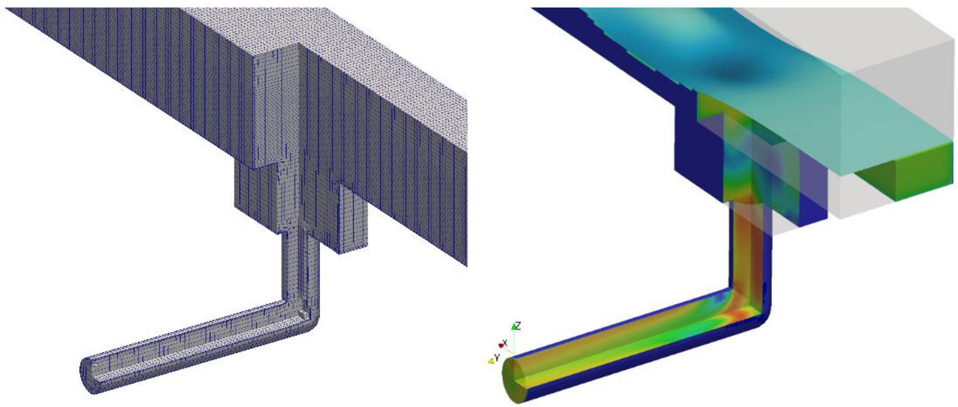
Hydraulic Structures - *Comparison Of Gully Flow Due To Different Gully Outlets*



by Md. Nazmul Azim Beg[1,2], Rita F. Carvalho[1,2] and Jorge Leandro[2,3]

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QUICS - Quantifying Uncertainty in Integrated Catchment Studies, European Union's Seventh Framework Programme for research, technological development and demonstration

Introduction

Aim

- An urban drainage system flow depends on the surface and the sewer network as well as on their **linking elements**.
- **Gullies** are common elements in an urban drainage system which collect runoff from roadside curbs and **conveys** it to the buried drainage system - accurate prediction of **discharge capacity of a gully is important as it decides the amount of flow between surface and underground drainage network ➔** Different types of gully outlets may have **different discharge capacities** due to its size and positioning; which often ignored in preparing a flood routing model
- OpenFOAM® CFD modelling toolbox with the solver *interFoam* that includes Volume of Fluid (VOF) method is able to simulate this kind of flows

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Introduction

objective

- **simulate numerically** the hydraulic performance of a gully, sizing 0.6 m × 0.24 m × 0.32 m (L × W × D) connected below a 0.5 m wide rectangular channel and draining to a manhole of 1 m diameter.
- validate model simulation with data from Dual Drainage Multiple Linking Element experimental installation located at the Laboratory of Hydraulics of the University of Coimbra.
- investigate flow hydraulics, flow efficiency and discharge coefficient of the gully for different gully outlet pipes.
- find uncertainty in gully discharge coefficient due to different gully outlet geometry

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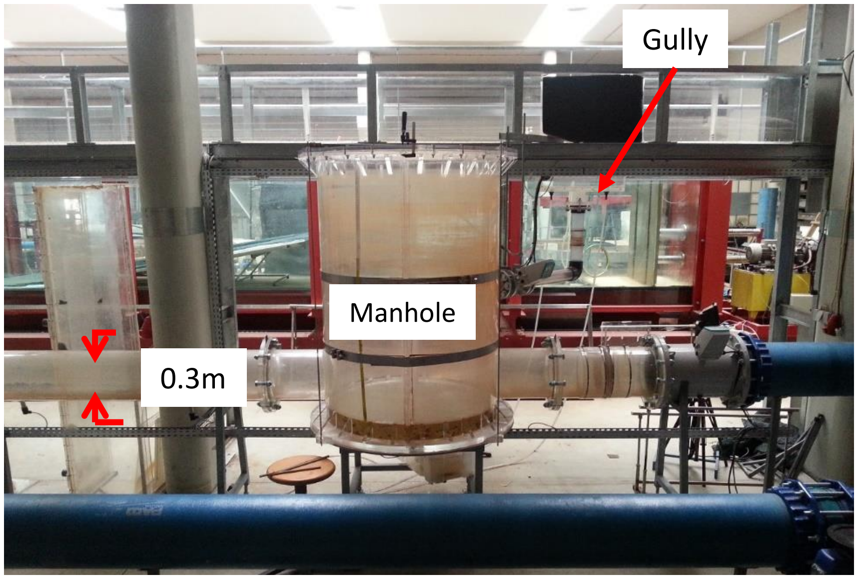
Methodology

