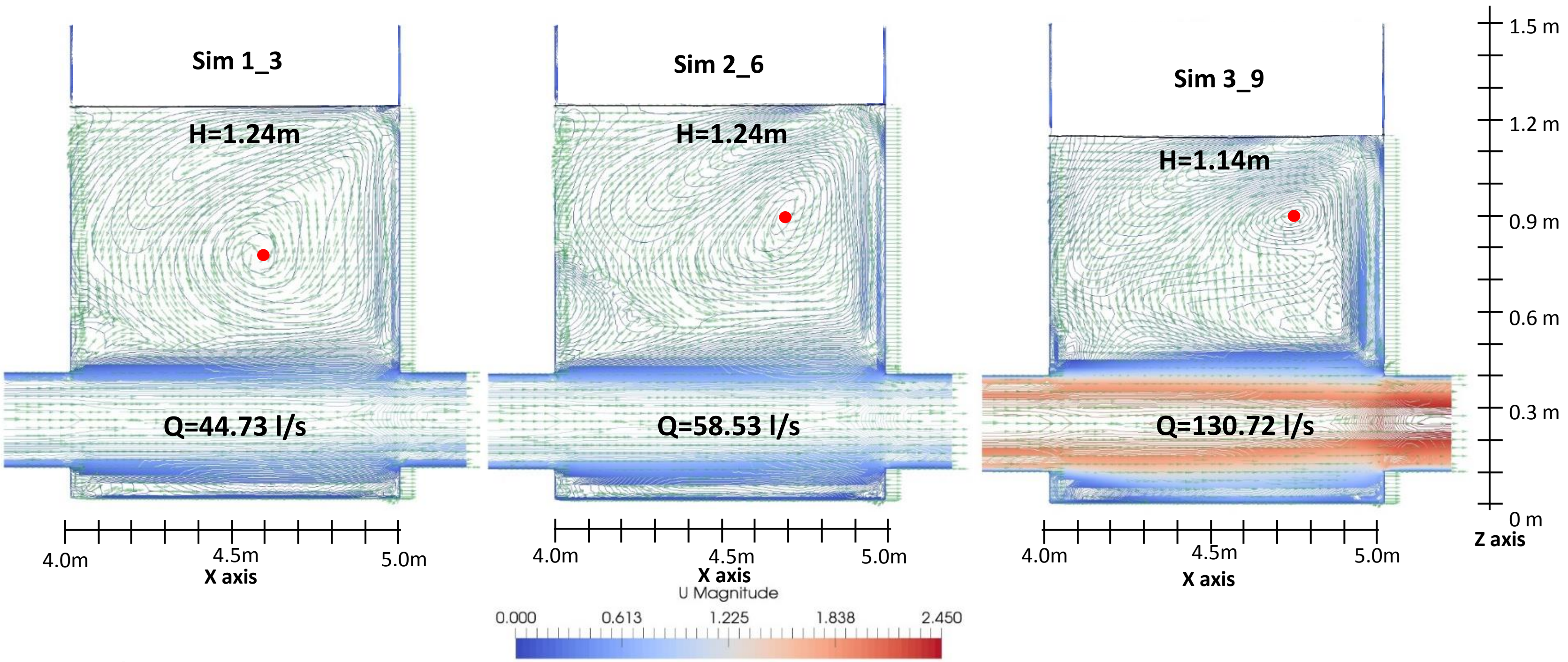
- Comparison with measured discharge (electromagnetic discharge meter) and pressure (pressure sensor)



