

# Applying EPANET to represent air phase flows during water distribution network priming

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# Introduction

As water is admitted during the priming of a drinking water system, displaced air is discharged through available ventilation, typically through open hydrants.

The degree to which air pressurizes during priming operations is essentially unknown and assumedly low.

This pressurization depends on available ventilation and the priming/inflow rate.



Source: *City of Pittsburg*, <https://www.pittks.org/>

# Introduction

Quantifying air pressurization and air velocity during large-scale WDN priming is an open question as there are no tools or approaches to help in such calculations.

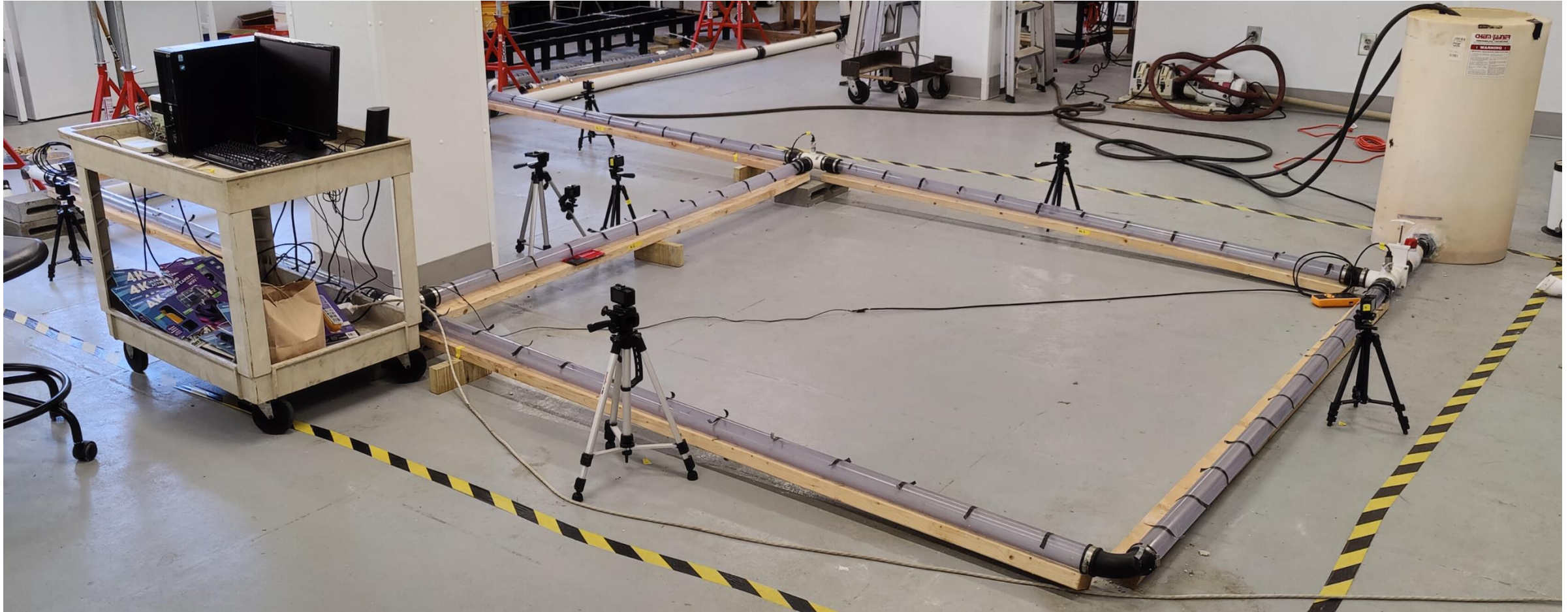
This work included a scale-model laboratory study on the priming of a WDN considering changing inflows and ventilation conditions.

Also, EPANET was adapted to represent the air phase during the WDN priming.



Source: *Rossman, L. A., M. Tryby, and R. Janke. 2020. EPANET 2.2 User Manual. Cincinnati, Ohio.*