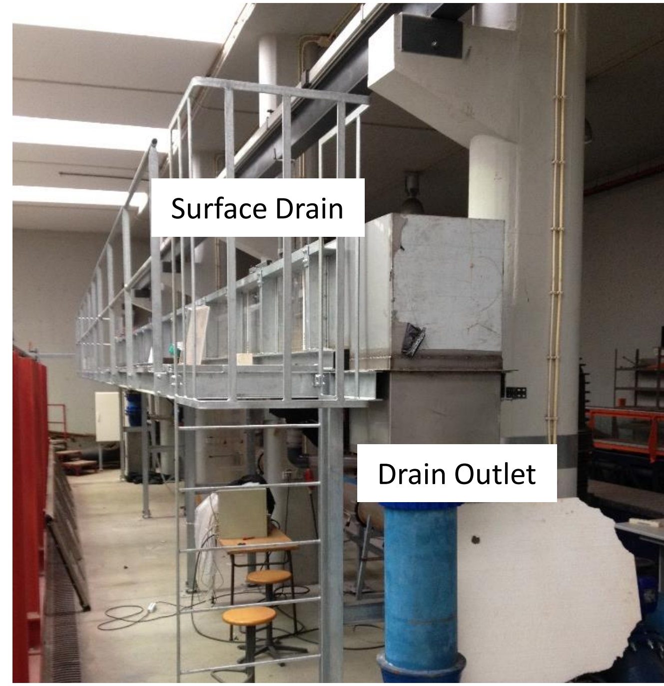
- A validated methodology is adapted from Beg et al. (2017)
- Replication of experimental real scale facility at University of Coimbra containing a surface drain, a gully and a manhole
- Comparison of point velocity at the gully
- Comparison of surcharge and discharge level at the manhole

Comparison Of Gully Flow Due To Different Gully Outlets

Methodology

Experimental setup



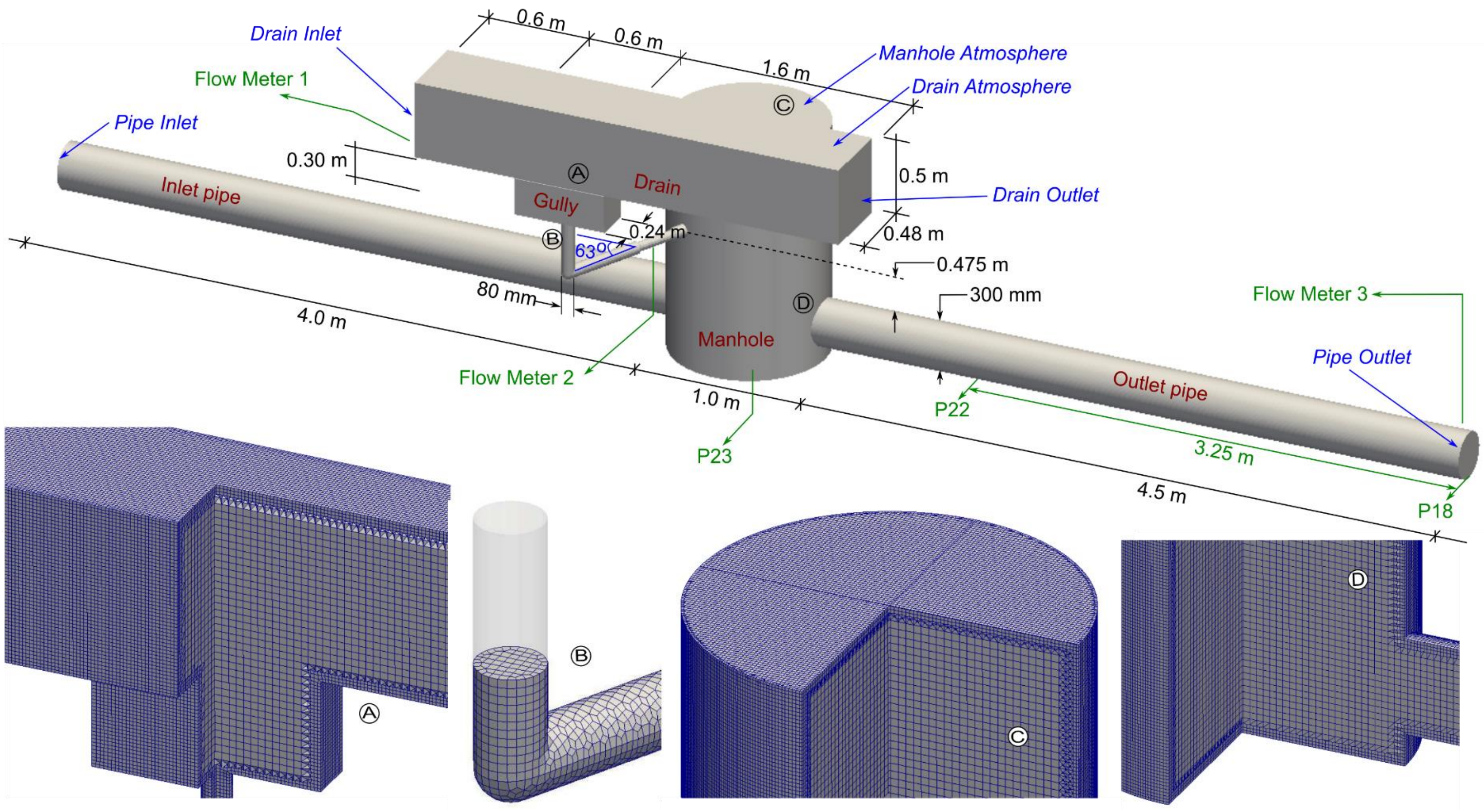


The physical model facility is installed at the Department of Civil Engineering, University of Coimbra.

