

EPA's Research into Premise Plumbing Systems, Dispersion, and Applications

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IAHR-UK Chapter Event: Mixing Processes in Pipes Sewers and the Natural Environment
from Theory to Practice

University of Sheffield

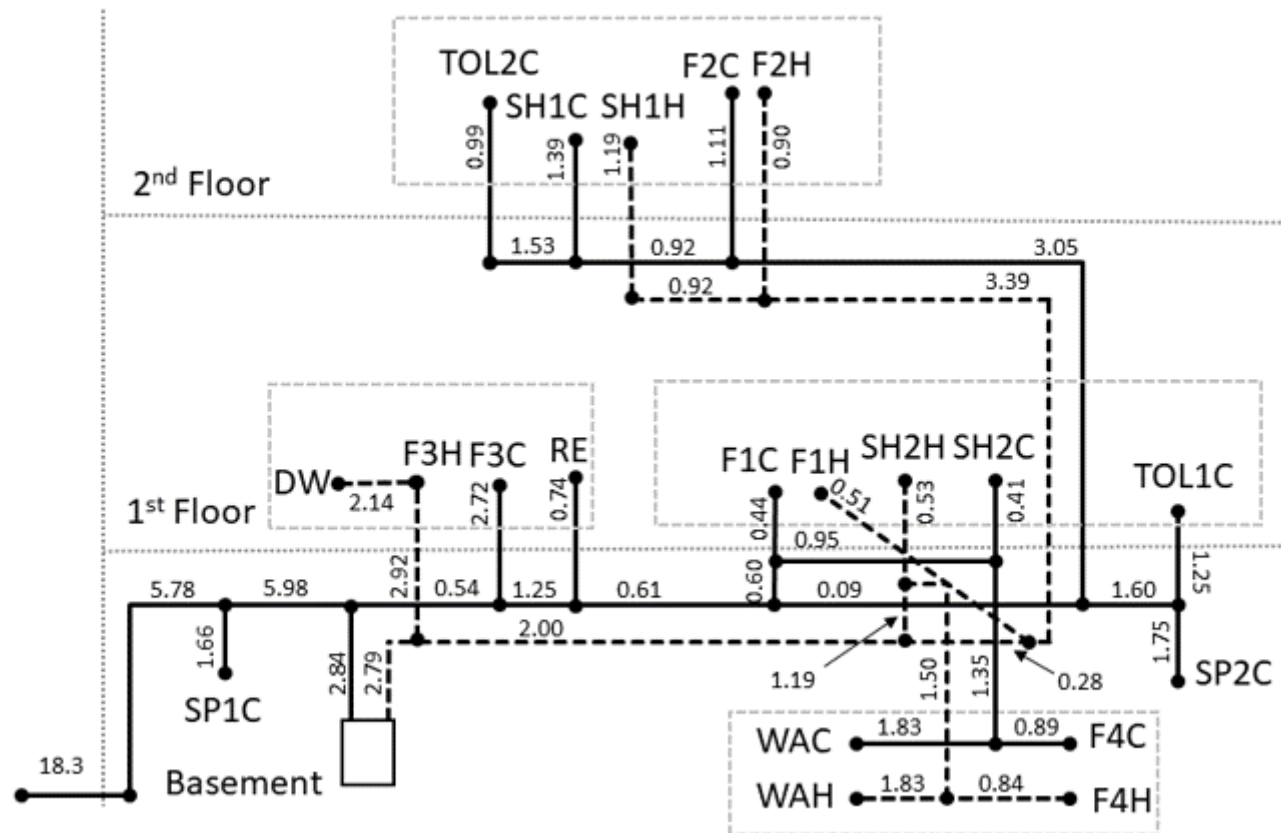
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- Needed to model premise plumbing systems
- Many uses result in flow rates in laminar to low turbulent ($Re < 20K$) conditions that might experience dispersion
- Wanted a model that could predict water quality transport





