Effect of surcharge on gully and manhole flow

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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

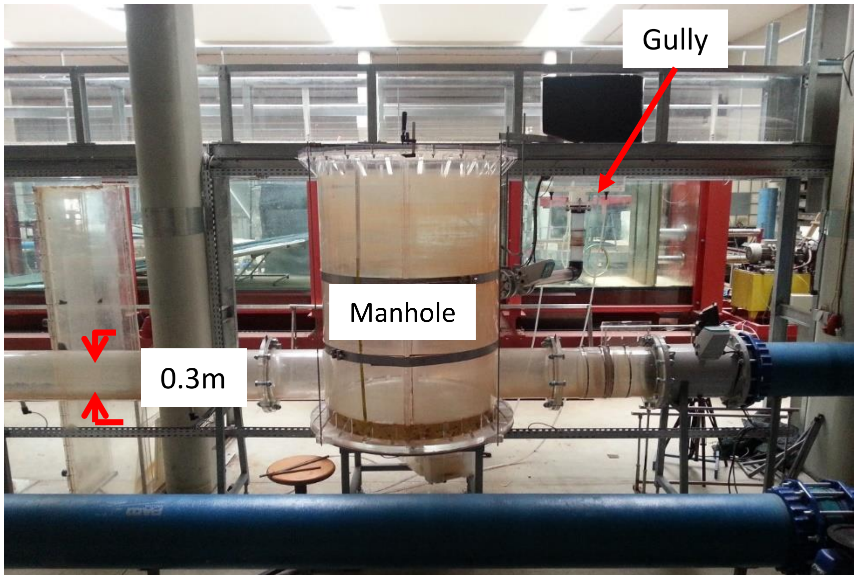
- Flooding is one the of biggest threats for a busy urban city
- Drainage system efficiency is dependent on the individual efficiency of each element
- State-of-the-art flood routing models in urban areas are Dual Drainage (DD) models that simulate both surface flow and flow in buried pipes simultaneously
- These models use discharge coefficients to connect the two systems through linking elements
- However, they also have weaknesses in considering linking elements as very few existing models are available to calibrate these coefficients (Djordjević et al., 2005)
- The effect of manhole surcharge on manhole head loss coefficients and manhole-gully discharge coefficients have been studied

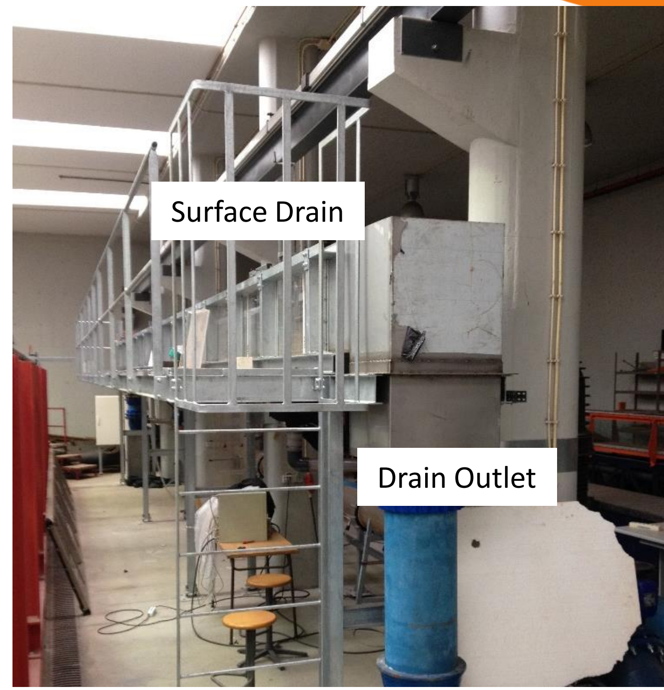
Objective

- To validate CFD model with experimental measurement at the laboratory
- To analyse the different flow behaviour inside a gully-manhole drainage system for different manhole surcharge

Methodology

Physical Model set up





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

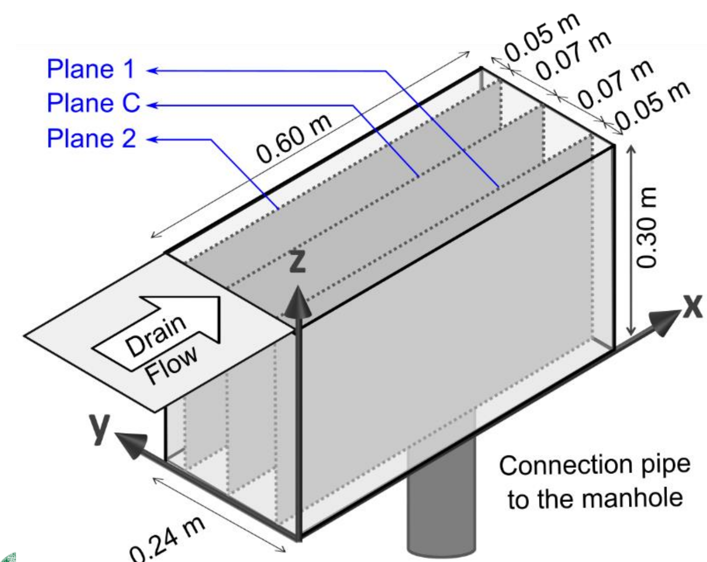
- 1m diameter manholes
- Connected by a Ø300 sewer pipe
- 0.5m wide and 1% slopped surface channel
- 0.6 × 0.24 × 0.32 [m] (L × W × D) gully