- 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

Model validation (Beg et al. 2017)



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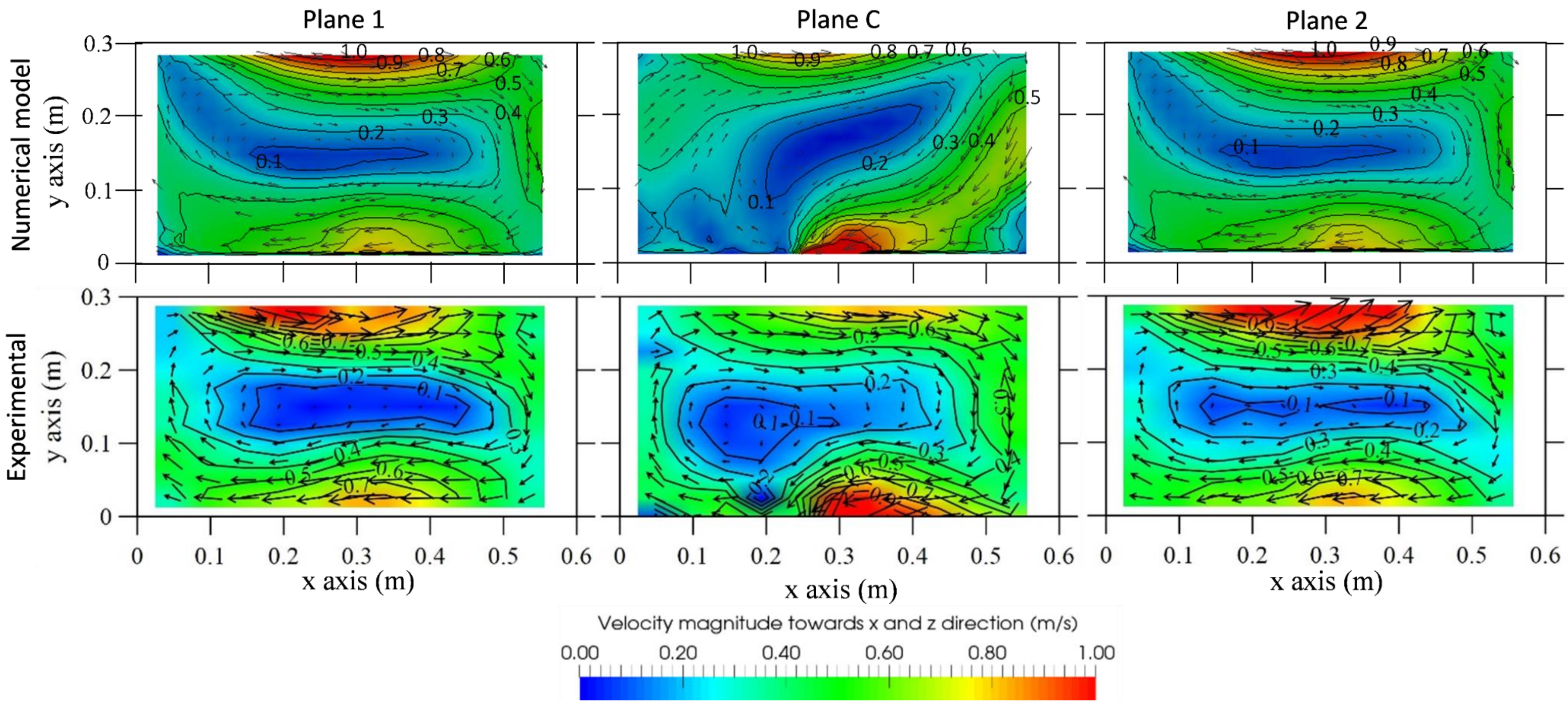
Methodology

Model validation (Beg et al. 2017)