Results

Flow comparison for different inflow

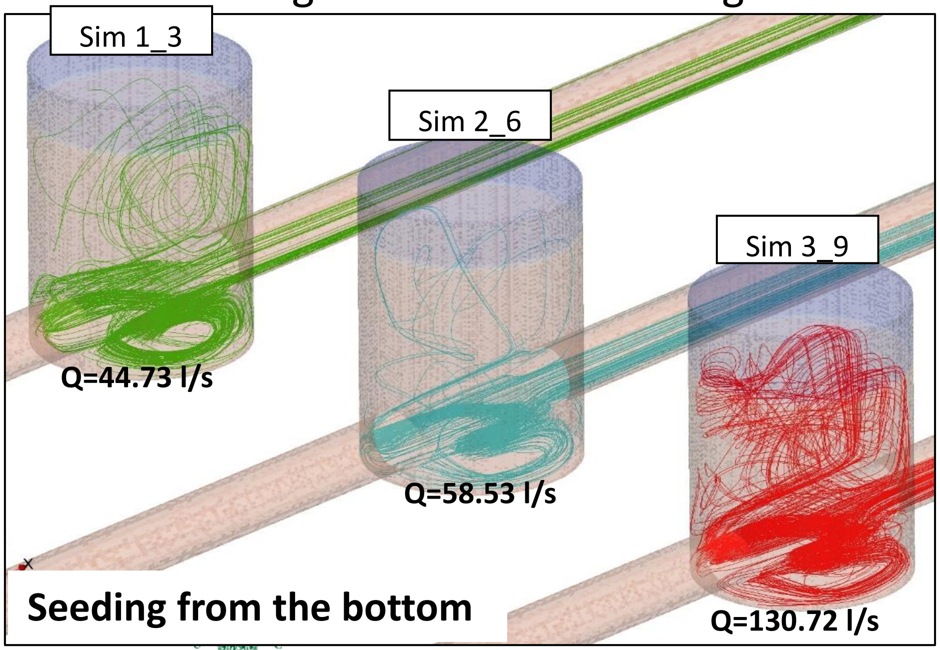
- Similar surcharge with different inflow
- Vortex formation is different
- Vortex centre moves higher and further from the inlet

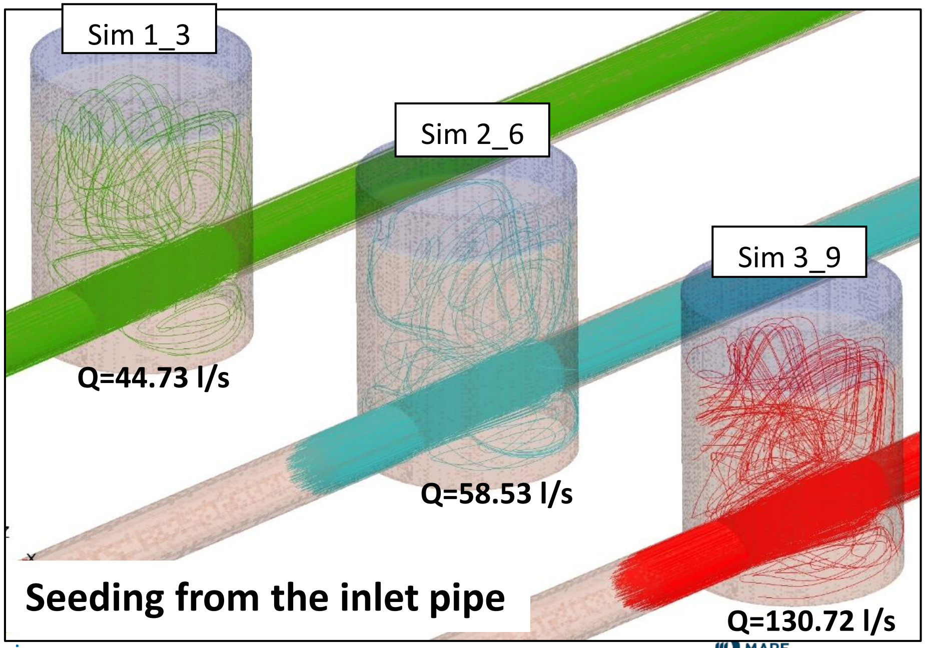


Results

Flow comparison for different inflow

- Two types of the streamlines have different pathways
- A particle from the bottom of manhole is likely to travel more inside
- For particle initially at manhole base:
  - Higher inflow>more traveling to the top>More residence time inside manhole
- For particle coming through inlet:
  - Higher flow>more mixing inside the manhole