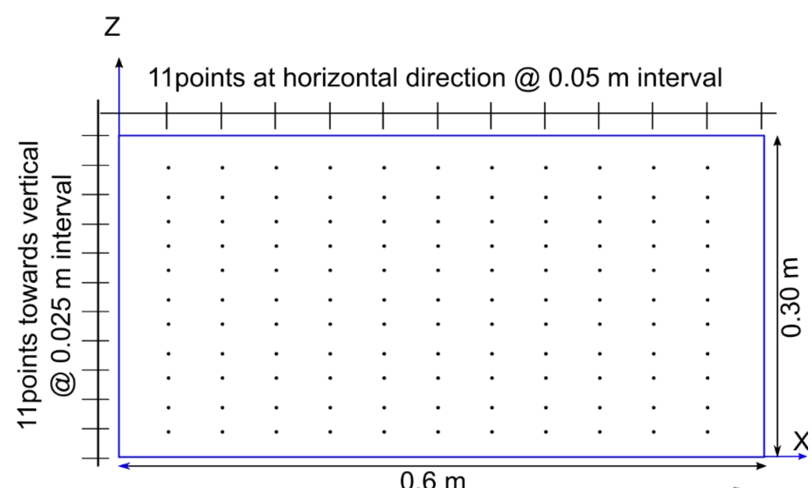
Methodology

Tests performed

- Experimental Scenario: combination of two different experimental studies:
- Scenario 1:
  - Constant flow through the drain and manhole inlet
  - Measurement of point velocity at three vertical planes of the gully using ADV

Drain inlet Q (l/s)	Manhole inlet Q (l/s)	Manhole surcharge level (m)	Remarks
19.8	43.7	0.67	Experimental case scenario





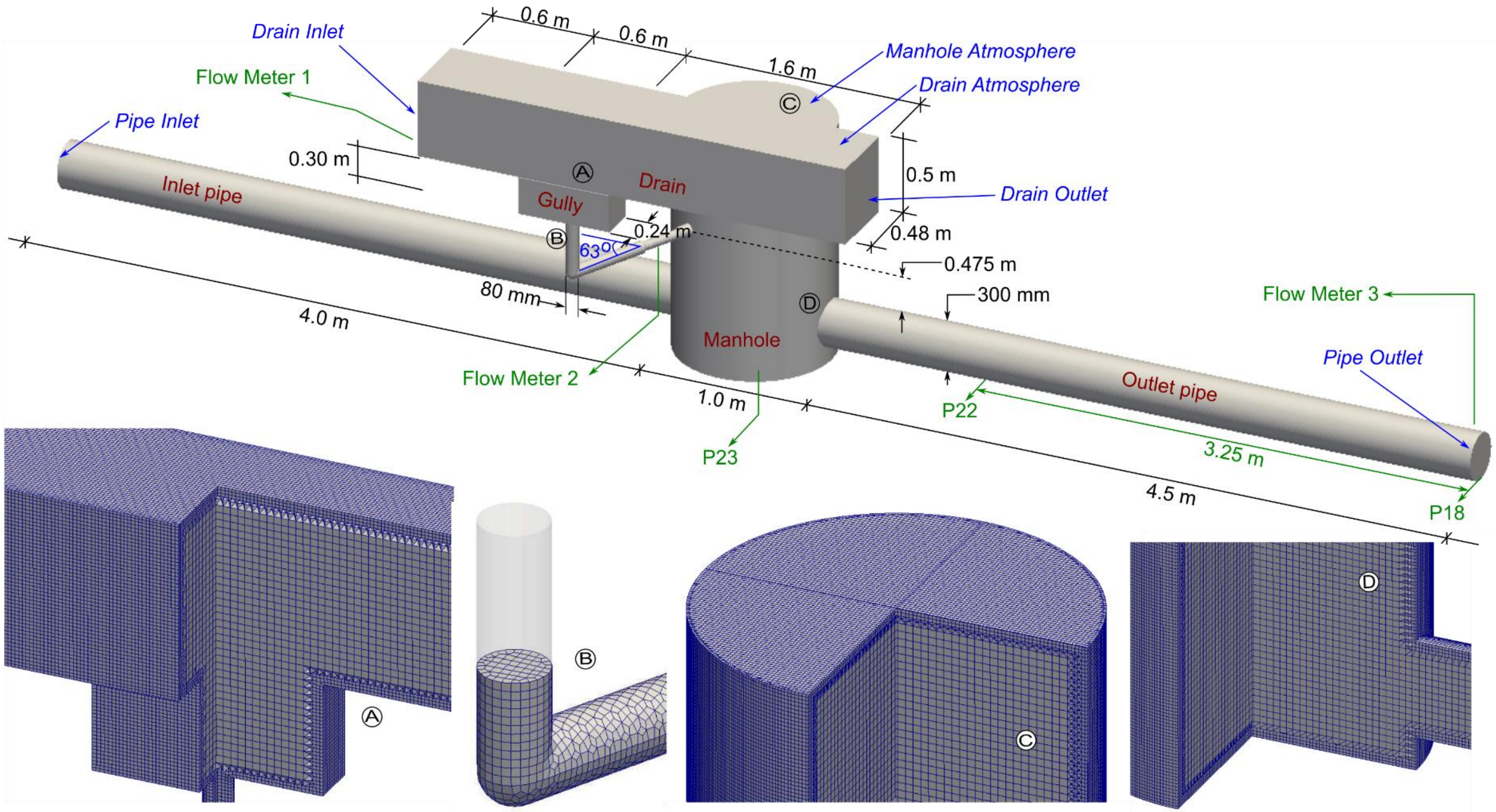
Methodology

Tests performed

- Scenario 2:
  - Different inflows and surcharge combinations at the manhole
  - 18 different combinations
  - Both free surface and pressure flow in the pipe
  - Measurement of pressure at the manhole using pressure sensors and discharge at the inlet