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



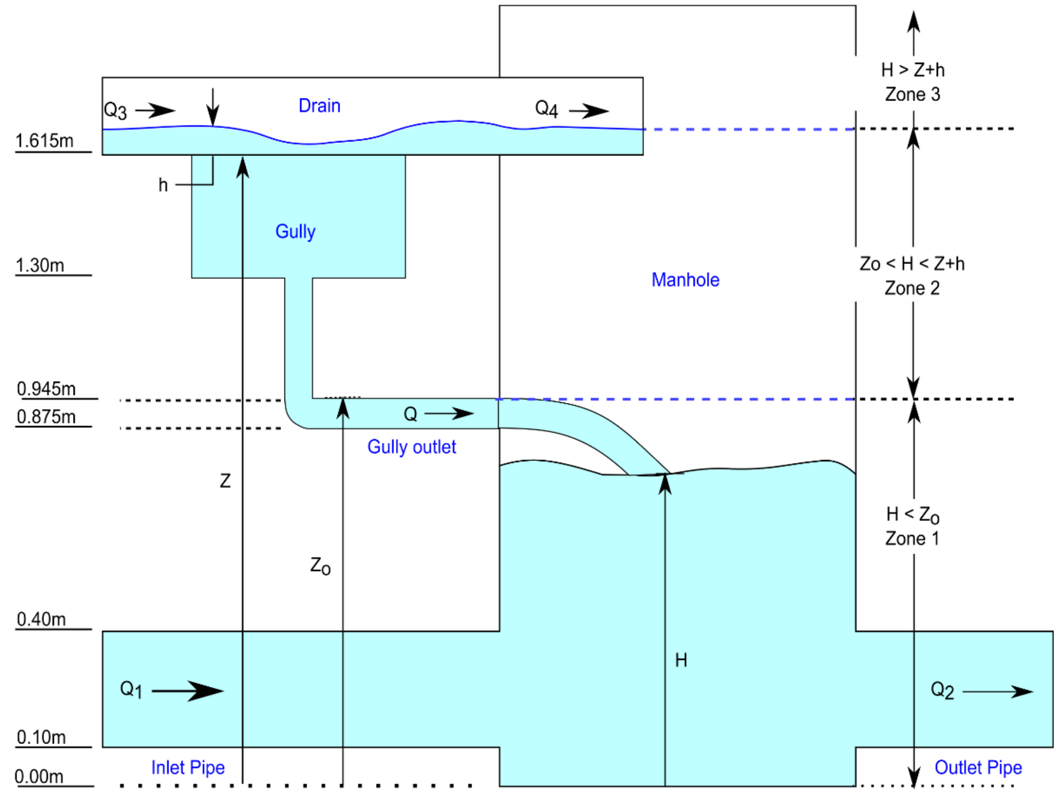
Methodology

Model validation (Beg et al. 2017)

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.



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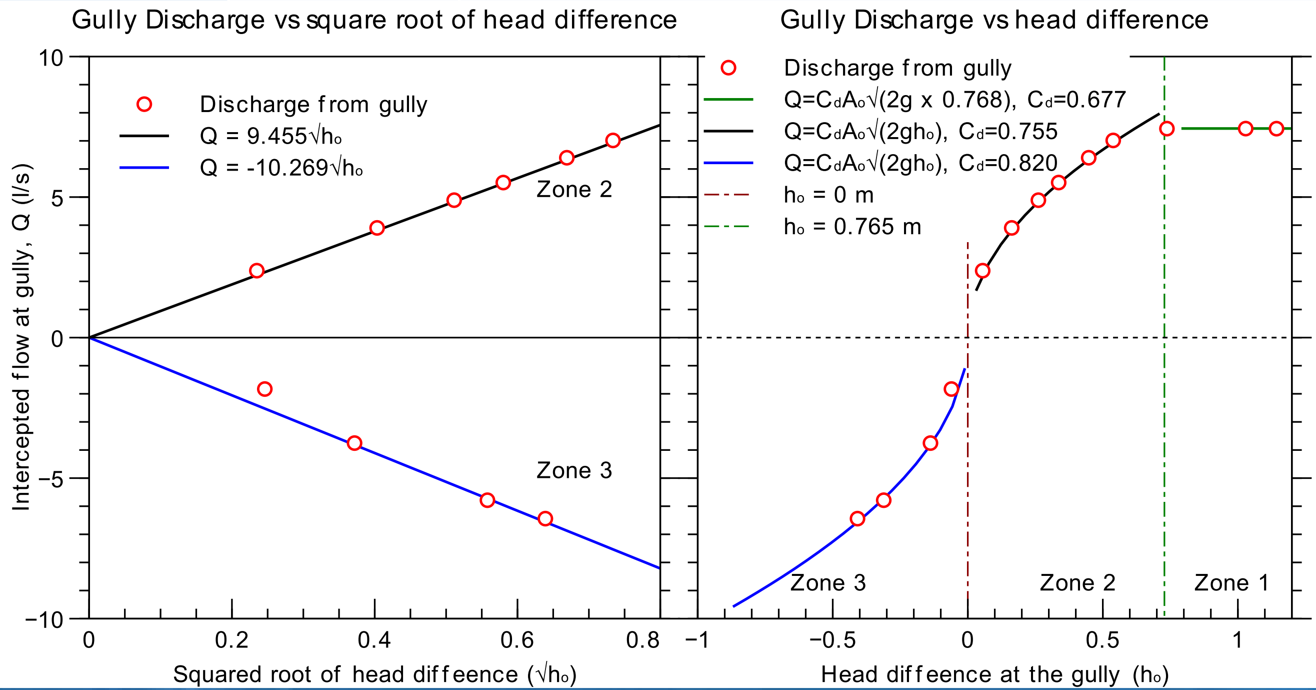
Methodology

Model validation (Beg et al. 2017)

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



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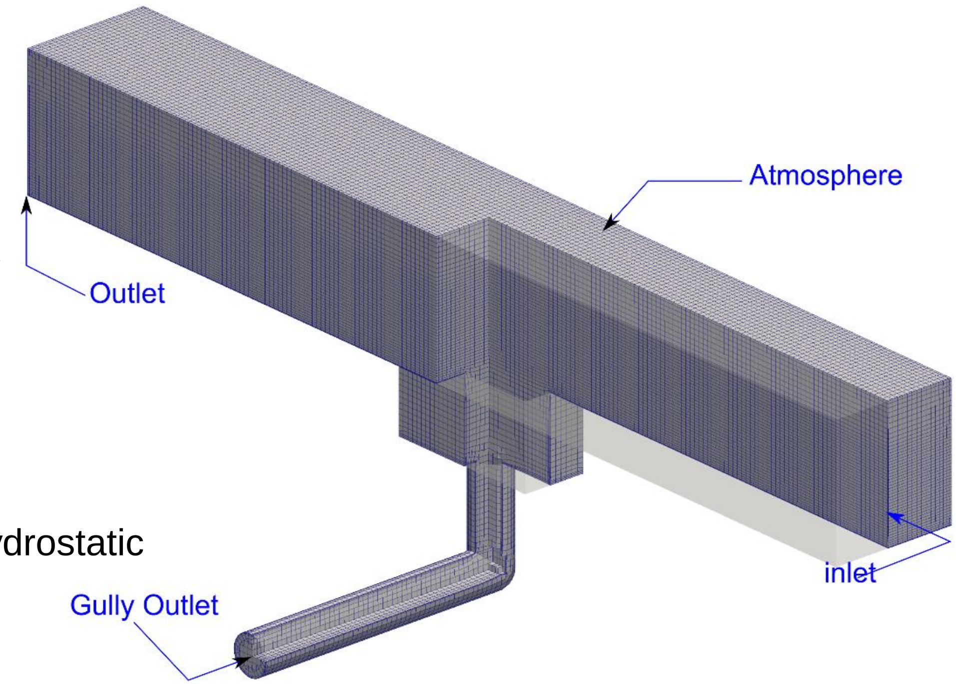
Methodology