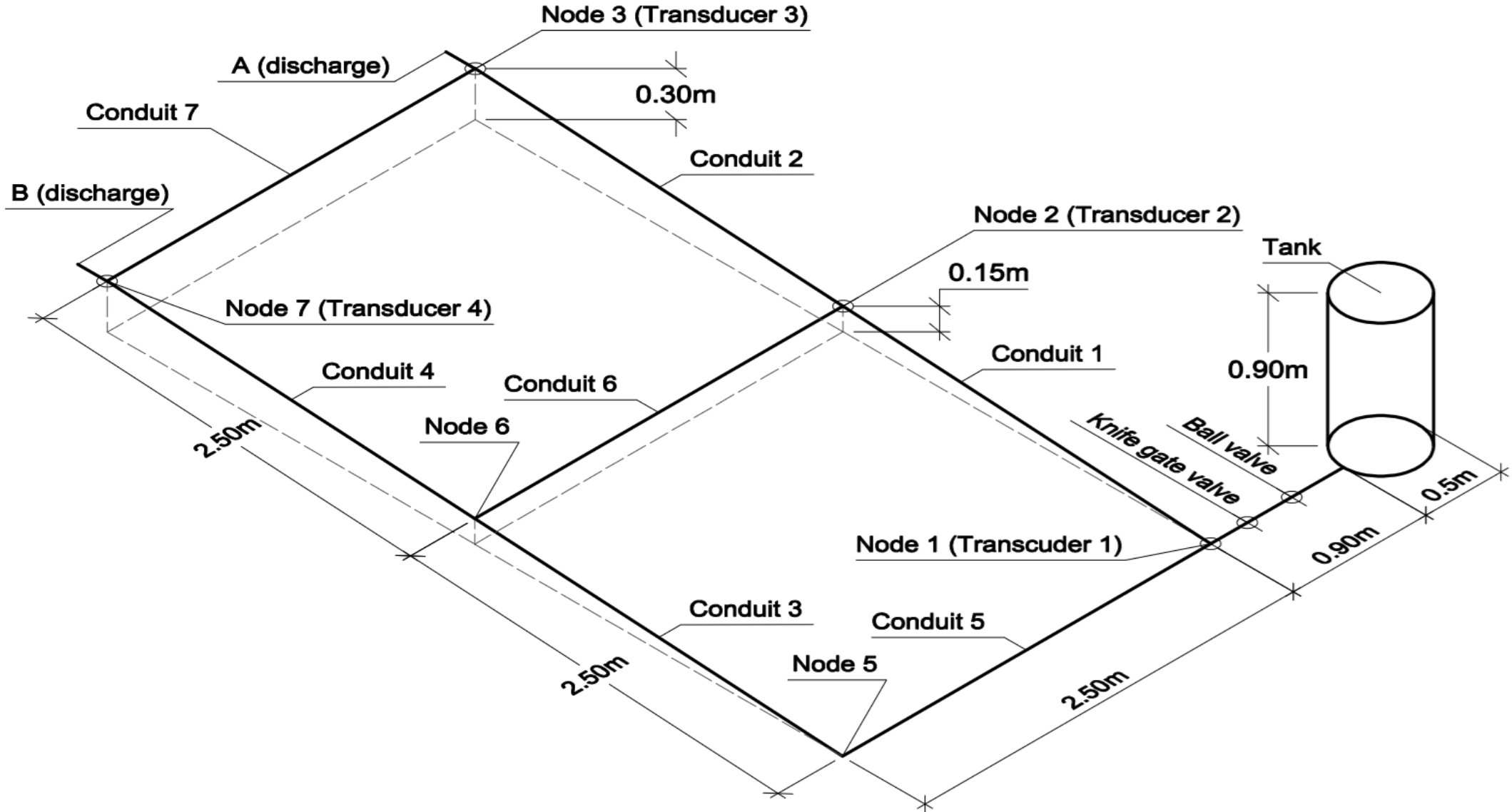
# Methodology – Experimental Apparatus



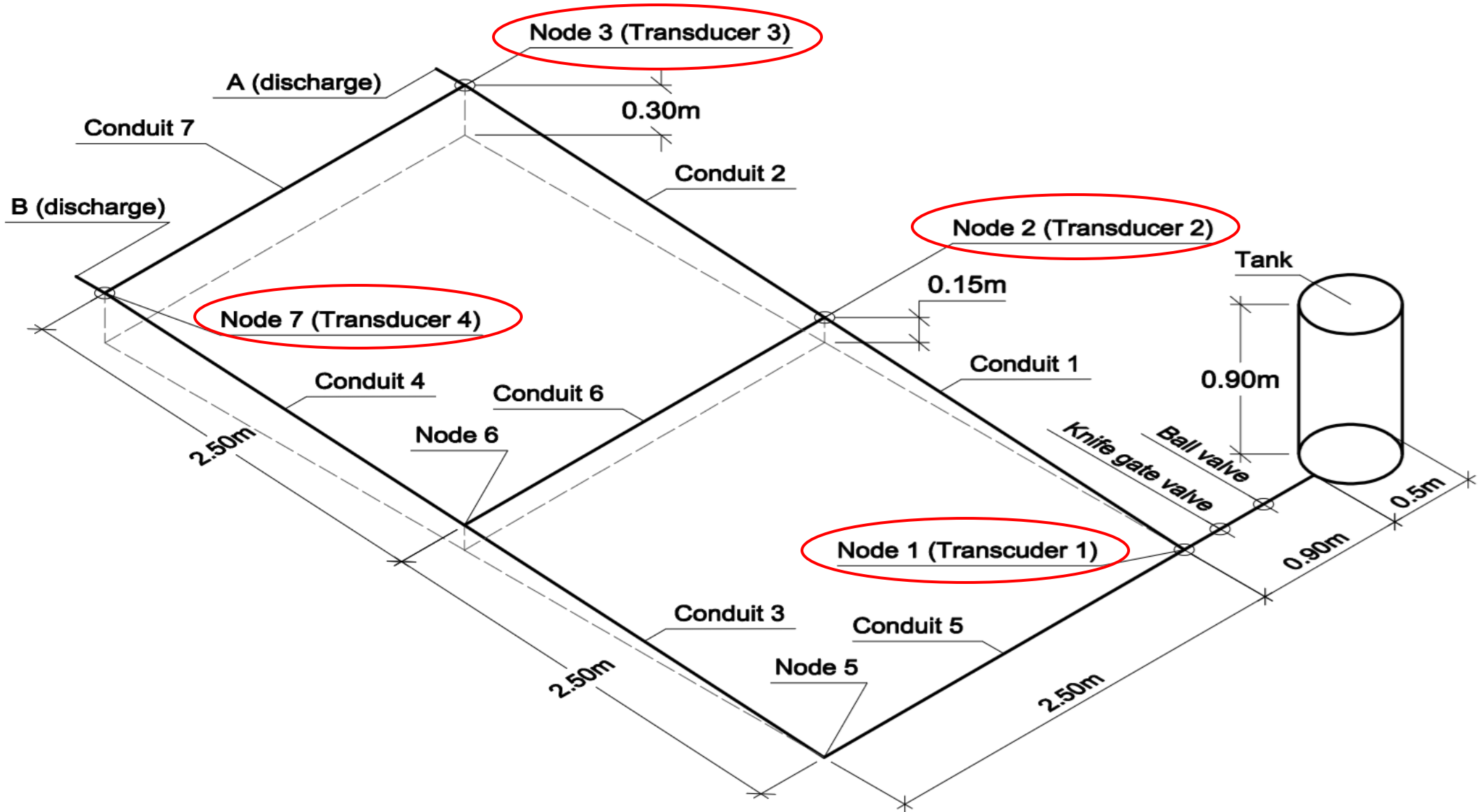
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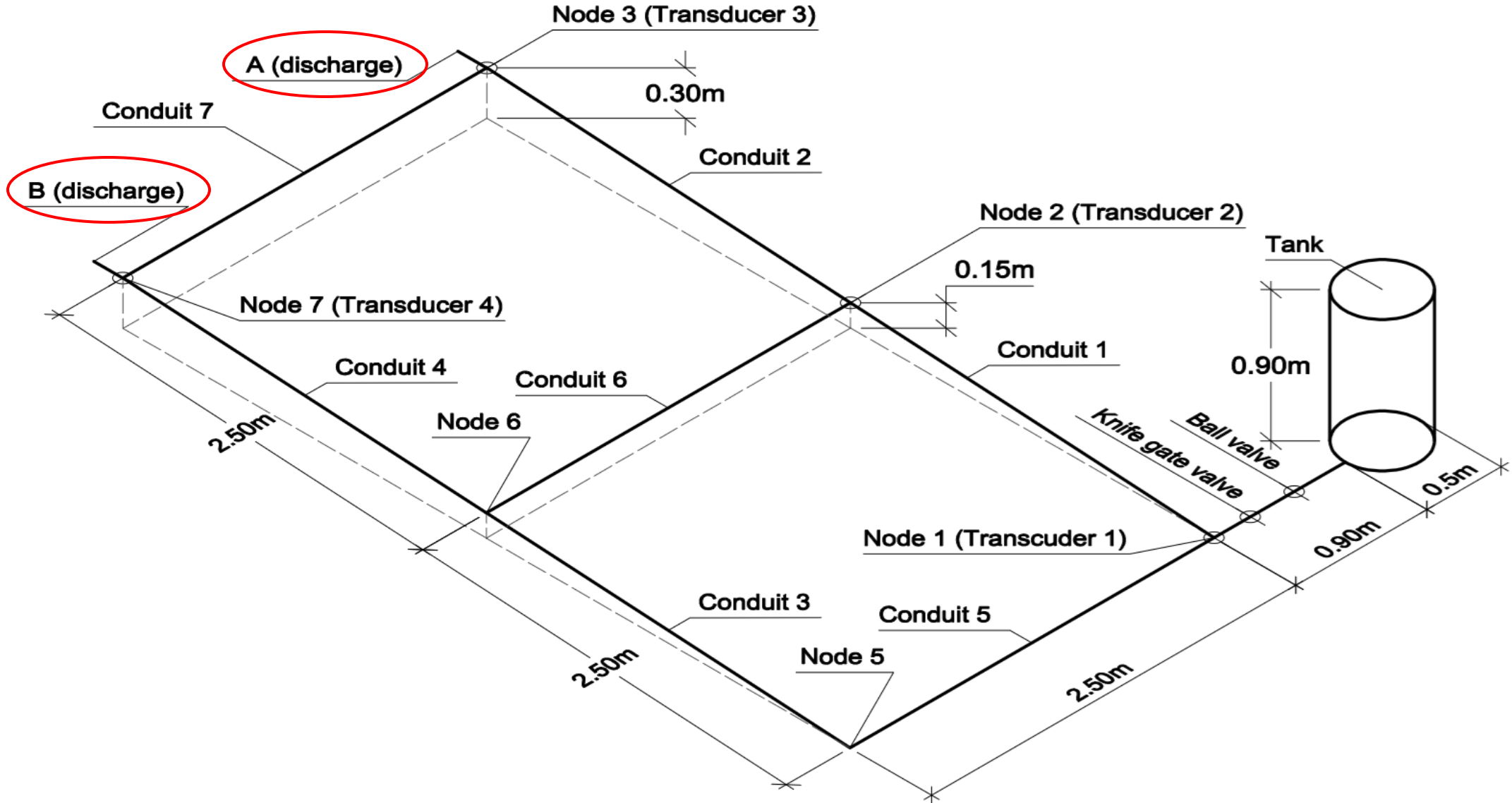
# Apparatus Schematics



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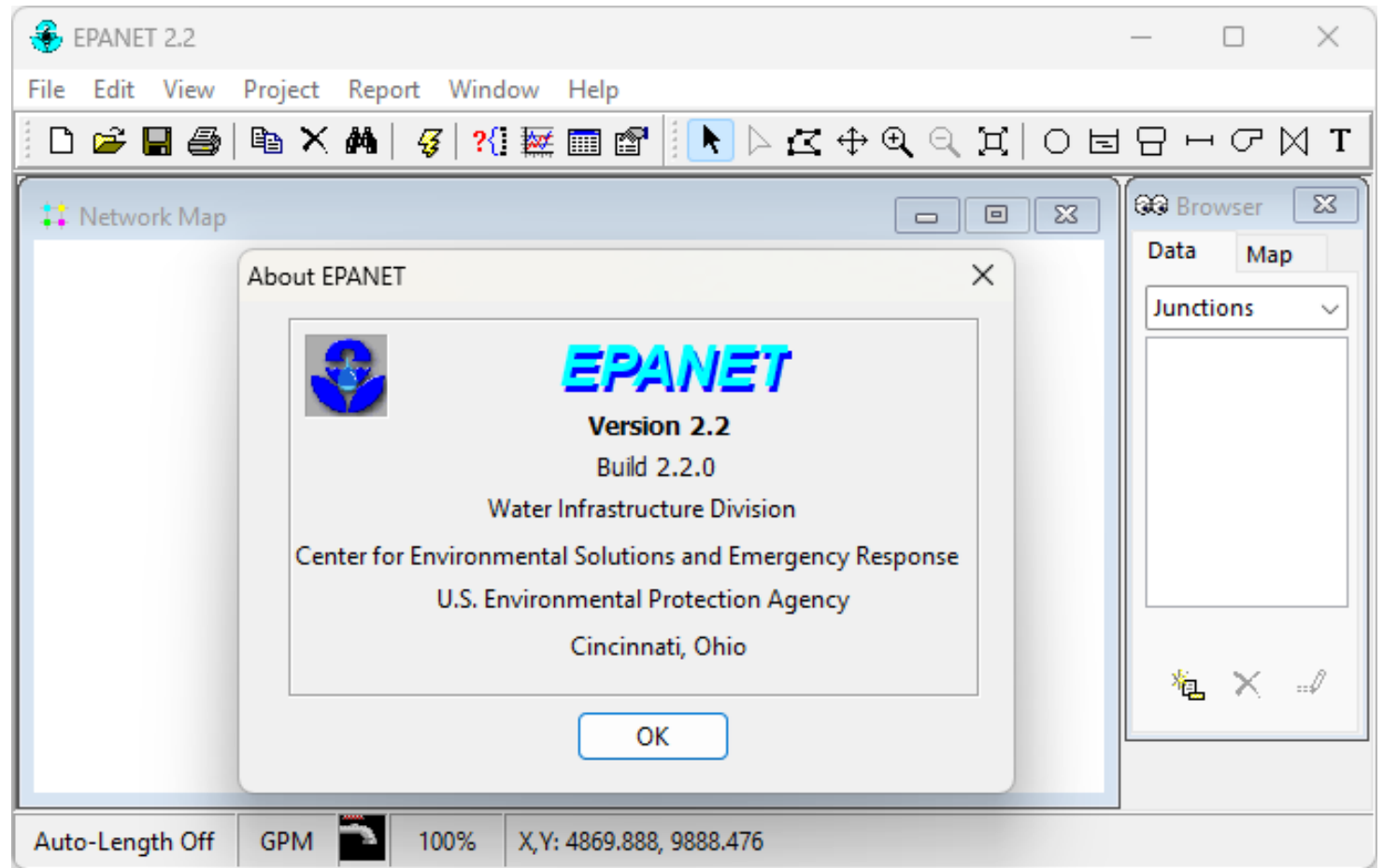
# Methodology – Valve openings and associated names

Discharge/Inflow conditions	Description
<b>D1</b>	$A = 3.2 \text{ mm}$ ( $d/D = 0.063$ ), $B = 0 \text{ mm}$
<b>D2</b>	$A = 6.4 \text{ mm}$ ( $d/D = 0.126$ ), $B = 0 \text{ mm}$
<b>D3</b>	$A = 12.7 \text{ mm}$ ( $d/D = 0.250$ ), $B = 0 \text{ mm}$
<b>D4</b>	$A = B = 3.2 \text{ mm}$ ( $d/D = 0.063$ )
<b>D5</b>	$A = B = 6.4 \text{ mm}$ ( $d/D = 0.126$ )
<b>D6</b>	$A = B = 12.7 \text{ mm}$ ( $d/D = 0.250$ )
<b>I1</b>	55° (ball valve partially opened)
<b>I2</b>	22° (ball valve partially opened)
<b>I3</b>	0° (ball valve fully opened)



# EPANET model assumptions

- Water, steady state flows
- Pressurized flow
- Single-phase model



EPANET 2.2.0

# Methodology – EPANET Setup

Emitter coefficient is the main nodal property considered for this simulation. The user is responsible for calibration of the emitter coefficient, defined as:

$$C_{e,w} = Q / \sqrt{H_w} = C_d A_o \sqrt{2g}$$

*Rossman, L. A., M. Tryby, and R. Janke. 2020. EPANET 2.2 User Manual. p. 16, Cincinnati, Ohio*