Methodology

Numerical Model set up



- *cfMesh*
- Mesh size 2cm
- 1 cm at the boundaries
- 821,500 computational with 1.01 million nodes

Methodology

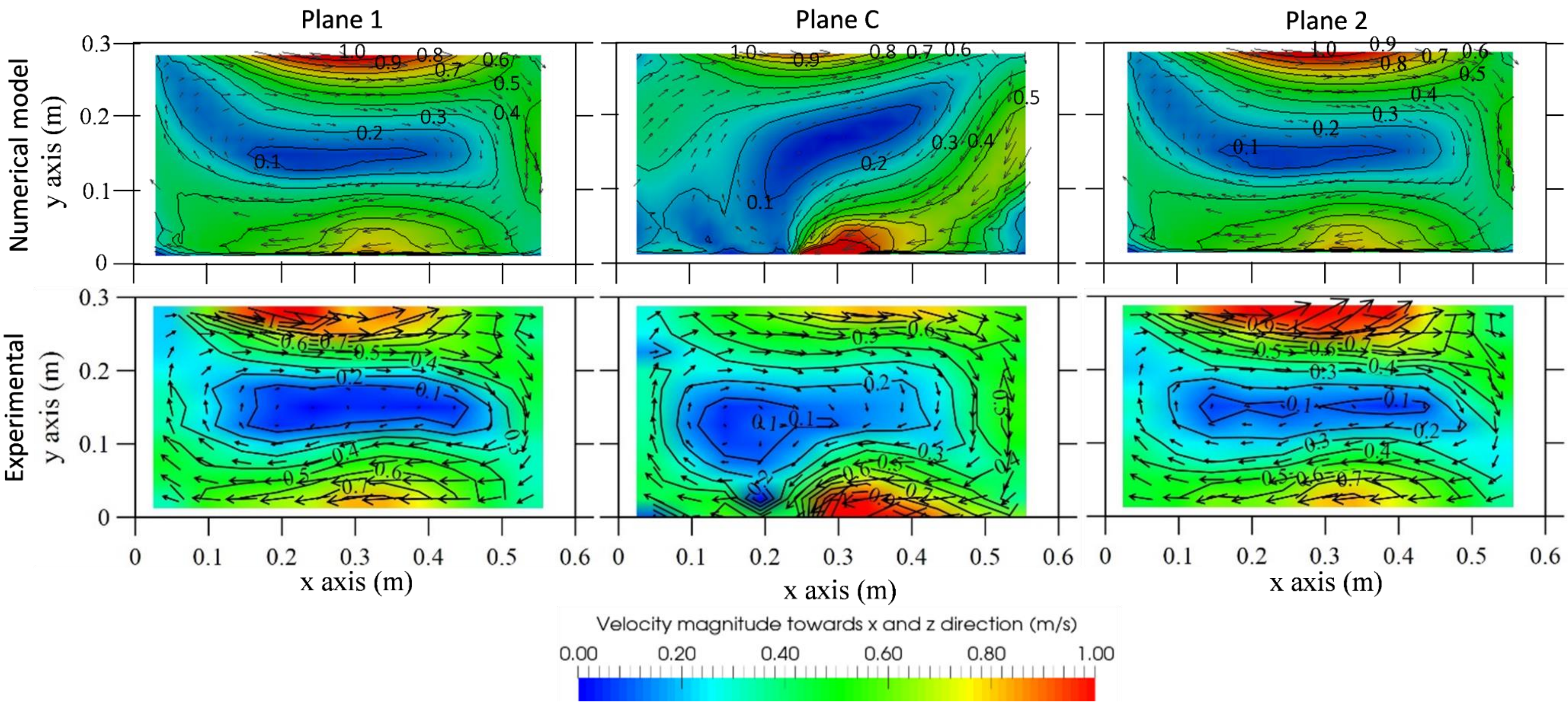
OpenFOAM simulation

- OpenFOAM v. 2.3.0
- *interFOAM* solver: considering isothermal, incompressible and immiscible two-phase flow (air and water for this case)
- Standard k-ε for (gully flow) and RNG k-ε turbulent model (for manhole flow) was used
- PISO algorithm is used

Validation

Comparison with experimental data

- The velocity measurement at the gully showed good match with the CFD data
- Average correlation coefficient, r: for vx=0.972, and for vz=0.571