Numerical Model set up

Mesh:
- cfMesh (v 1.1)
- Mesh size: 10 mm to 20 mm
- Boundary mesh layer: 5 layers
- y+: ranging from 30 to 300 at different walls



Boundary conditions:
- Inlet: fixed discharge: 120 l/s
- Drain out let: atmospheric pressure
- Atmosphere: atmospheric pressure
- Gully outlet: fixed pressure: according to hydrostatic water head
- Wall: no friction; noSlip; wallFunction

Numerical model
- VOF model
- interFoam solver
- Turbulence model: Standard k-epsilon
- Turbulence: considered medium intensity
- Run: MPI mode, using cluster computing at UC

Results
- 35 sec run to get steady state
- 5 sec of results saved at 0.05 sec interval, totalling 101 time steps
- All results are based on averaged data of 101 time steps

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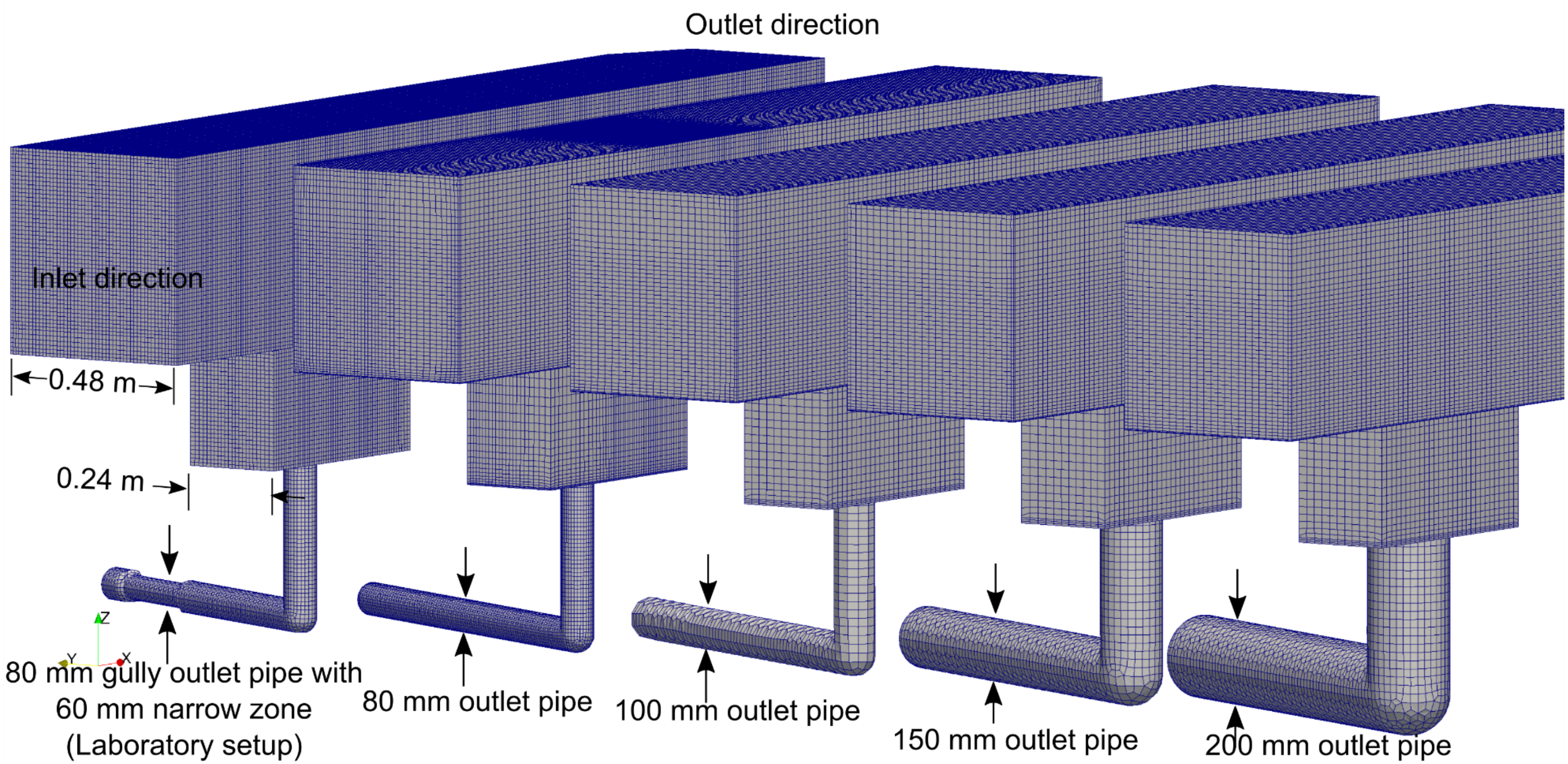
Methodology