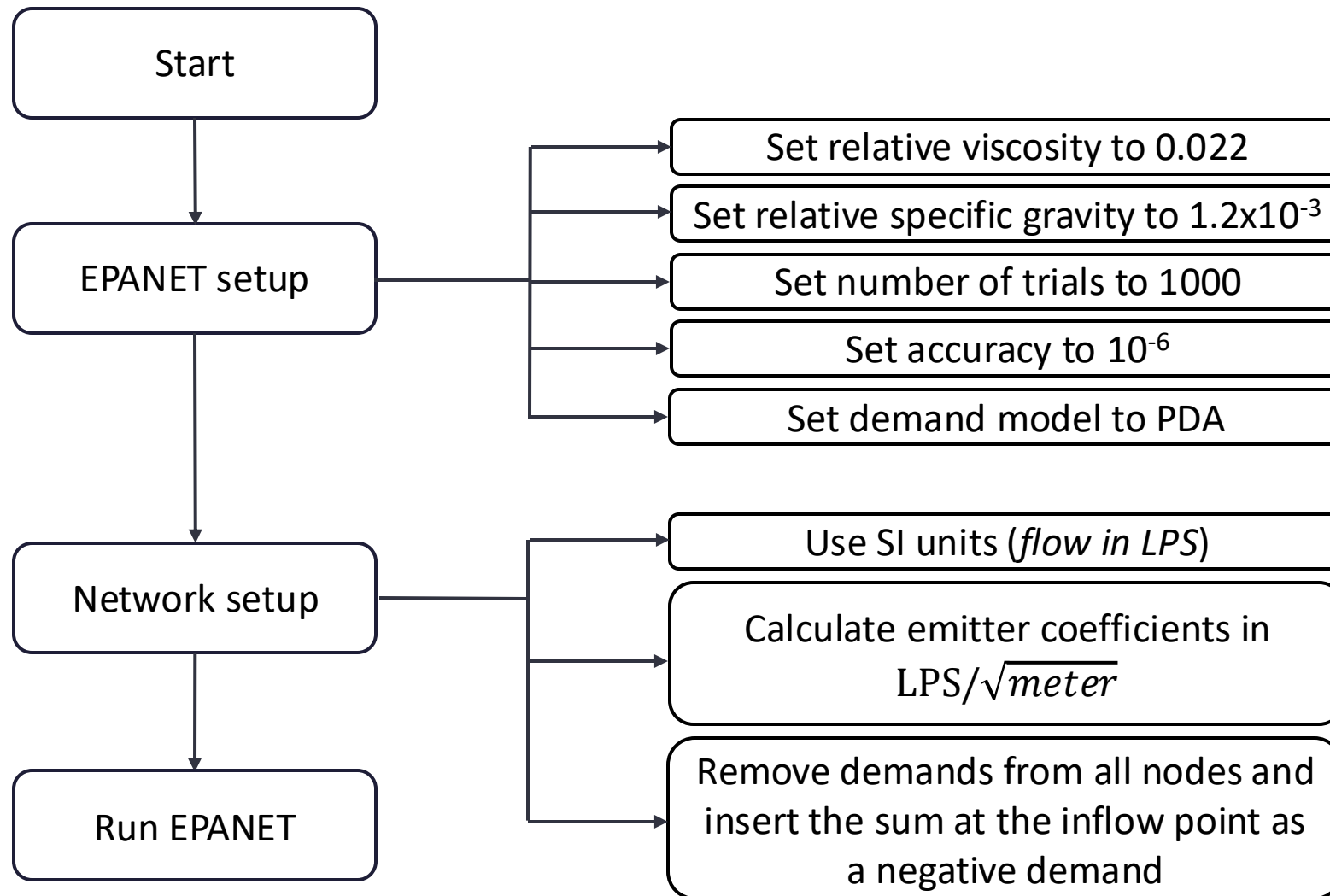
# Methodology – EPANET Setup

EPANET allows for selection of an arbitrary specific gravity and relative viscosity.

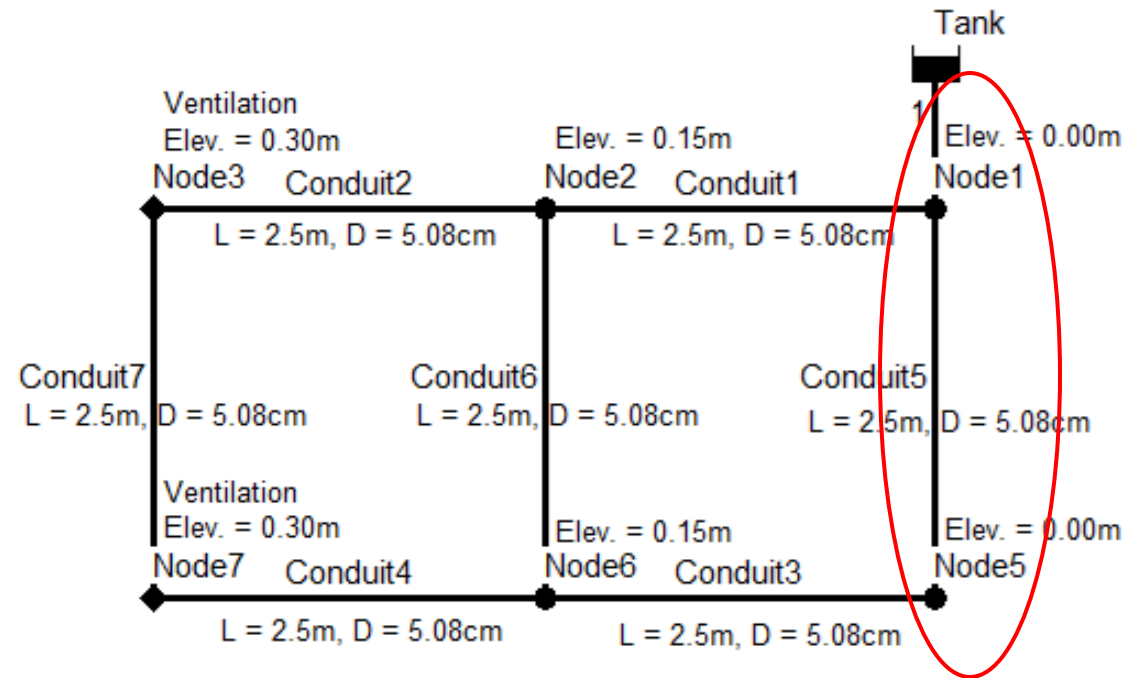
If the air discharge behaves similarly to an orifice, the model can relate air discharge to water pressure head through the adjustment equation:

$$Q_{air} = C_d A_o \sqrt{2 \frac{g \rho_w H_w}{\rho_a}} = C_{e,w} \sqrt{\frac{\rho_w}{\rho_a}} \sqrt{H_w} = C_{e,a} \sqrt{H_w}$$