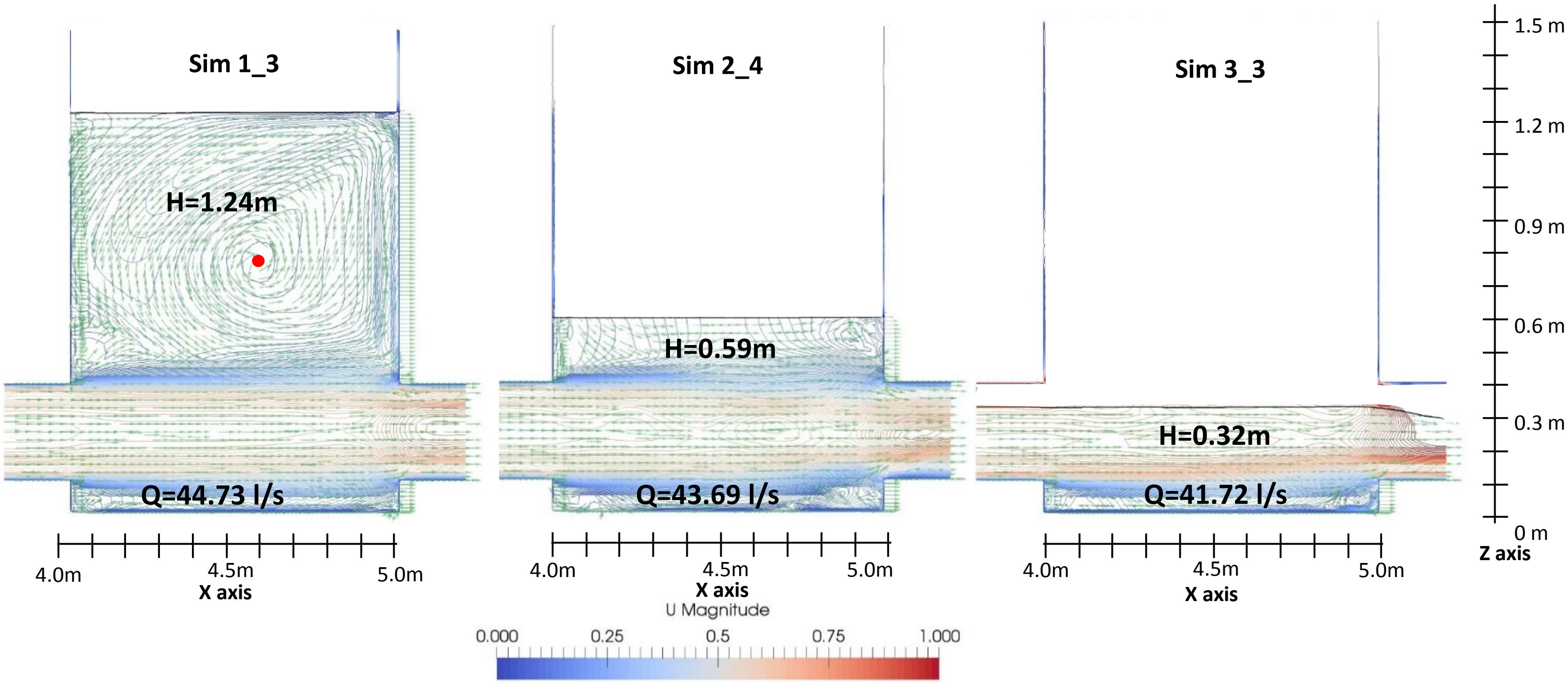




Results

Flow comparison for different surcharge

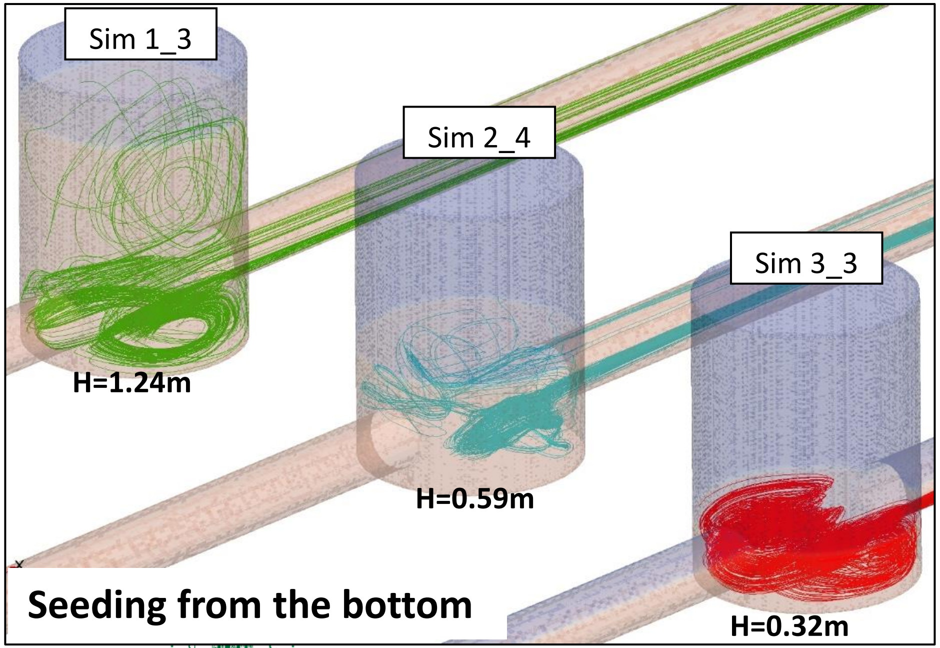
- Similar inflow with different surcharge
- Vortex forms only over a certain surcharge depth
- At lower surcharge, flow is mostly parallel to the dominant direction