Numerical Model set up

Explore further to check the coefficient of discharge for other types of gully outlet



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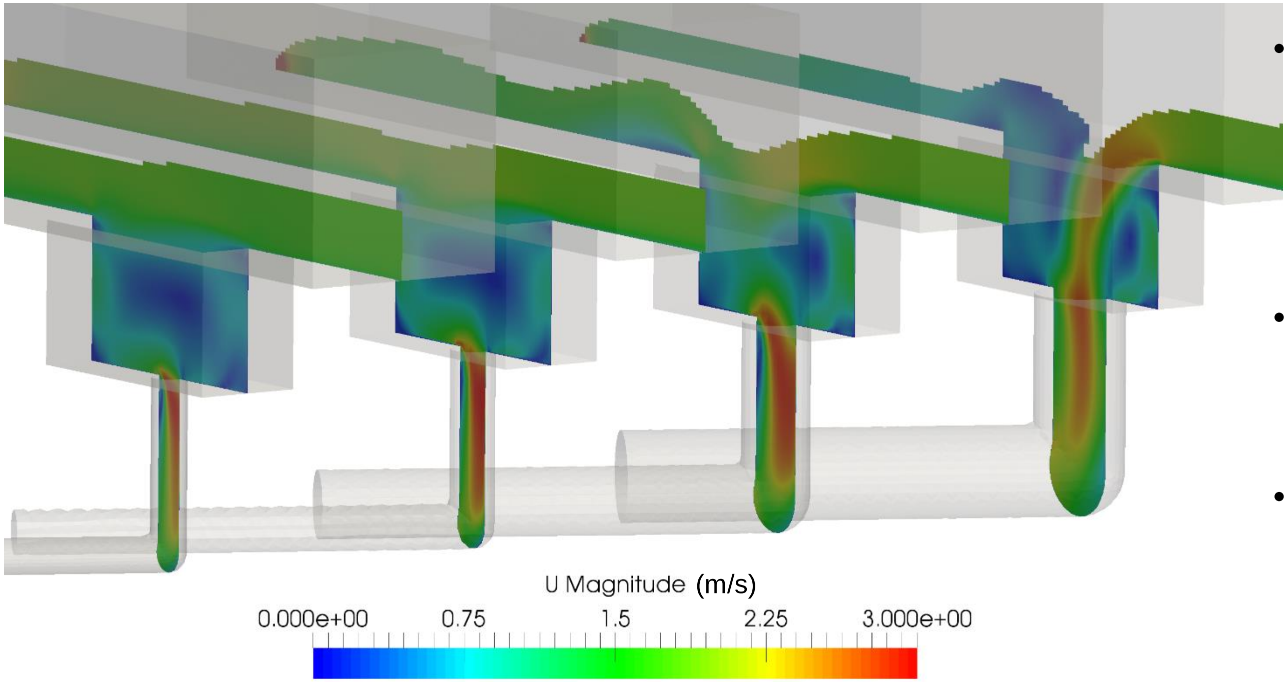
Results

Velocity at different gully



- In smaller diameter of outlet pipes, high velocity zone is concentrated at smaller area: which is at the same side of the inlet
- In a bigger diameter outlet pipe, the high velocity zone is moved towards the centre
- Ratio of effective area becomes larger in bigger diameter outket