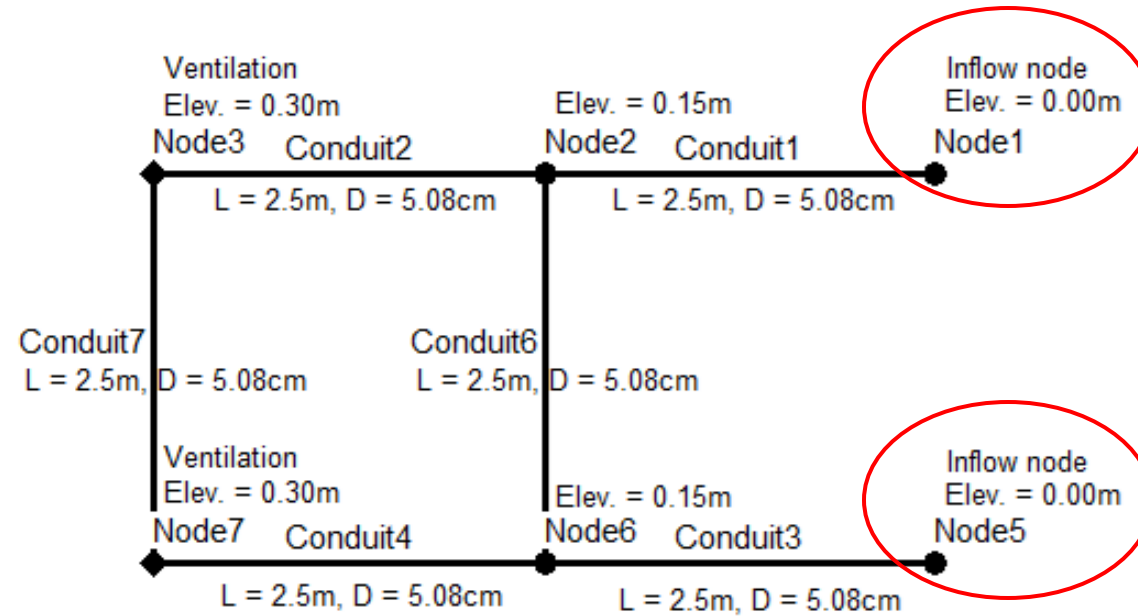
# Methodology – Overview



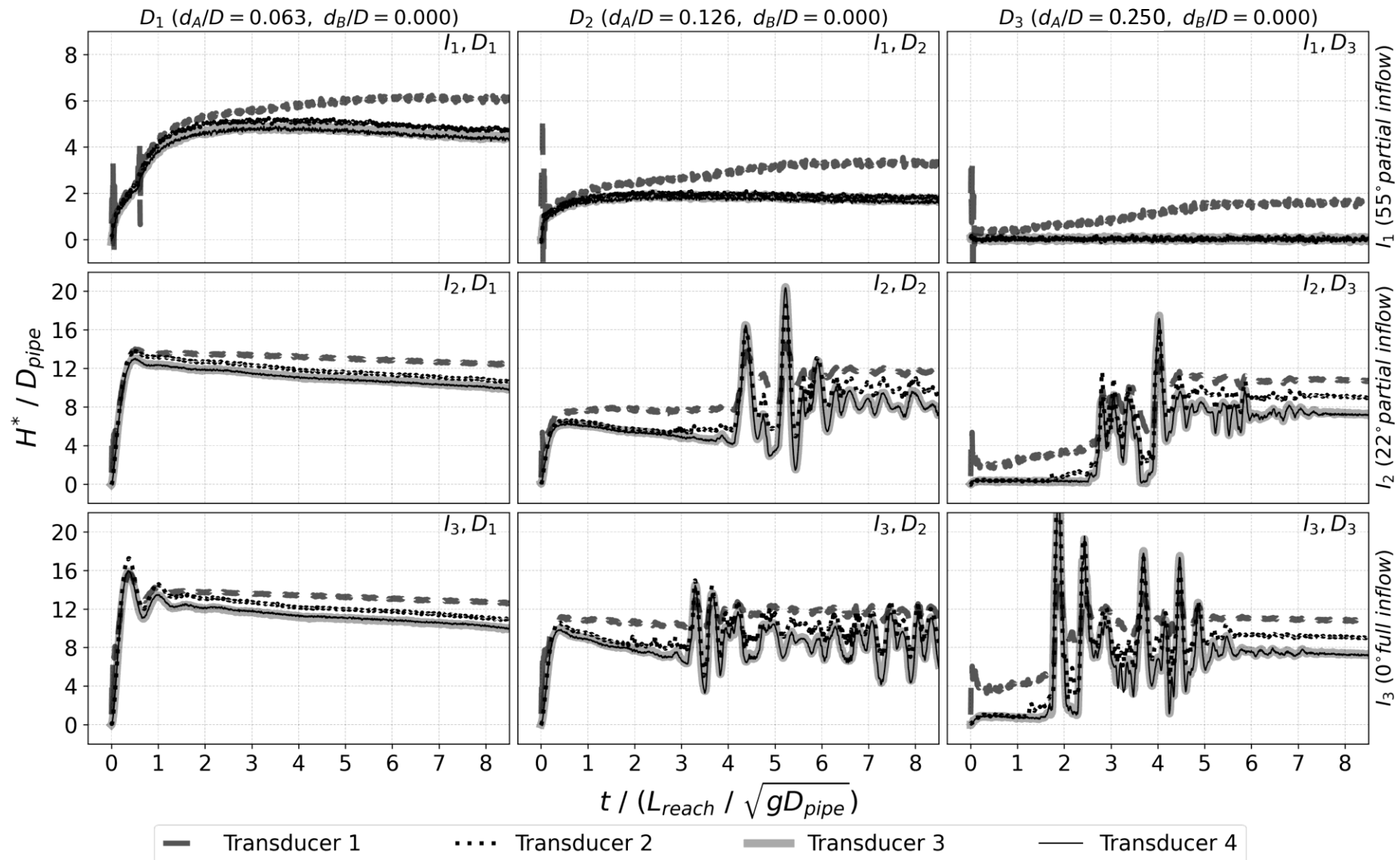
# Experimental Apparatus in EPANET



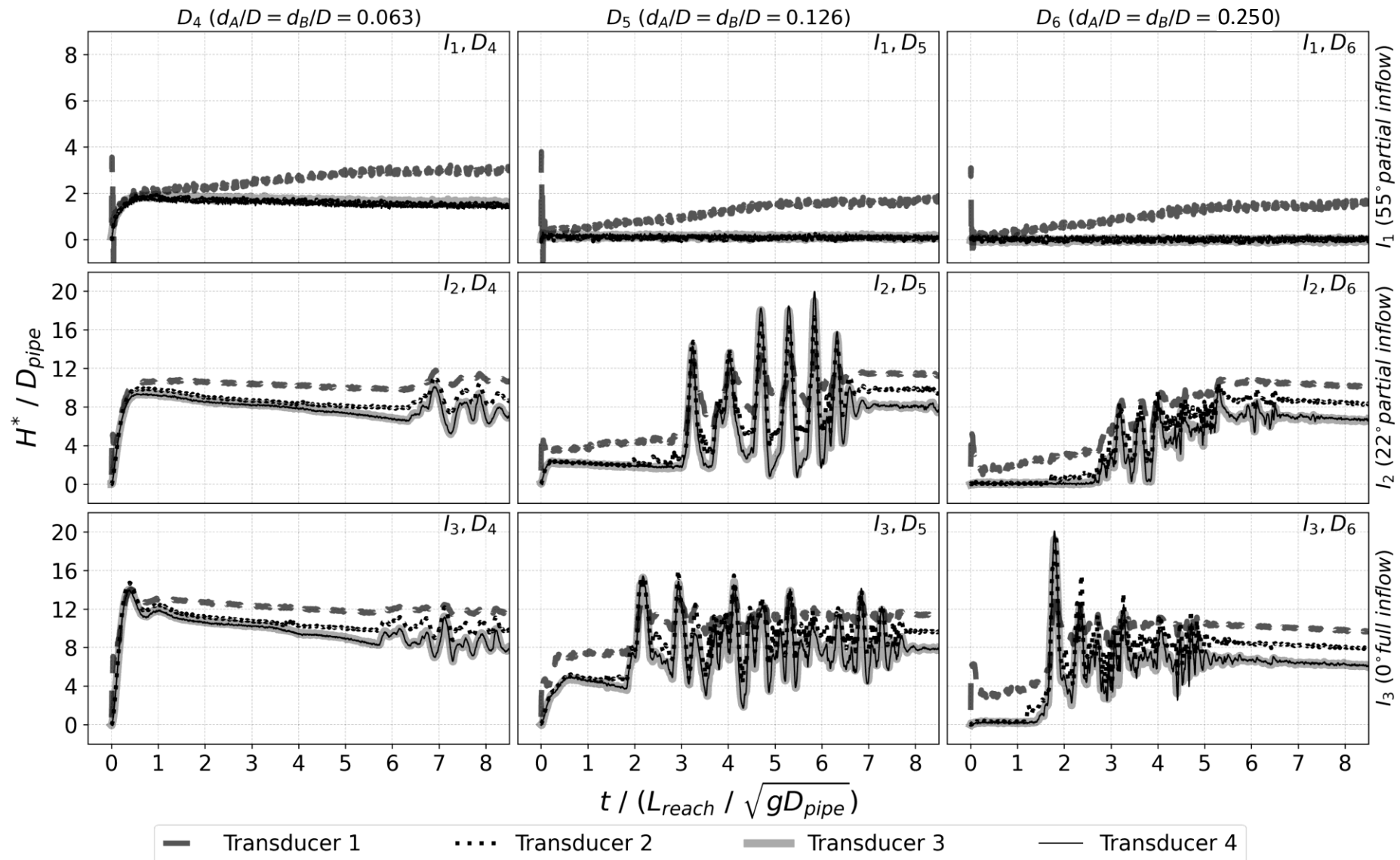
# Experimental Apparatus in EPANET



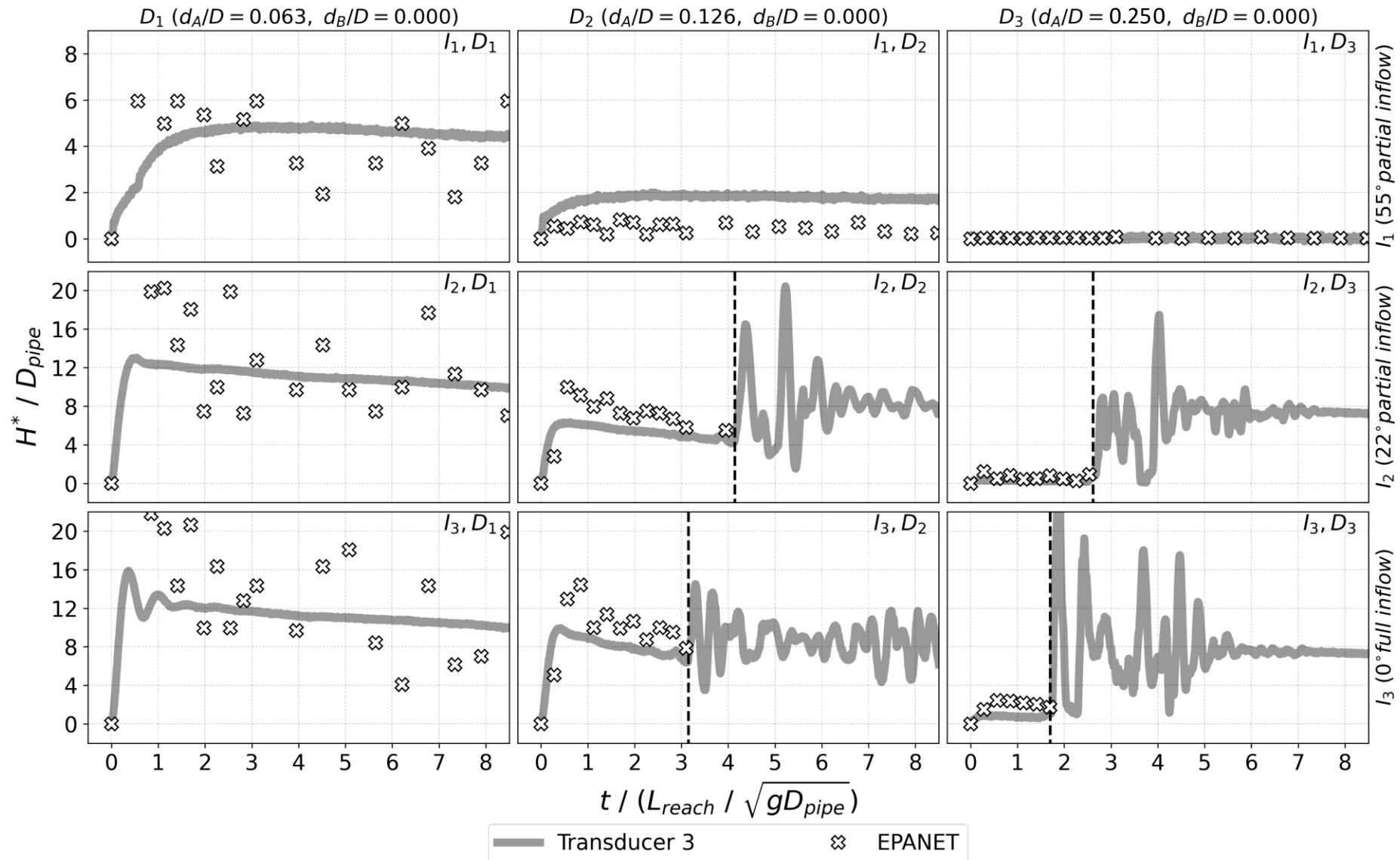
# Methodology – Collected Pressures



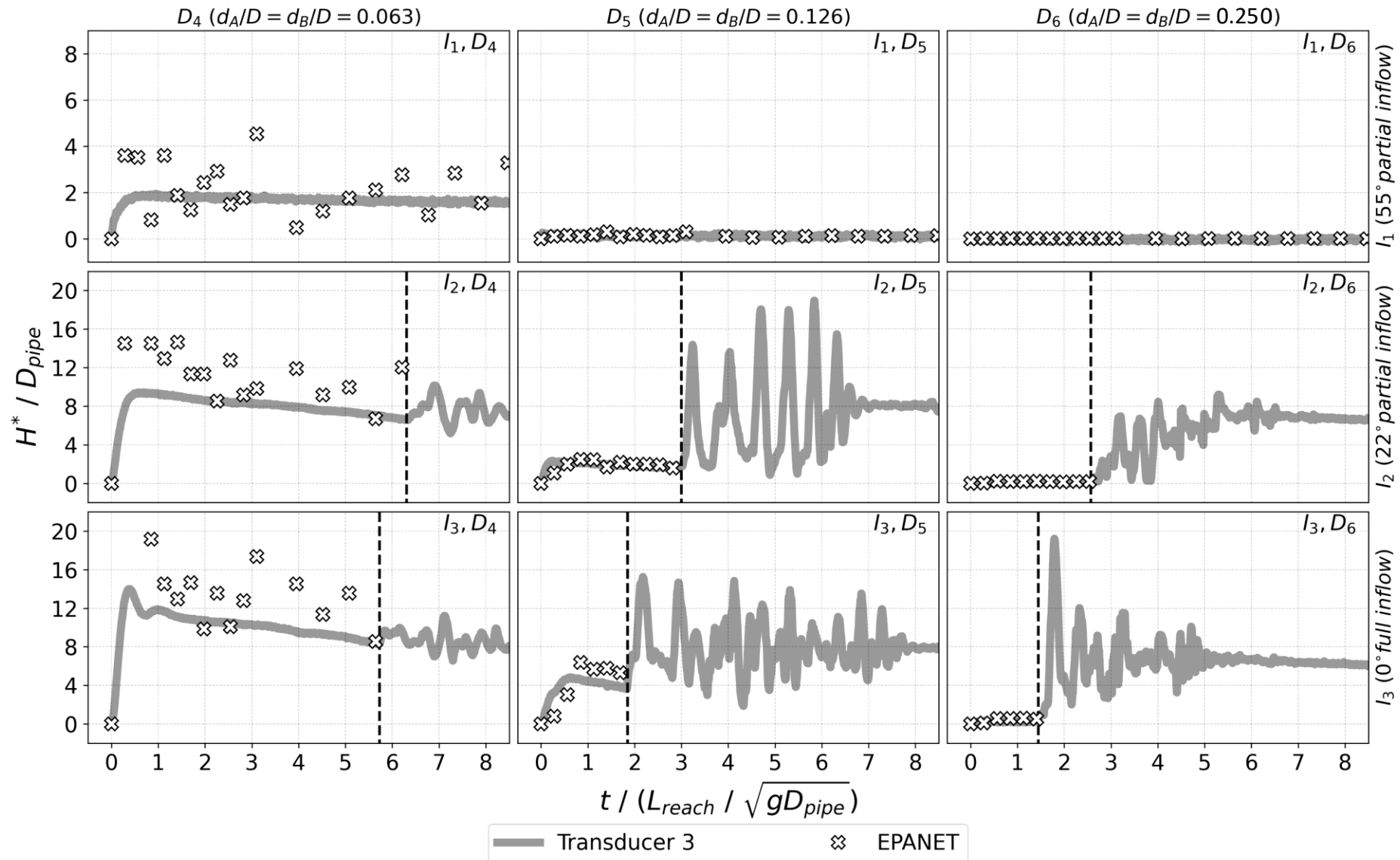
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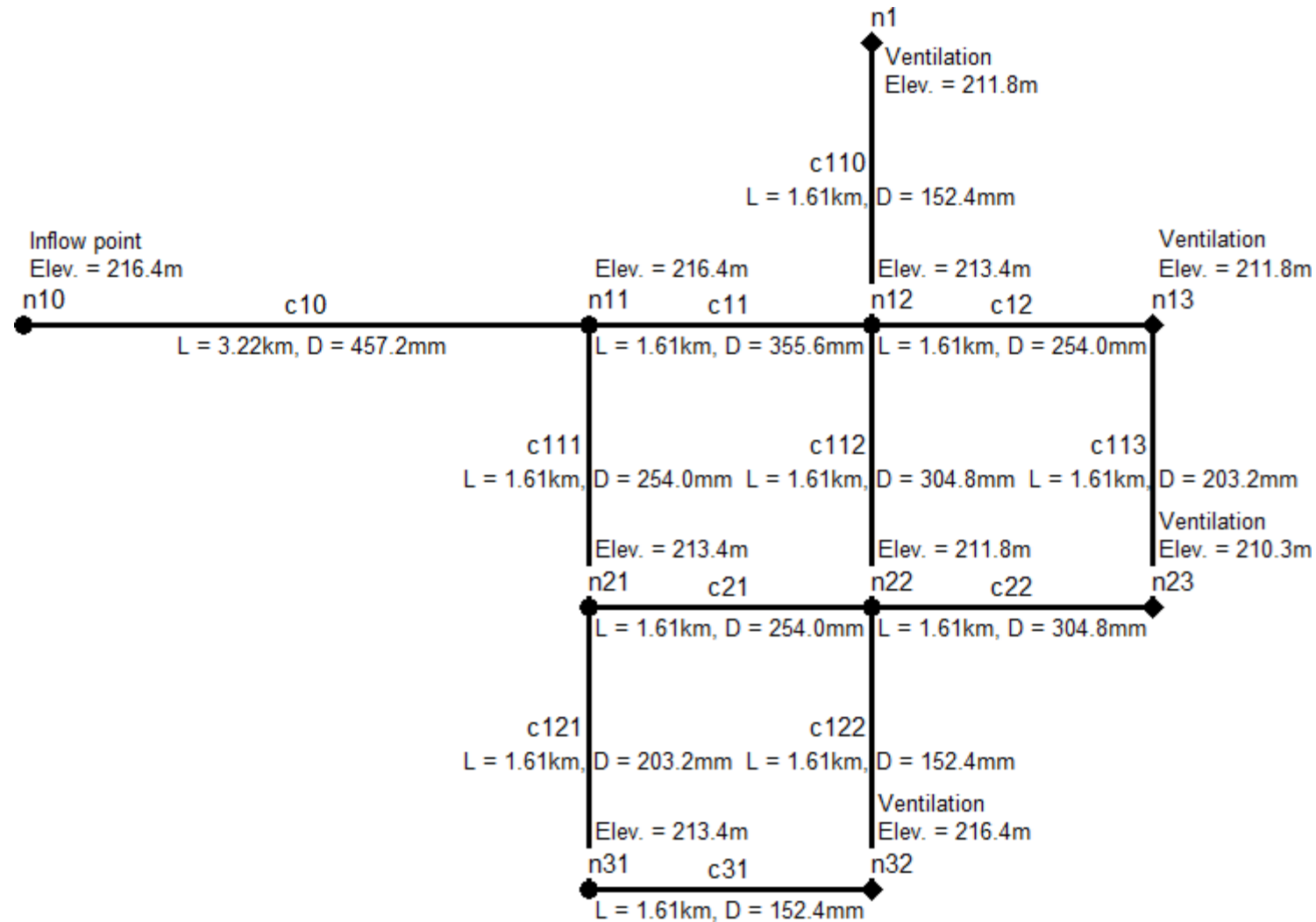
# Methodology – EPANET's Predictions at the Discharge