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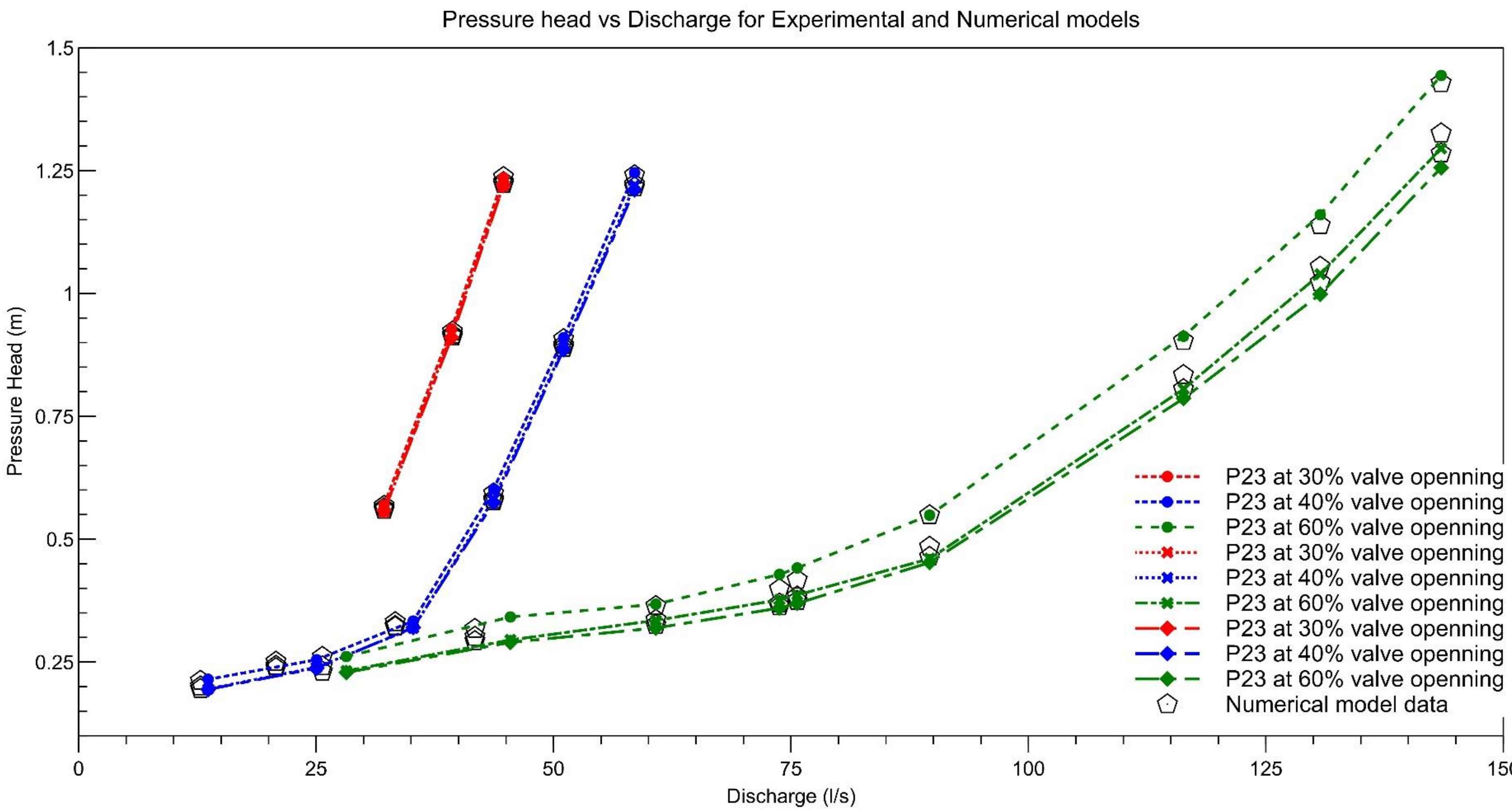