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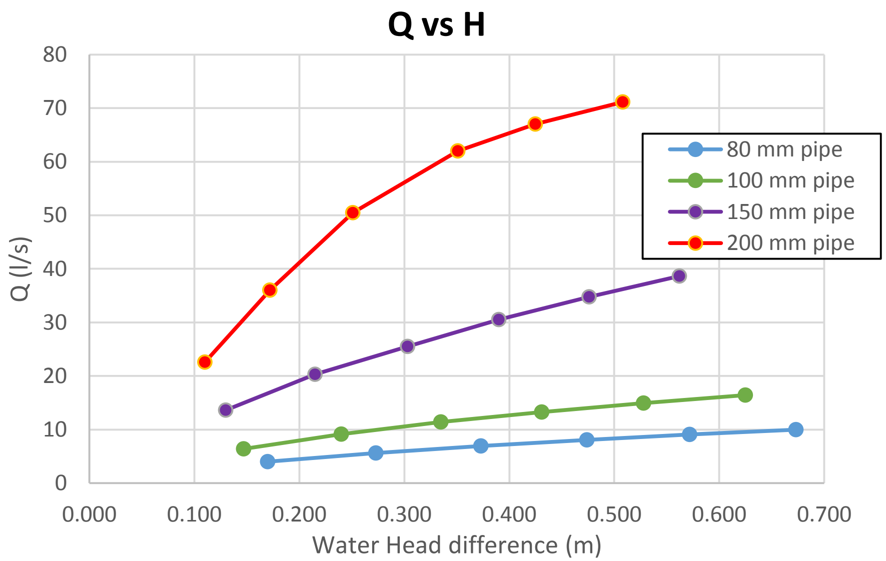
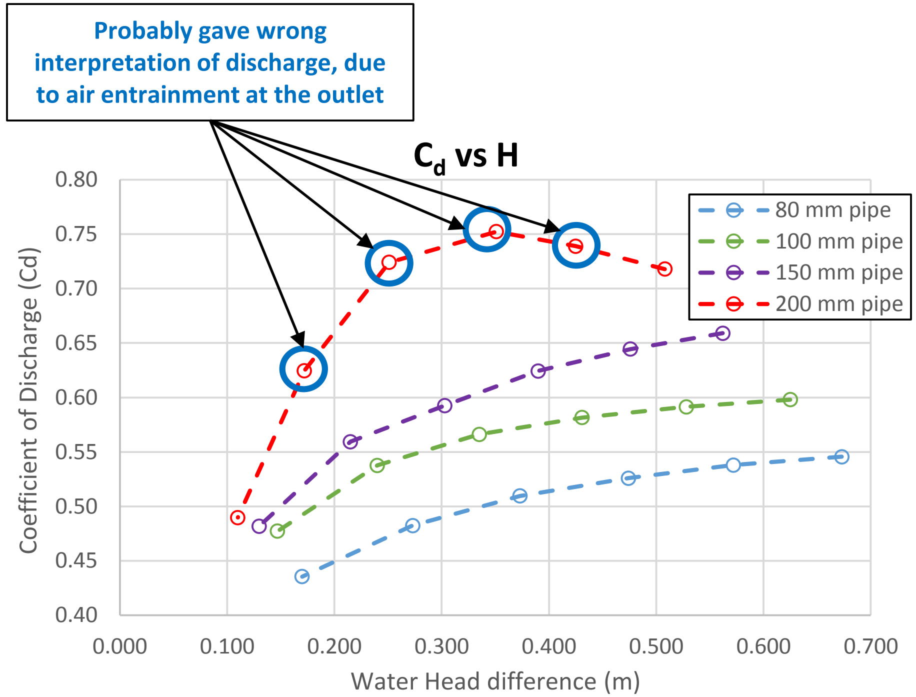
Results

Effects of different size of gully outlet





- With the increase in pipe diameter, the gully flow increases
- The flow rate increases with head difference
- However, the discharge coefficient, C_d increases with the increase in pipe diameter
- At higher head difference, the C_d increases

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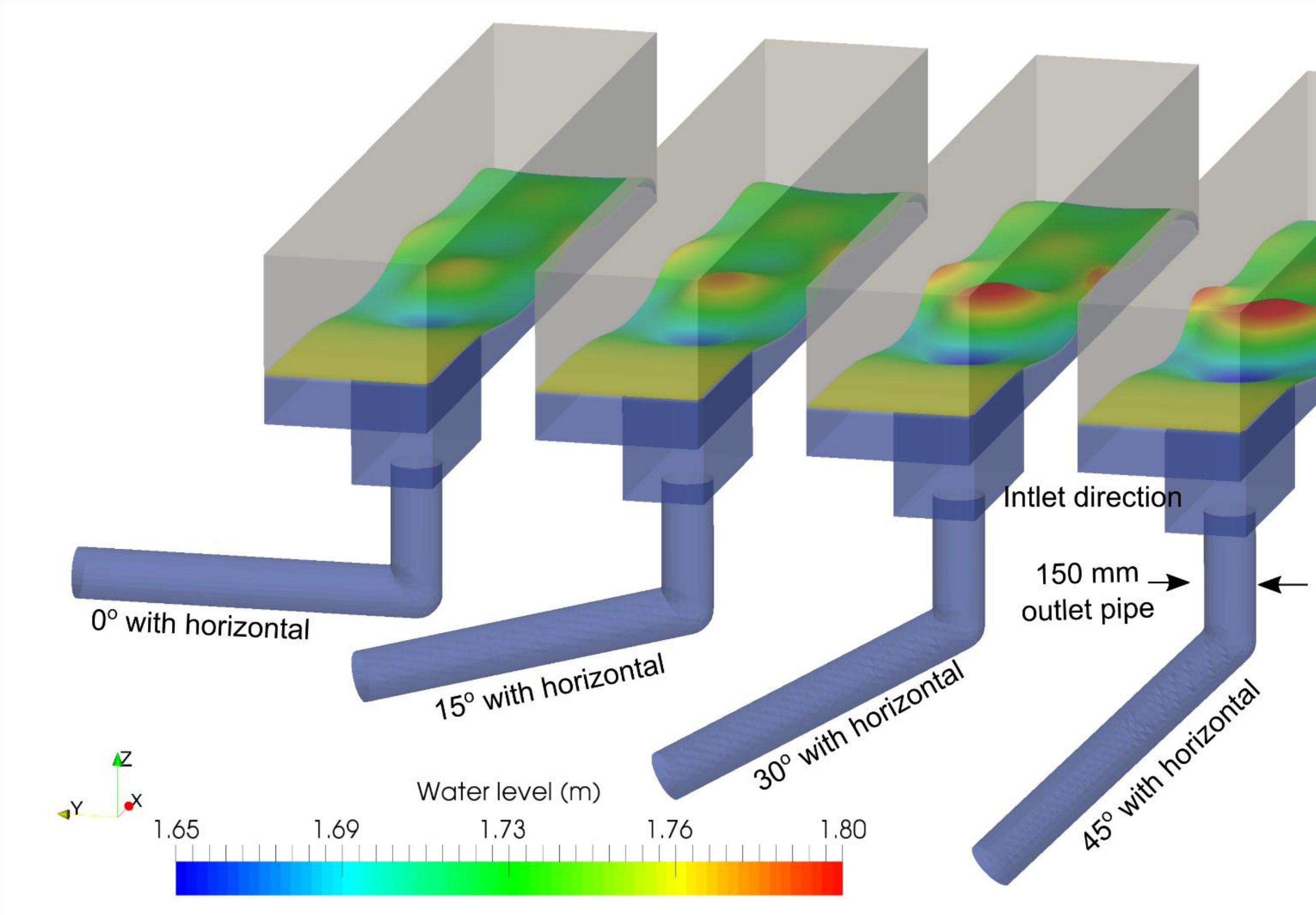
Results