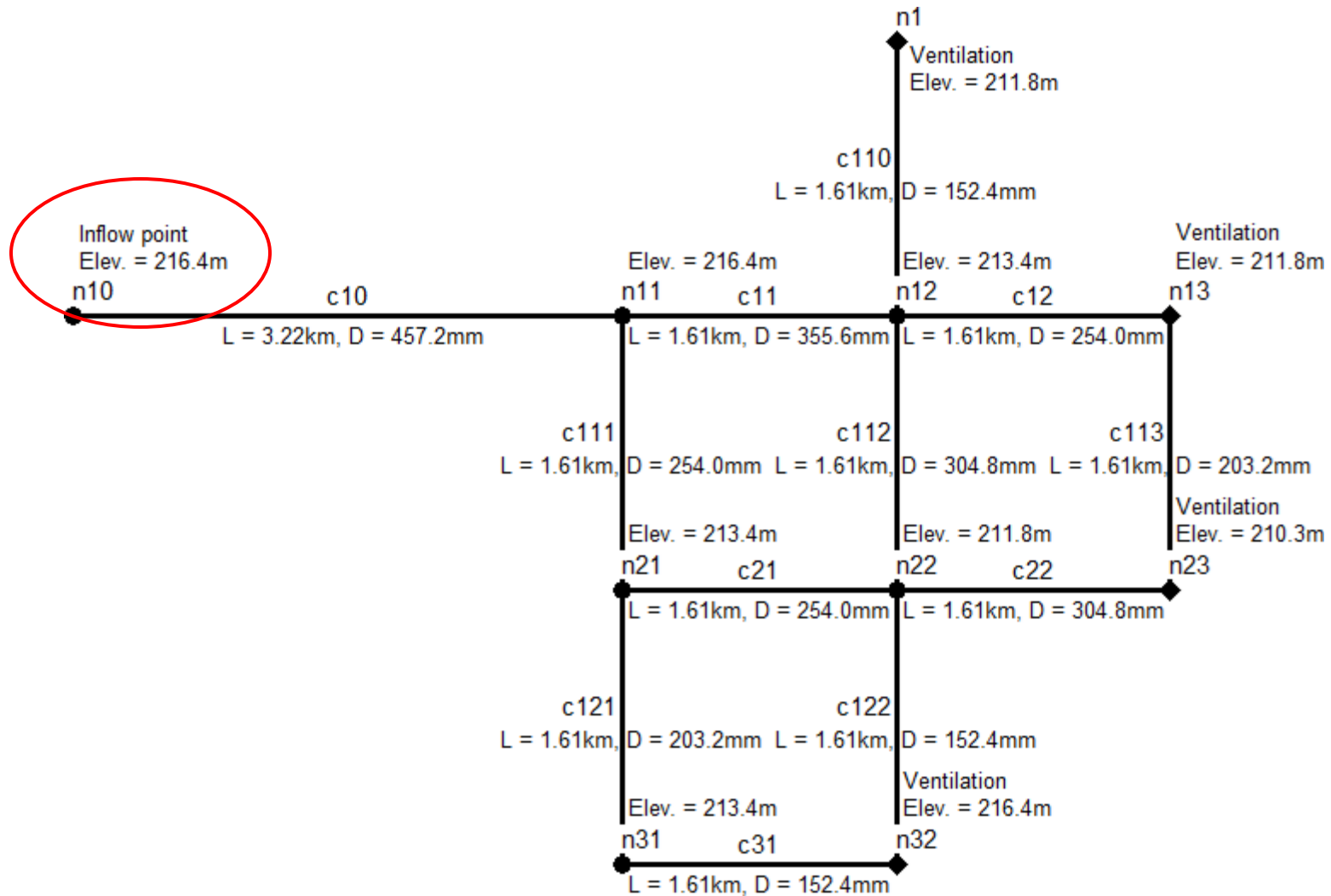
# Methodology – EPANET's Predictions at the Discharge



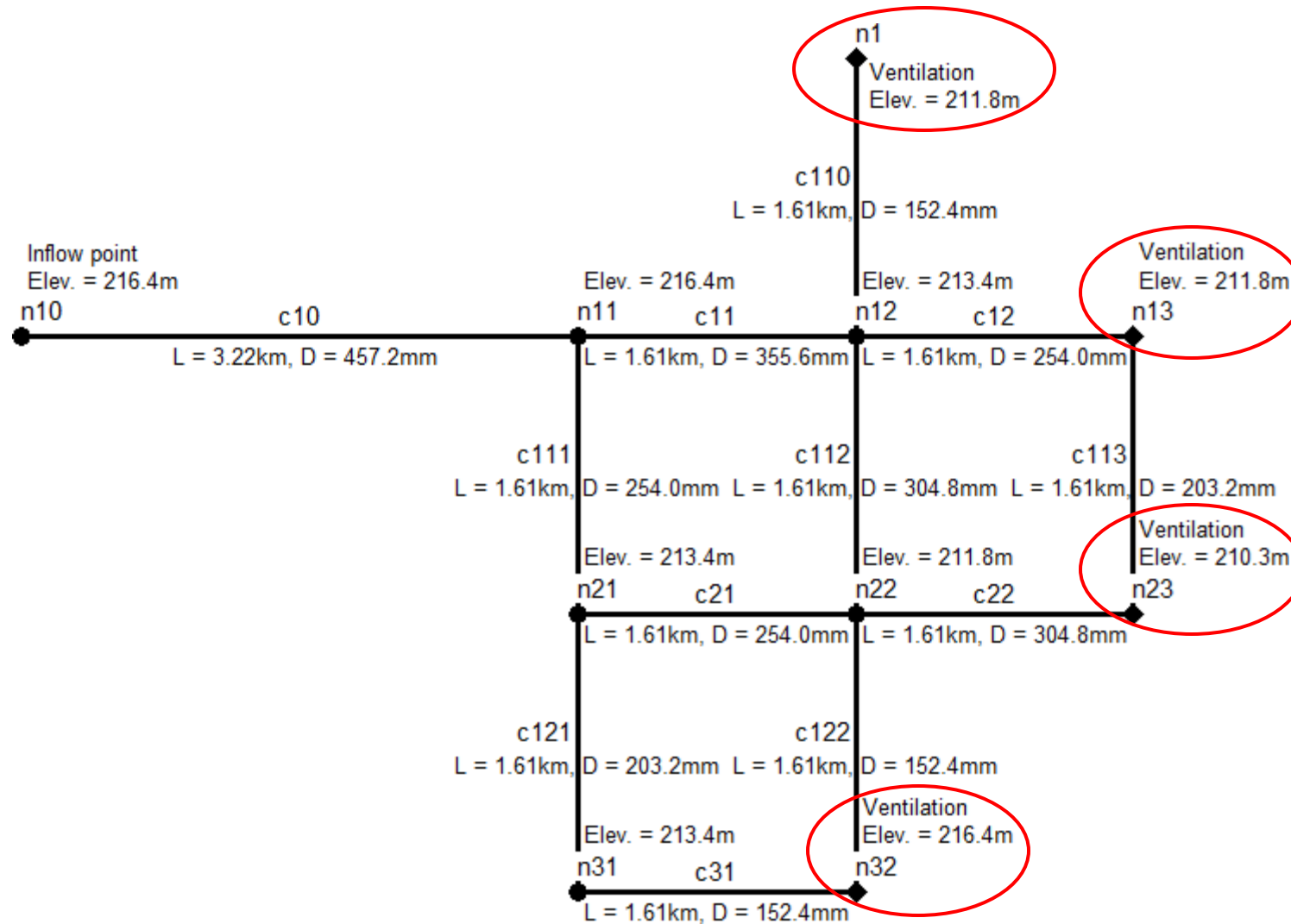
# Methodology – Application on a Larger Network



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# Case 1 – Calculating Emitter Coefficients

Case scenario:

- Hydrants with a diameter of 114.3mm, with 5% of opening;
- Discharge coefficient ( $C_d$ ) of 0.6;

$$C_{e,air} = C_{e,water} \sqrt{\frac{\rho_w}{\rho_a}}$$

$$C_{e,air} = C_d A_o \sqrt{2g} \sqrt{\frac{\rho_w}{\rho_a}} \cdot 1000 \left[ \frac{LPS}{CMS} \right]$$

$$C_{e,air} = 39.353 [LPS/\sqrt{m}]$$



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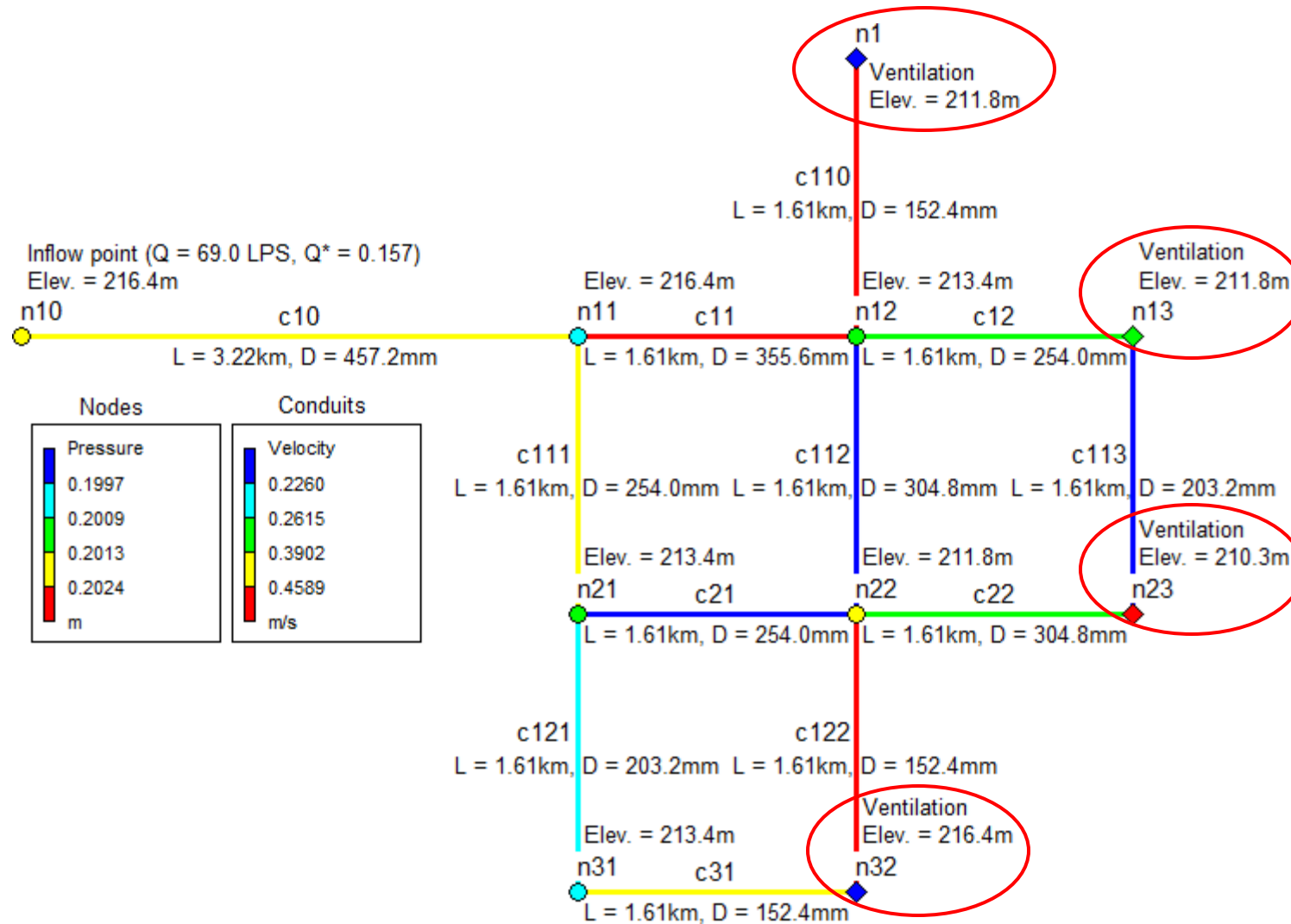
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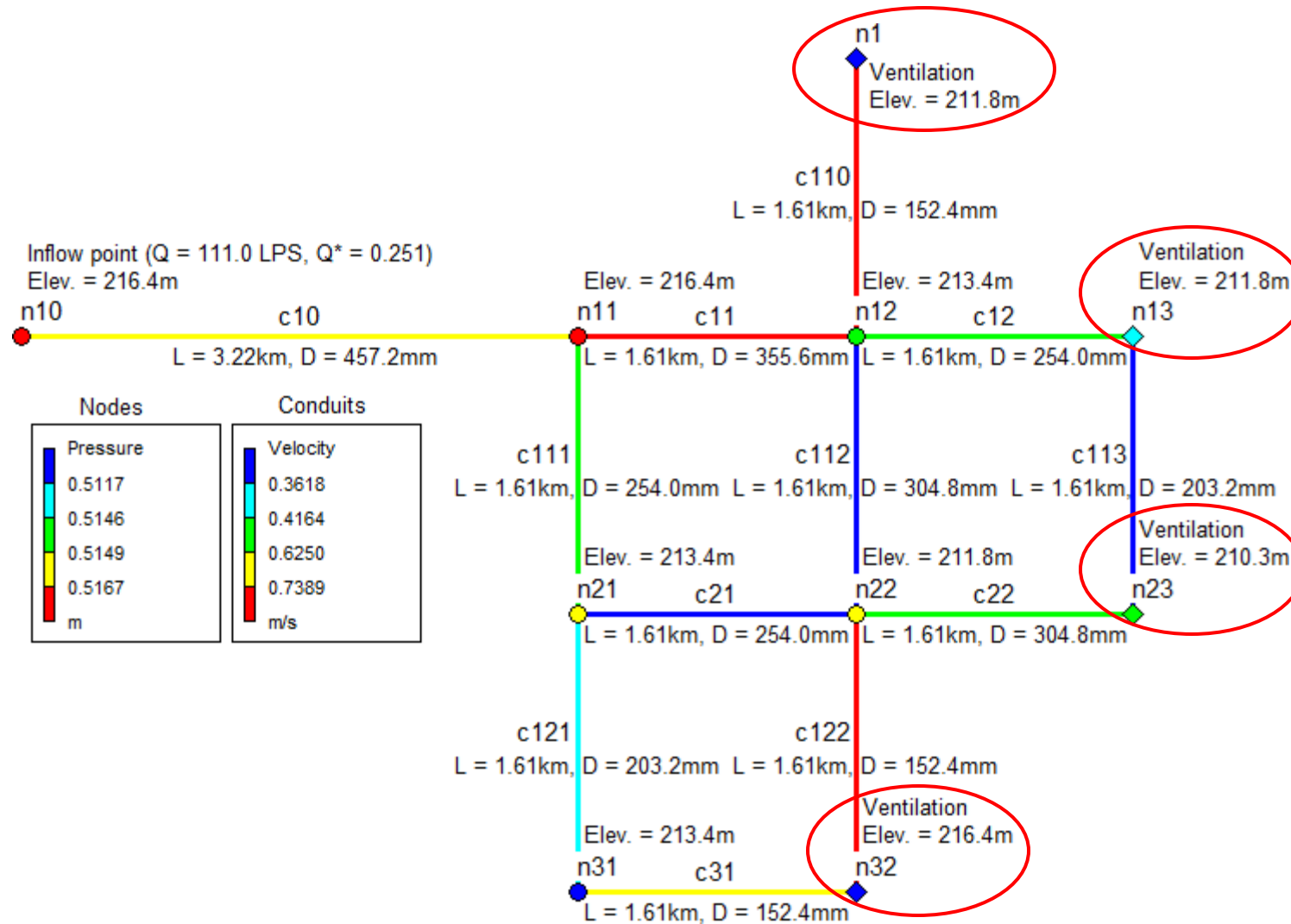
$$C_{e,water} = 1.363 [LPS/\sqrt{m}]$$



# Results – Inflow of 69.4 LPS ( $Q^* = 0.157$ )



# Results – Inflow of 111.0 LPS ( $Q^* = 0.251$ )



## Case 2 – Calculating Emitter Coefficients

Case scenario:

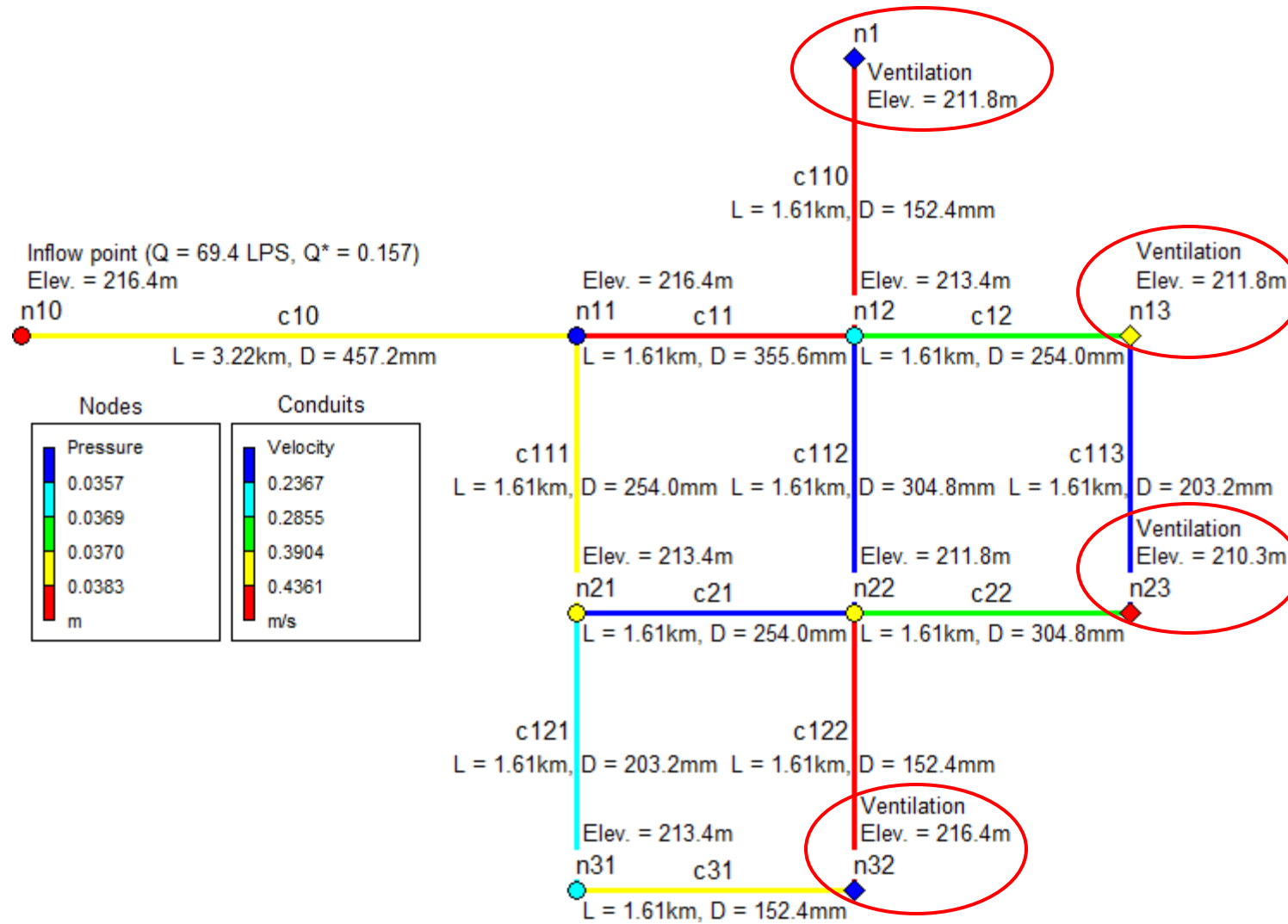
- Hydrants with a diameter of 114.3mm, with 12.5% of opening;
- Discharge coefficient ( $C_d$ ) of 0.6;