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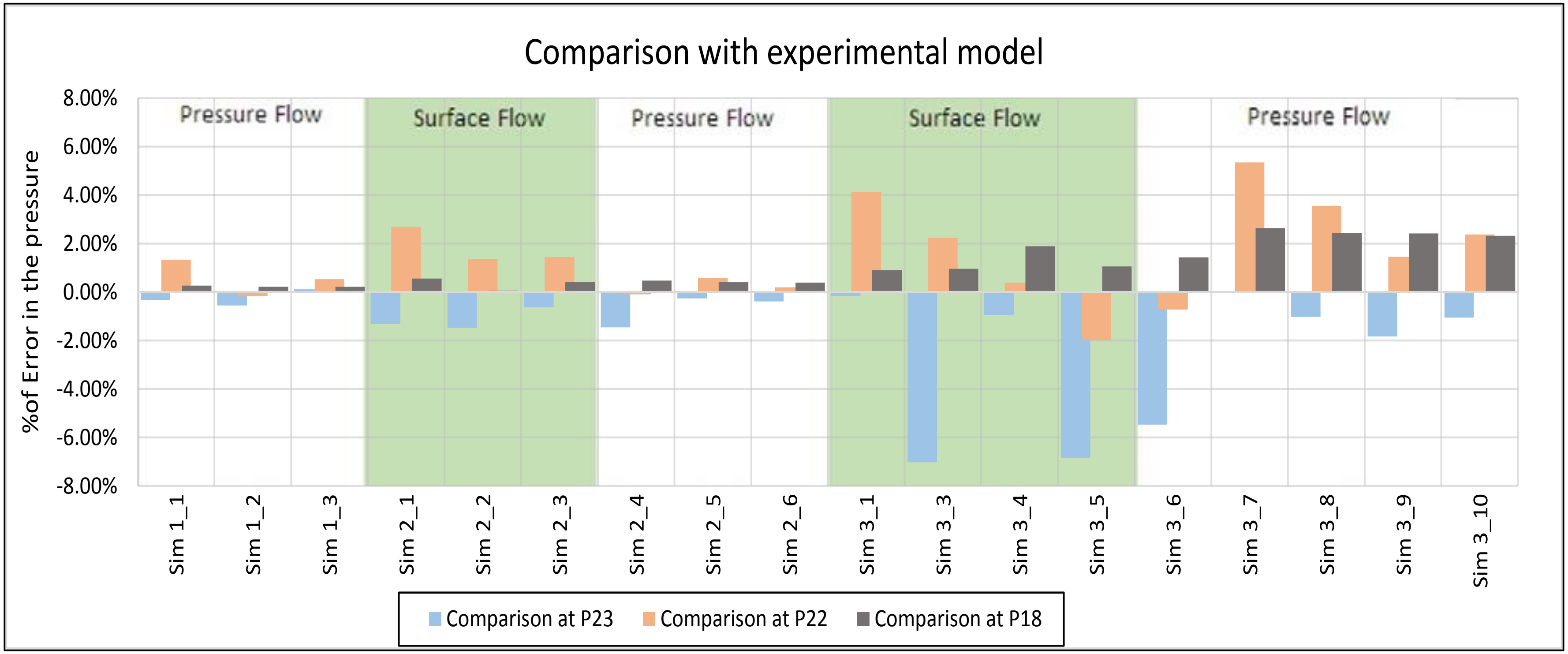
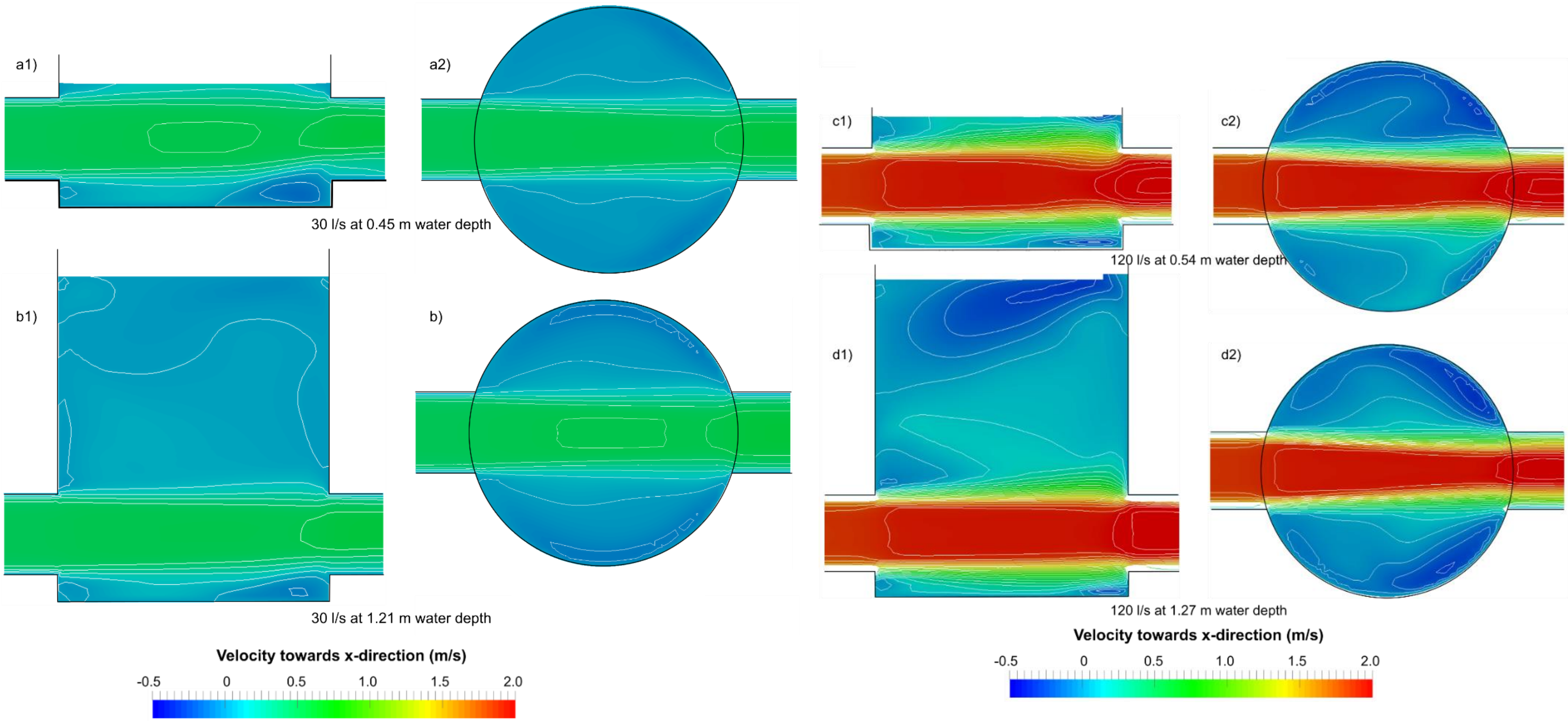