Effects of different angle of gully outlet



- Four comparisons have been made
- Each with 150 mm outlet pipe
- Making 0º, 15º, 30º and 45º with the horizontal direction

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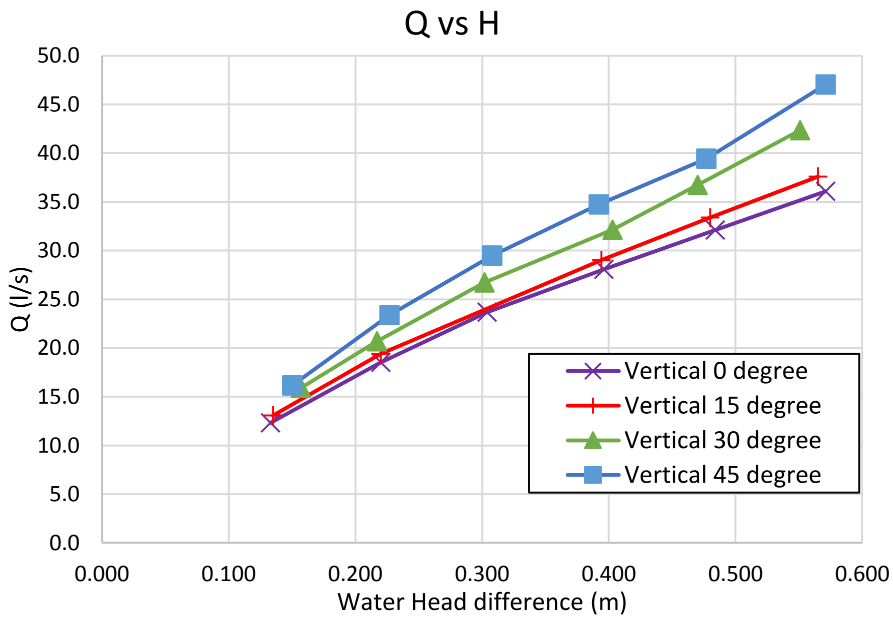
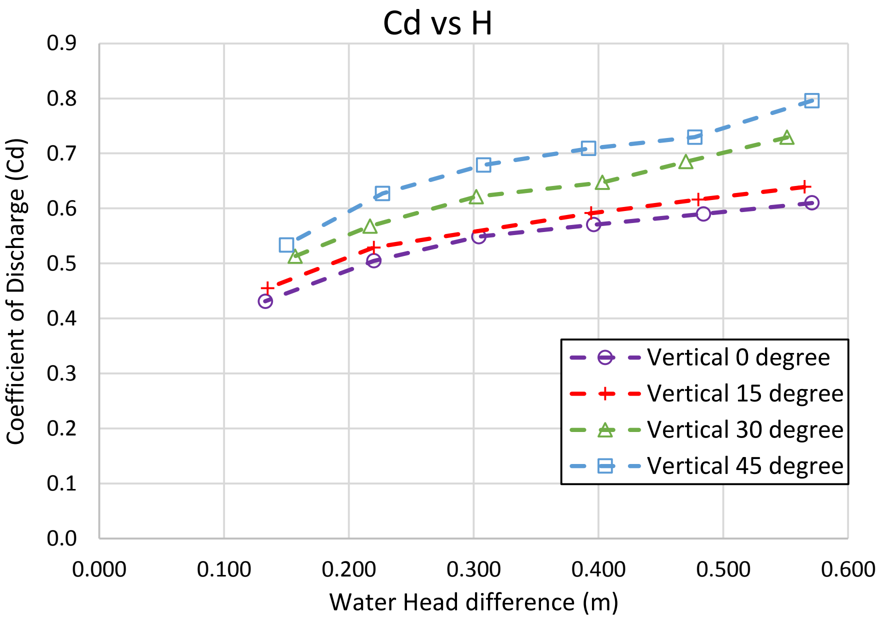
Results

Effects of different angle of gully outlet





- When the outlet is more inclined to vertical, the outlet draws more discharge
- Discharge coefficient, C_d increases with the increase of the angle to horizontal plane
- The percentage of increase of C_d is higher at higher head difference and lower at lower head difference

Conclusion

- A real scale gully model was made using OpenFOAM
- The model methodology was validated at Beg at al. (2017)
- Discharge coefficient was checked from different size and position of gully outlet pipe
- Larger outlet pipes showed higher discharge coefficient compared to smaller outlet pipes
- Gully outlet having different angles with the horizontal showed different discharge coefficients
- The uncertainty in the gully discharge coefficient will be quantified at a latter stage of the research

Thank you for your attention

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