$$C_{e,air} = 98.382 \text{ [LPS}/\sqrt{m}]$$

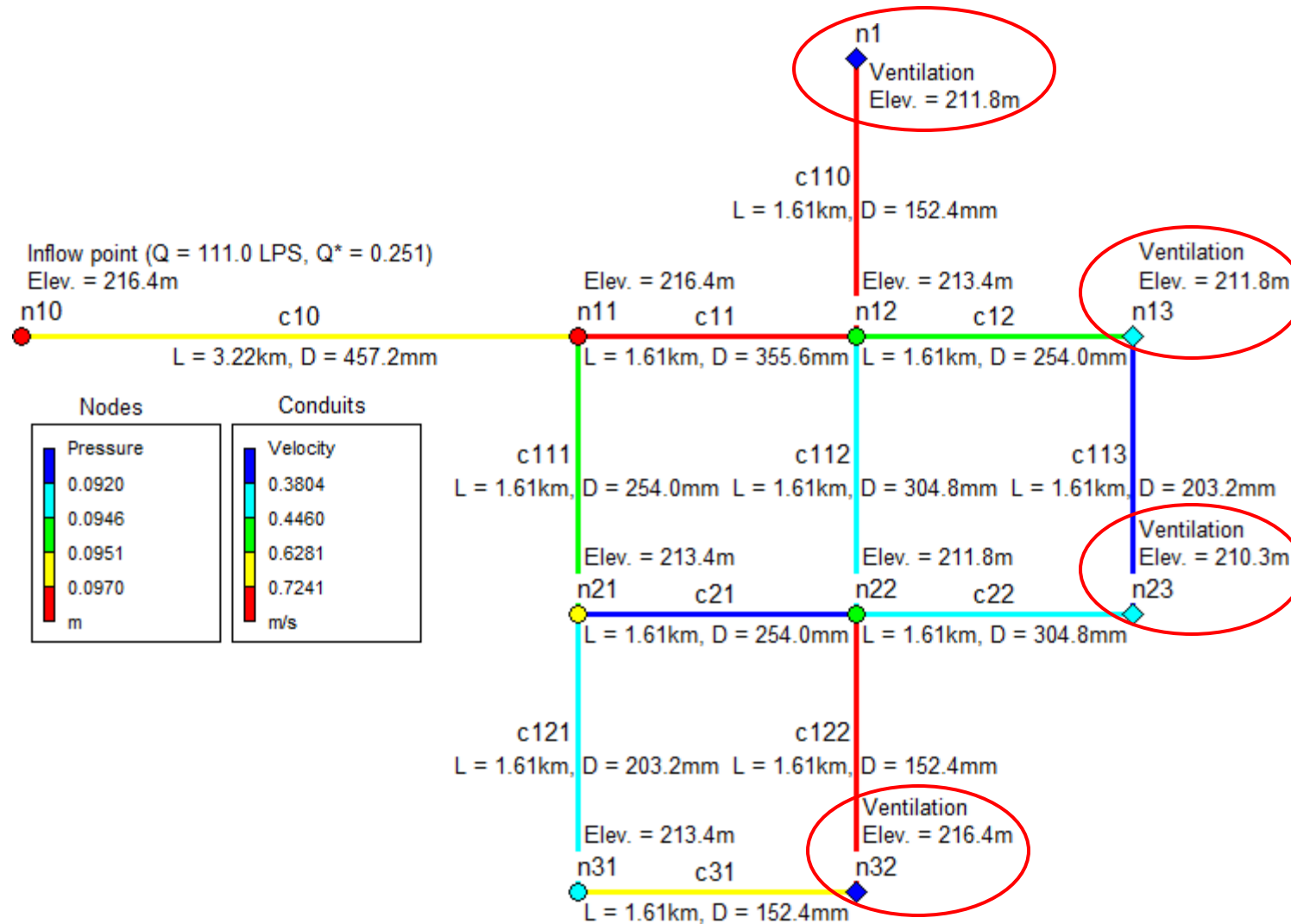
$$C_{e,water} = 3.408 \text{ [LPS}/\sqrt{m}]$$



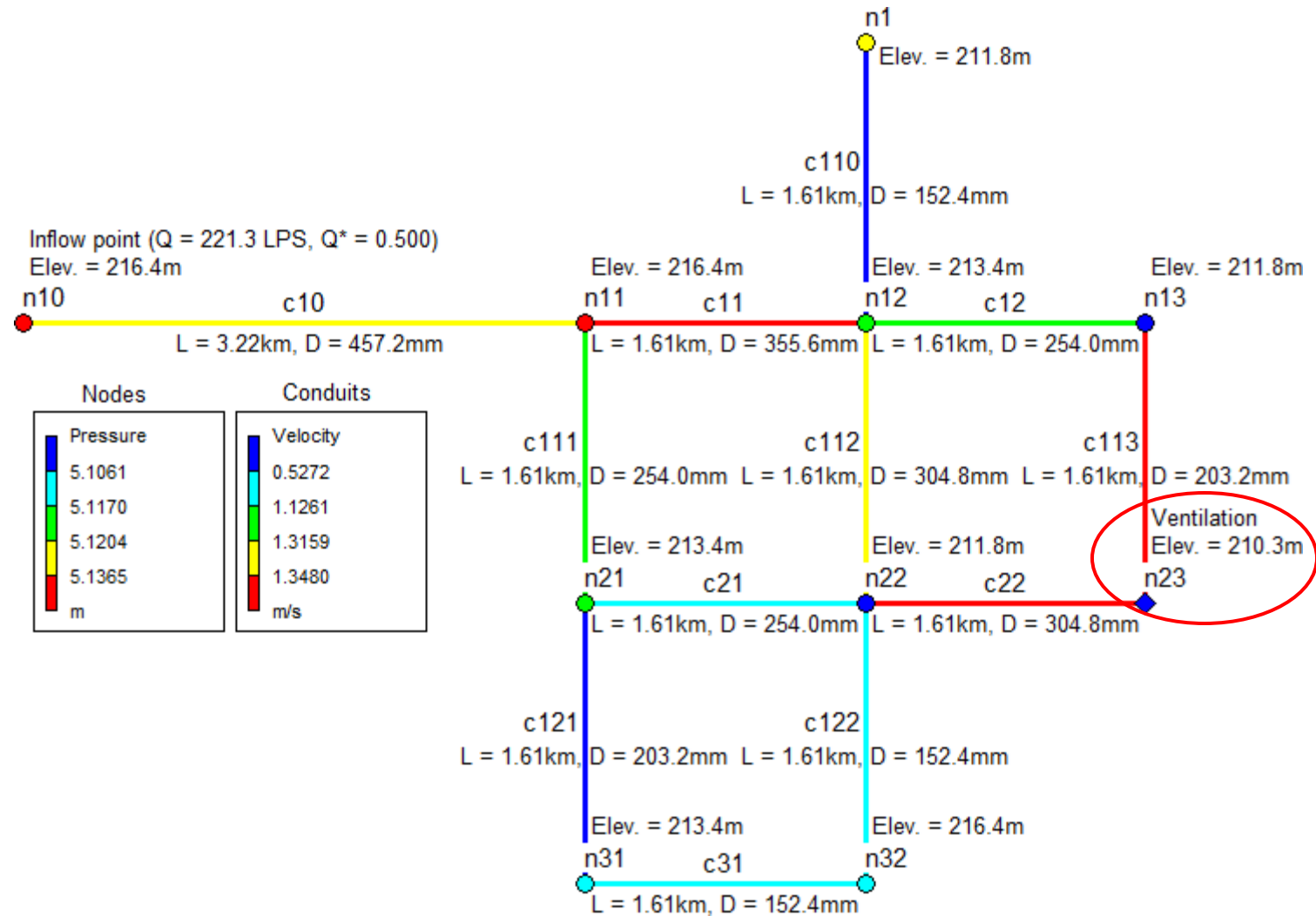
# Results – Inflow of 69.4 LPS ( $Q^* = 0.157$ )



# Results – Inflow of 111.0 LPS ( $Q^* = 0.251$ )



# Results – Inflow of 221.3 LPS ( $Q^* = 0.500$ )



# Conclusions

- This study promoted the filling of a closed conduits in a more complex topology (i.e., non-linear) leading to air pressurization. Findings of the experimental data collection indicate:
  - Pressurization depended on ventilation and inflow rates, as expected.
  - Discharge conditions impacted flow distribution and pressure rise.
  - Complex air pocket mechanism were observed but were not focused here.
- Initial application could be to estimate the air pressurization in earlier stages of WDN priming, as these should decrease over time

# Conclusions

- This study has shown EPANET can model air pressurization during priming, with adjustments to density, viscosity, and the emitter coefficient.
  - Method does not track air-water interface, but it provides an estimate of how much air pressurization is expected for a given inflow scenario and hydrant opening conditions.
- This is a step towards addressing the challenges of modeling multiphase flows in complex pipe geometries.

# Acknowledgements

The authors would like to acknowledge the support of the National Science Foundation Award No. 2048607.