Results

Coefficient of head loss

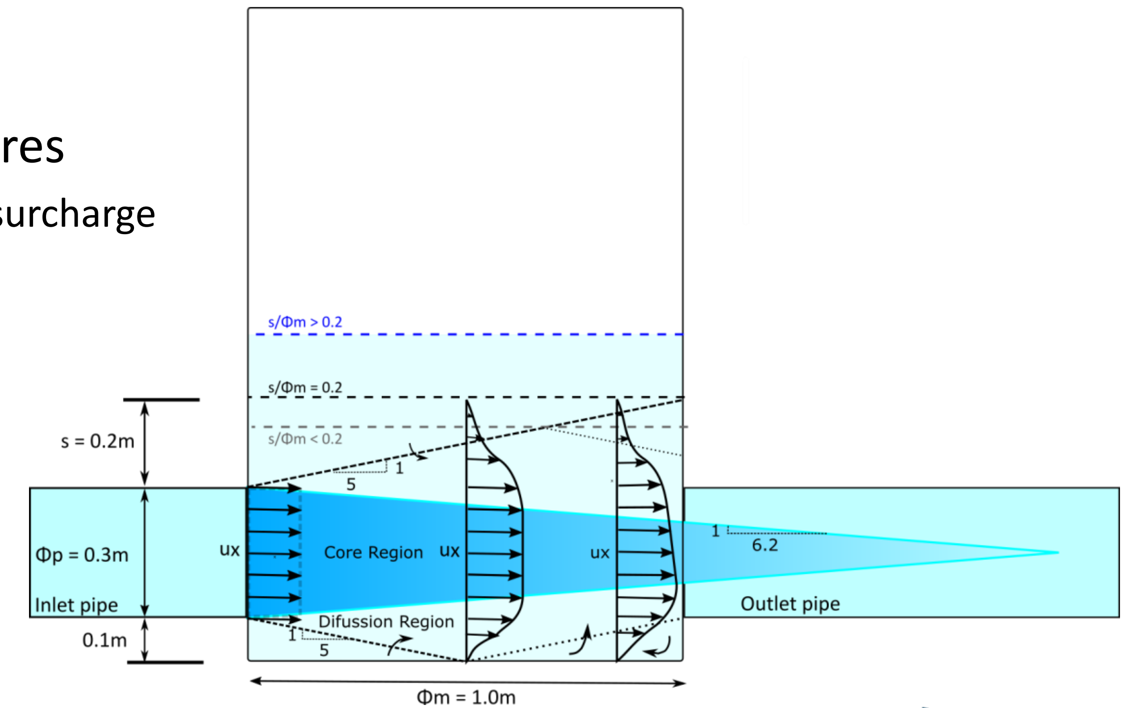
- The spread of the jet is different at different inflow and surcharge



Results

Coefficient of head loss

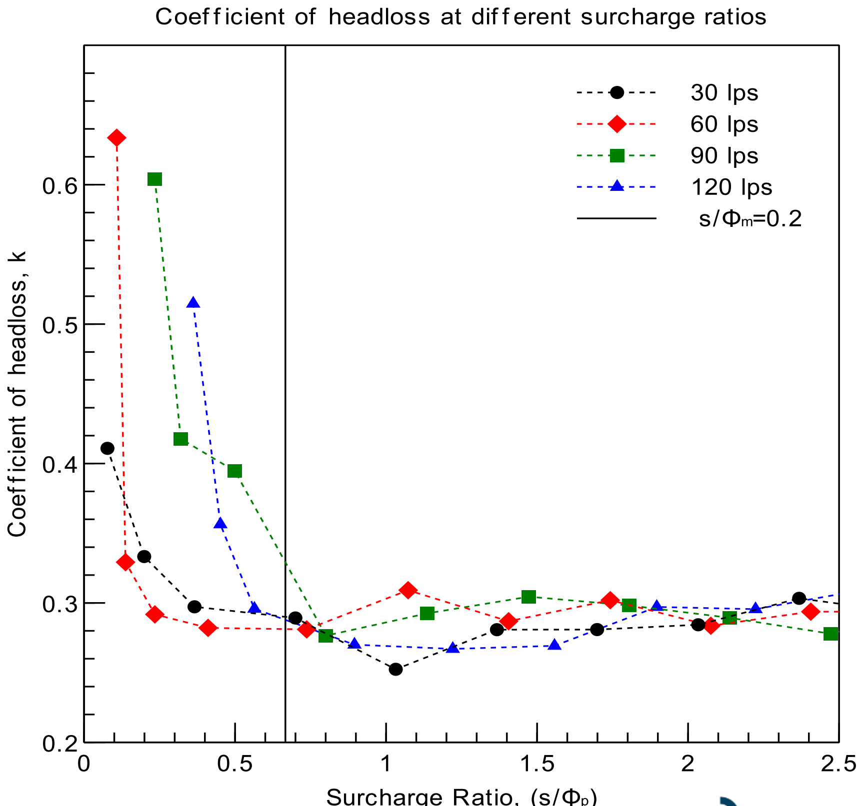
- Head loss coefficient, $k = \frac{\Delta H}{v^2/_{2g}}$
  - ΔH is the head loss in meters
  - v is the average velocity at the inlet
- It has two distinctive characteristics at two different surcharge conditions
  - Below threshold zone
  - Over threshold zone
- According to some literatures
  - Threshold surcharge = 20% surcharge
  - height of manhole diameter