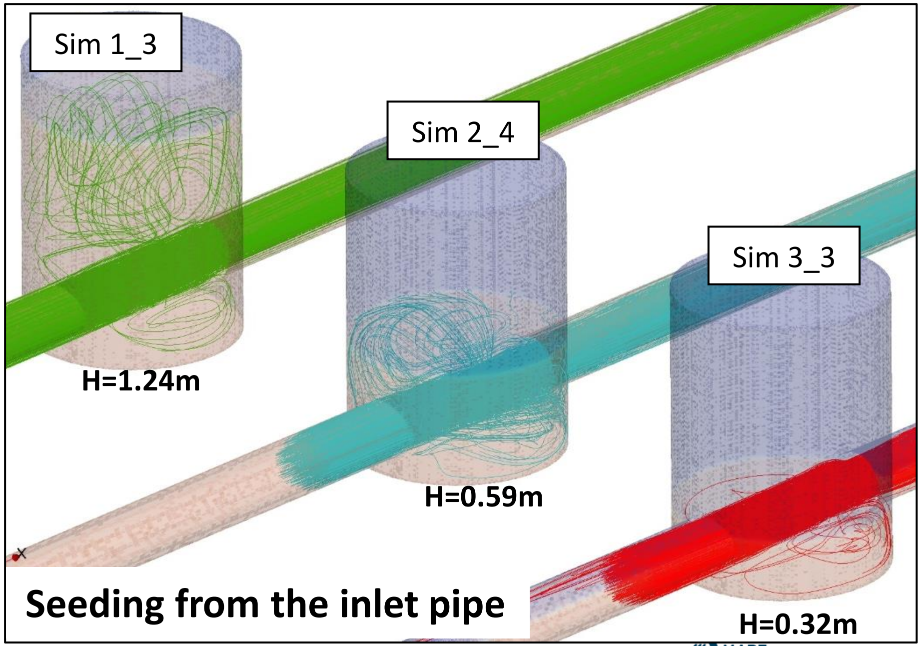


Results

Flow comparison for different inflow

- In Sim 3_3, most streamline from the bottom circulates inside manhole
- For particle initially at manhole base:
  - Lower surcharge > more particles stay inside
- For particles coming through the pipe
  - Lower surcharge > less mixing inside manhole

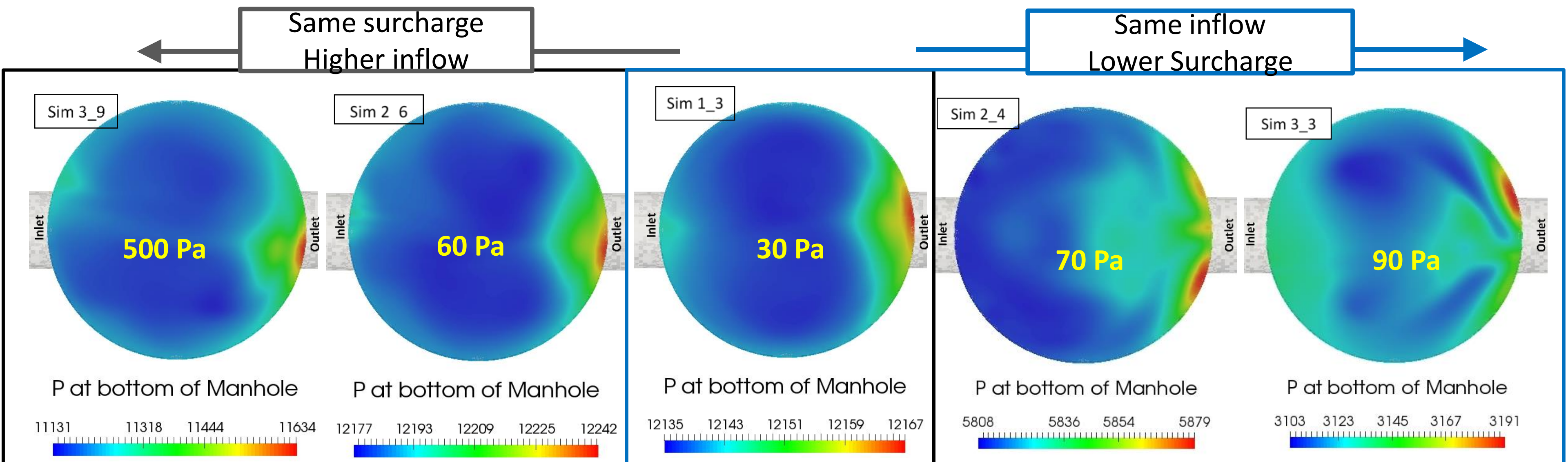




Results

Pressure level at the manhole bottom

- All have higher pressure near outlet
- Same surcharge:
  - Similar pressure gradient map
  - Diff. between max and min pressure rises with inflow
- Same inflow
  - Different pressure gradient map
  - Diff. between max and min pressure oppositely to the surcharge



Conclusion

- The work presented shows the first step numerical assessment of flow behaviour inside a manhole
- OpenFOAM® v. 2.3.0 with solver interFOAM was used with RANS k-ε turbulence model
- Numerical model shows good agreement with experimental pressure data (less than 7% error)
- Flow streamline and manhole bottom pressure show different characteristics with change in inflow and/or surcharge level in the manhole.

Future Work

- The model will be validated with flow measurement inside the manhole

- The work will be further developed to better understand the particulate transport phenomena inside the manhole-pipe drainage system

Thank you
for your attention

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