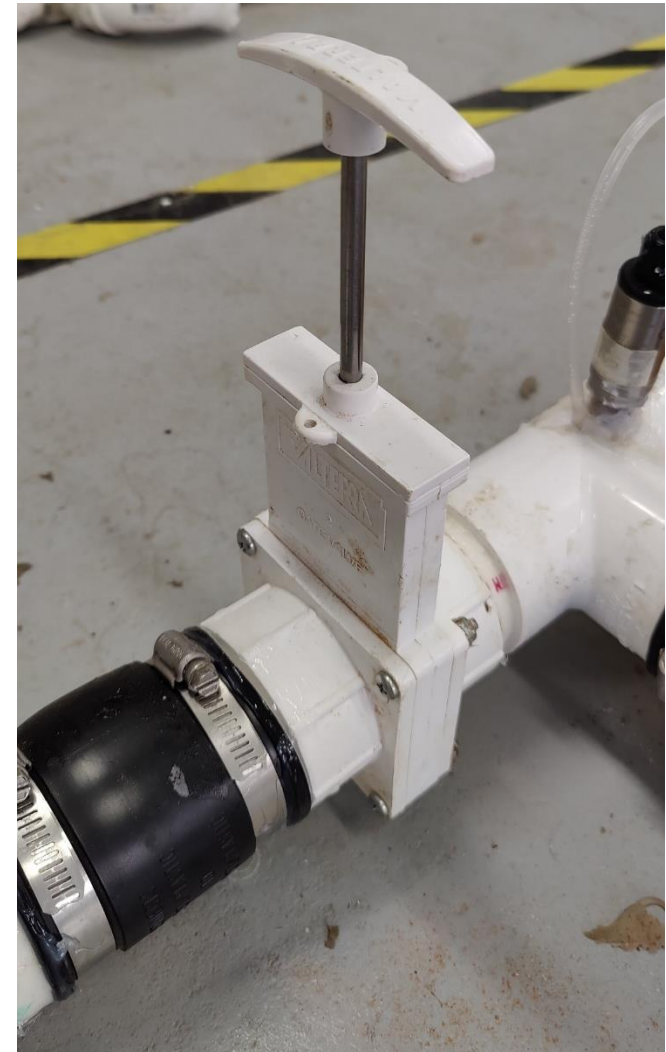
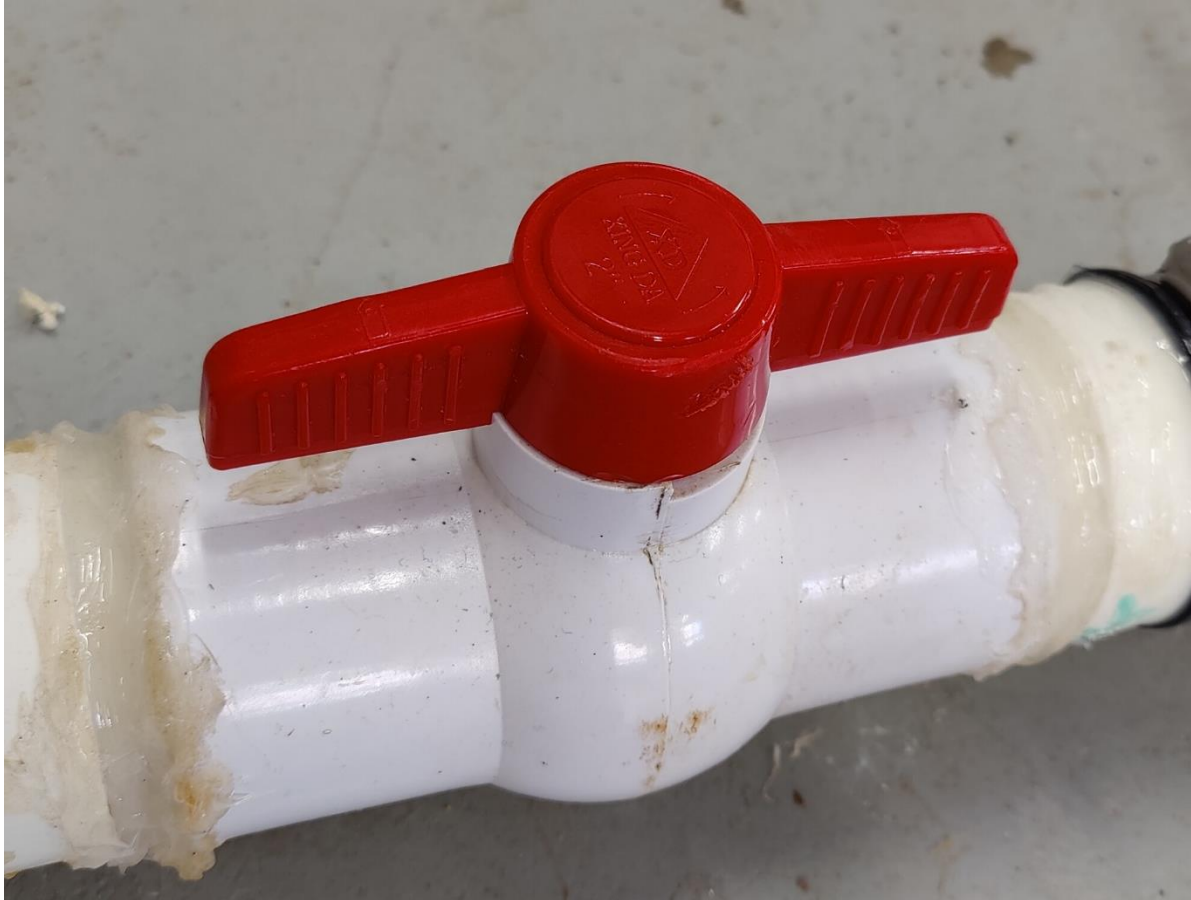


National Science Foundation

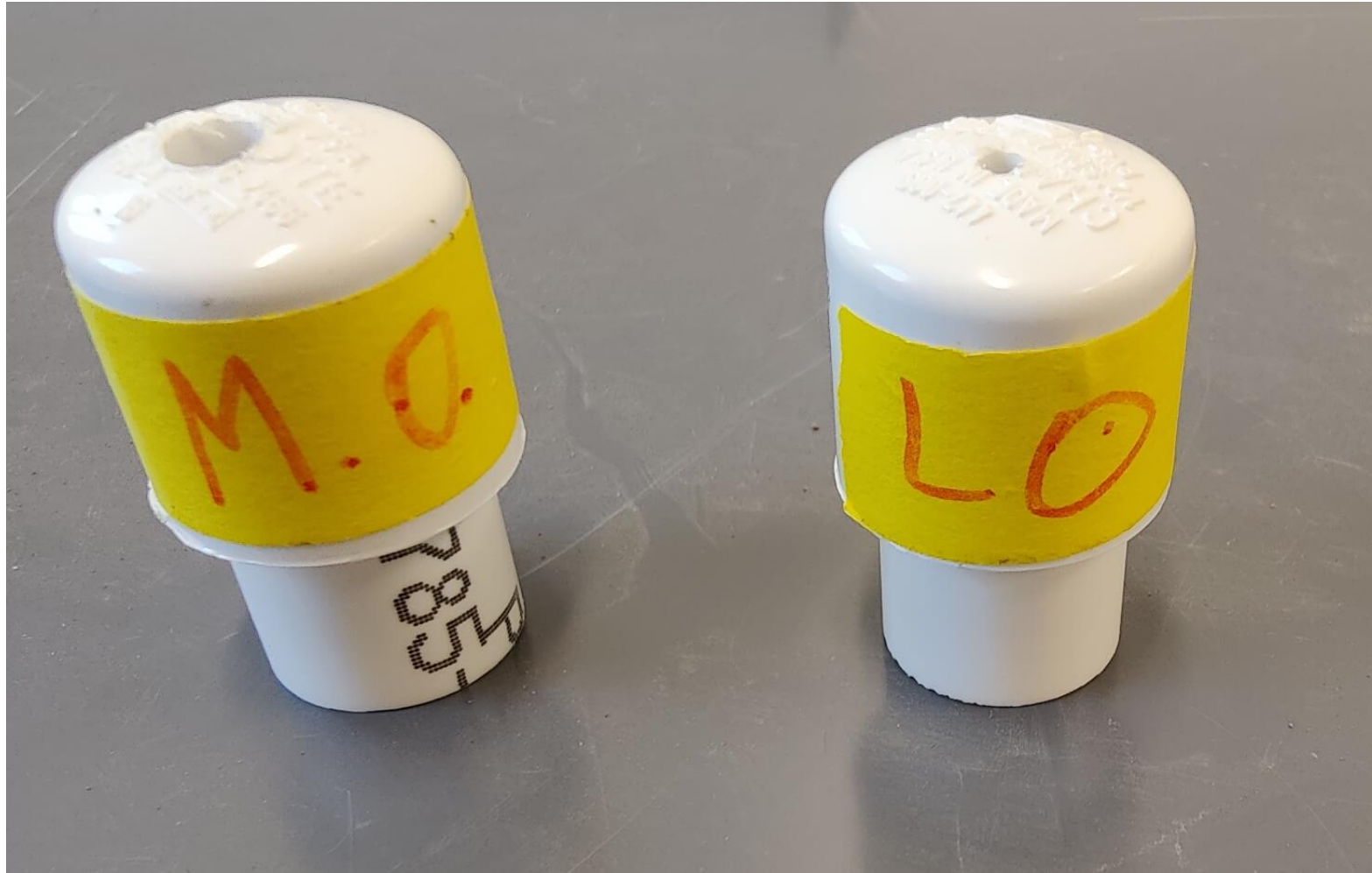
**Thank you**



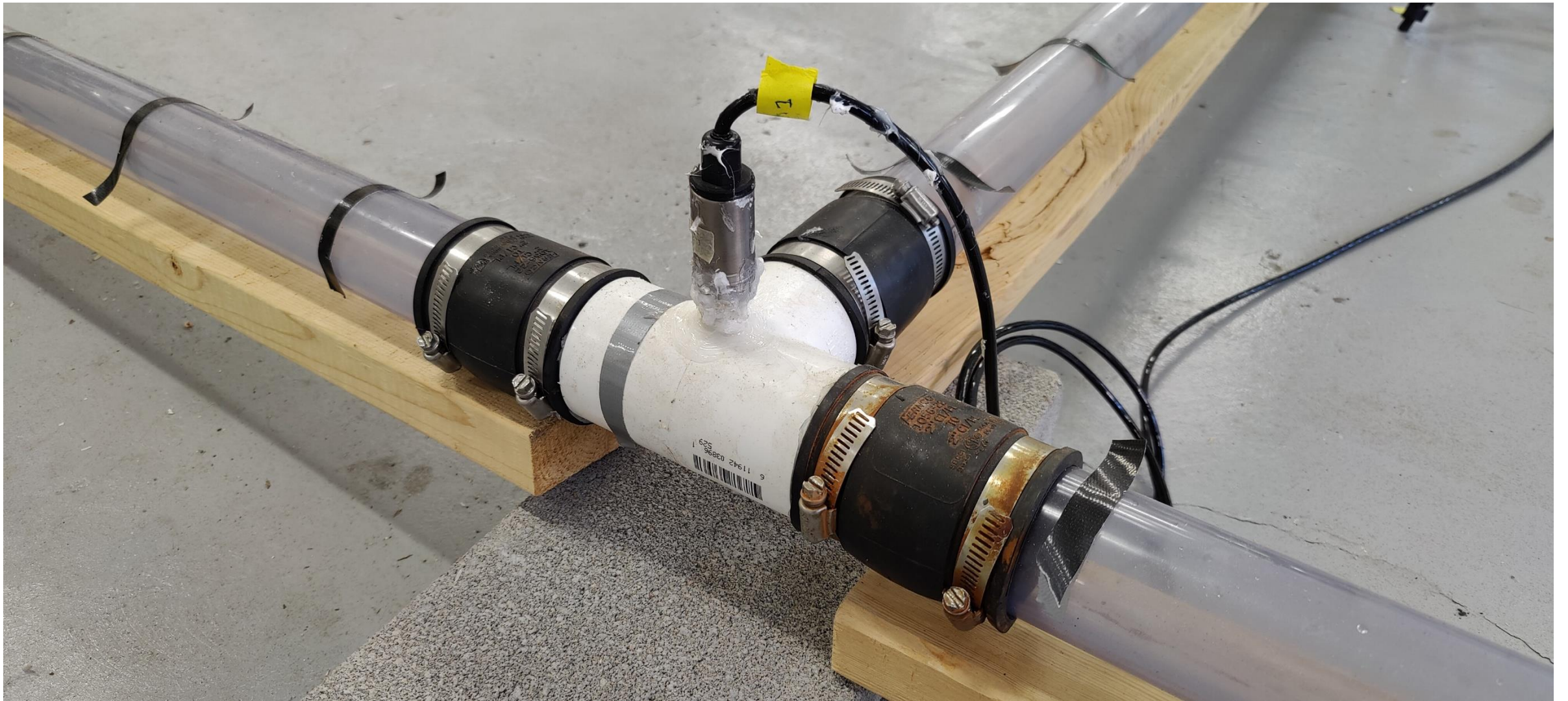
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