Results

Coefficient of head loss

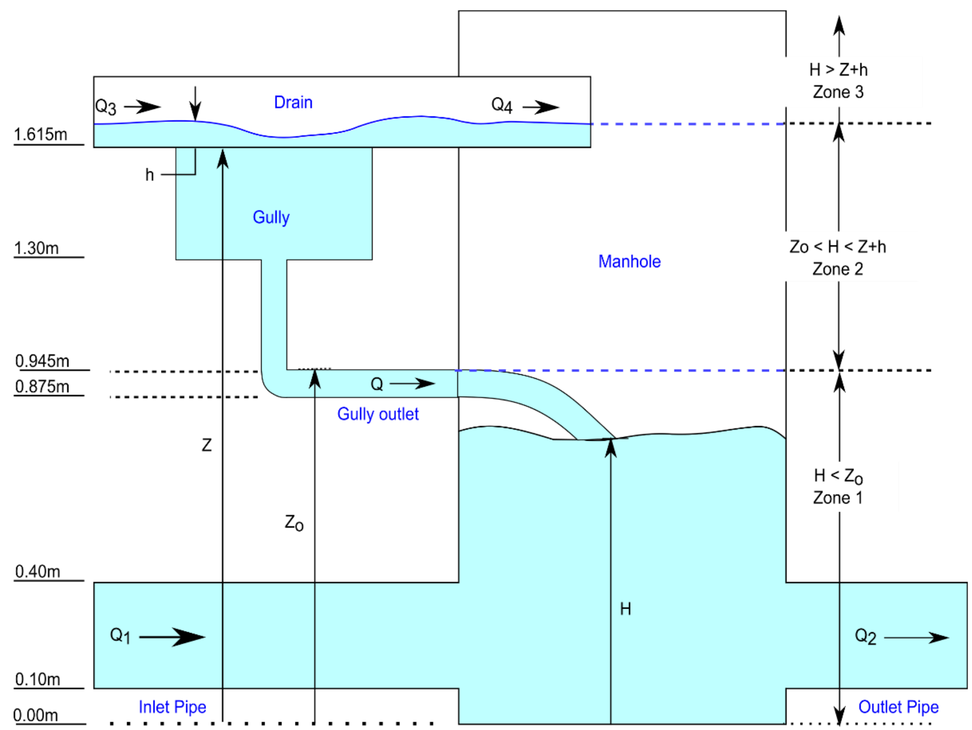
- Coefficient of head loss (k) vs surcharge ratios (s/Φ_p) were drawn
- At higher surcharge, the coefficient stays fairly around 0.3
- The coefficient is very high at below threshold surcharge
- For below threshold zones, head losses did not follow any particular trend
- No justification could be drawn for these variations



Results

Coefficient of discharge

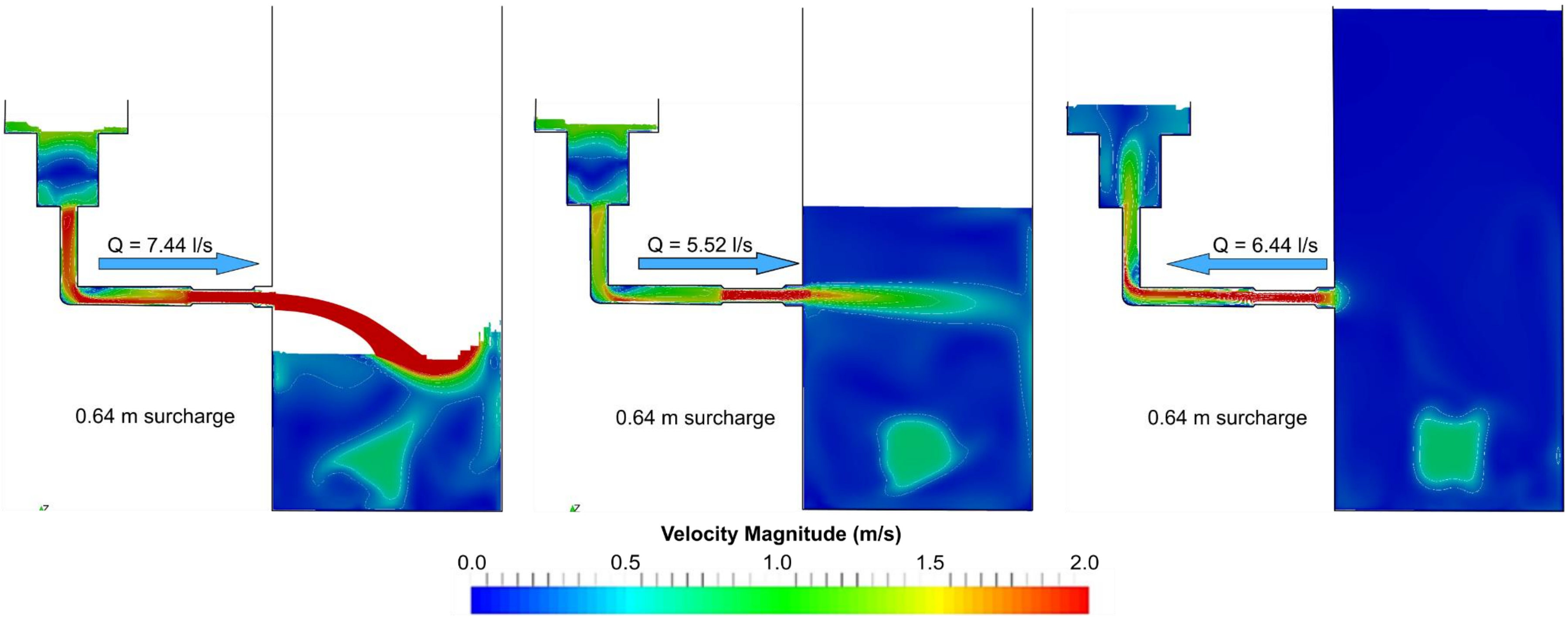
- Considering orifice flow equation
- Coefficient of discharge at the gully pipe C_d, where $Q = C_d A_o \sqrt{2gh_o}$
- Q = discharge from the gully, variable at different manhole surcharge
- A_o = Cross sectional area of the orifice,.
- h_o = Head difference from the surface drain to the gully outlet.
- Here, at zone 1, ho is constant, which is equal to (h+Z-Zo=) 0.786 m. At zone 2 and 3, ho is a variable and can be calculated as the difference between (Z+h) and H.



Results

Coefficient of discharge

- Three different zones considering the gully outlet flow
  - Zone 1: Free outlet
  - Zone 2: Outlet as a submerged jet
  - Zone 3: Reverse flow

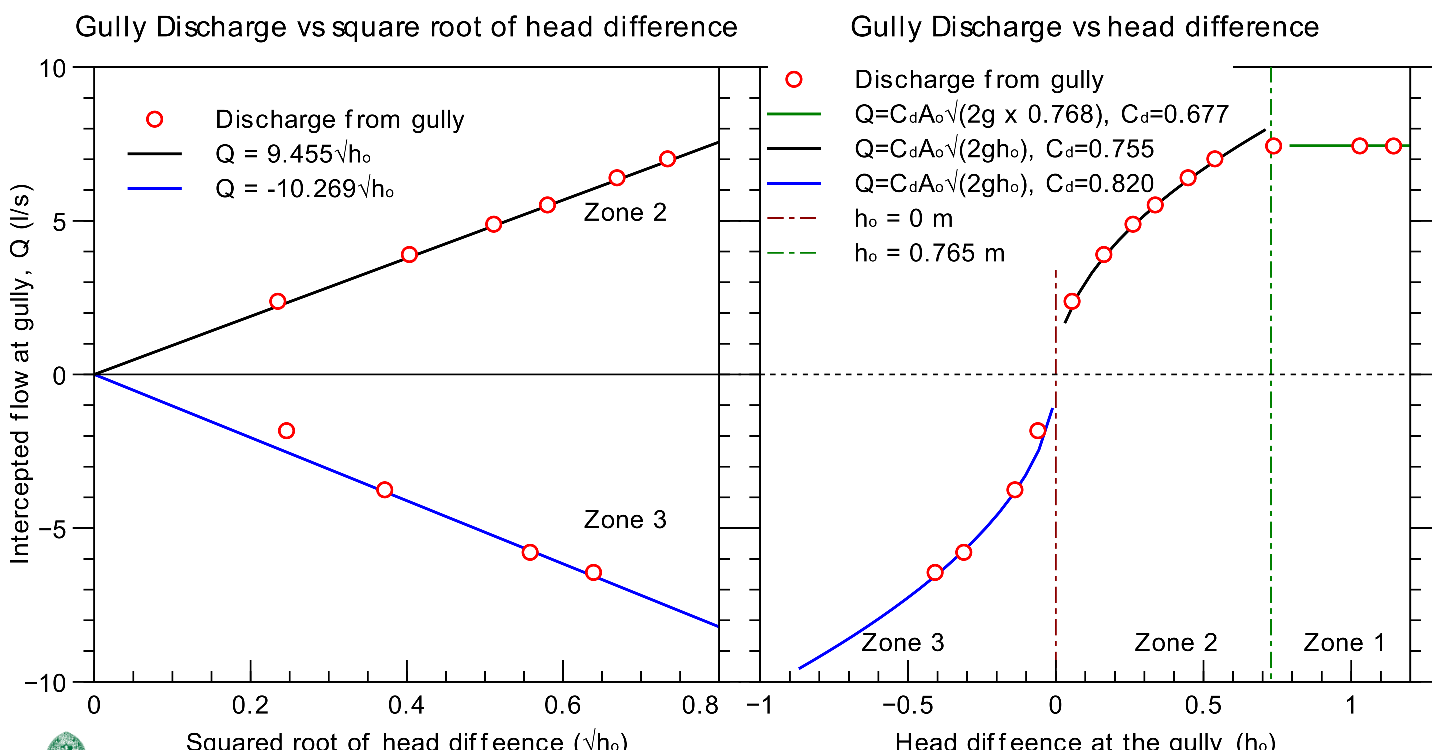


Results

Coefficient of discharge

: Three different discharge coefficients were identified for the gully outlet at different surcharge conditions

	C_d	Remarks
Zone 1	0.677	Free outfall to the atmosphere, like a plunging jet to the manhole
Zone 2	0.755	Submerged jet condition
Zone 3	0.820	Reverse flow from manhole to the gully



Conclusion

- The work presented shows the numerical assessment of flow behaviour inside a gully-manhole drainage system
- OpenFOAM® v. 2.3.0 with solver interFOAM was used with RANS k-ε turbulence model
- Numerical model shows good agreement with measured velocity at the gully
- Flow streamline show different characteristics with change in surcharge level in the manhole.

Future Work

- The model will be validated with flow measurement inside the manhole using PIV
- The influence of different gully outlet pipes on the discharge coefficient will be checked

Thank you
for your attention

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