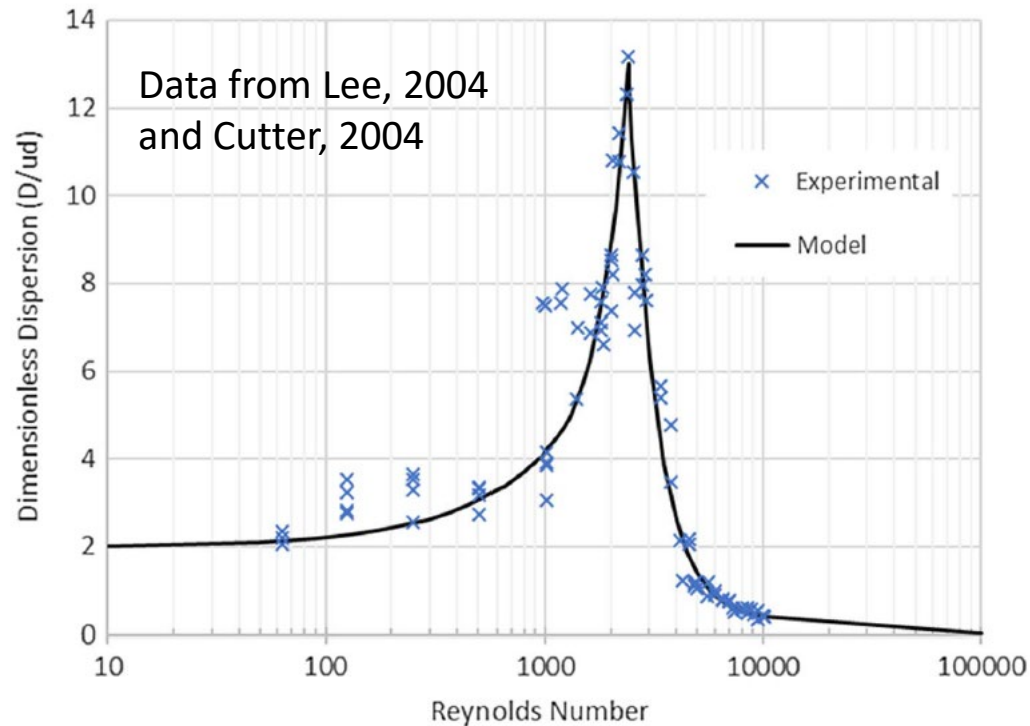
- Fully developed vs. Partially developed dispersion profile
What is the effective dispersion coefficient for premise plumbing systems?
- How big of an impact will dispersion have in premise plumbing systems?
- **Can we ignore it?**



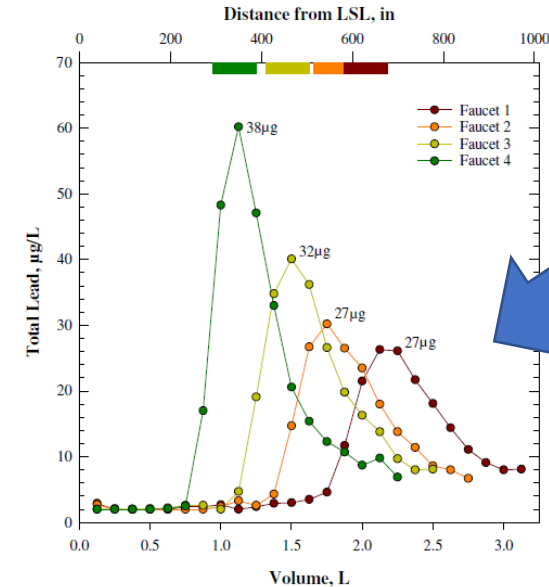
Previous Work



Sampling results didn't match simple advection only modeling (EPANET)

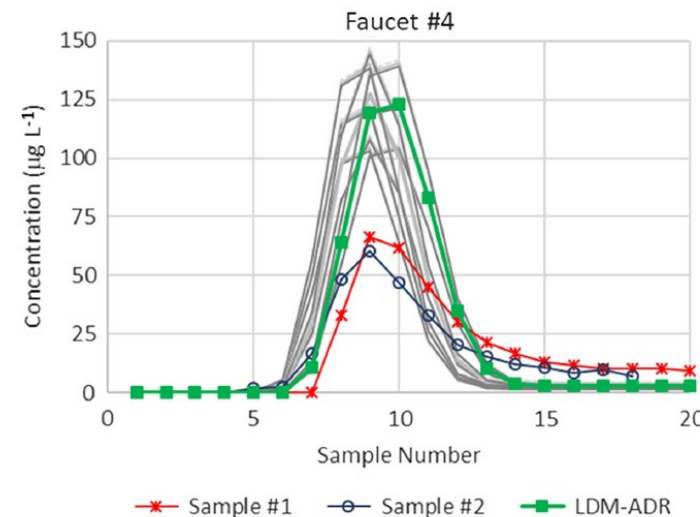


$$\frac{D}{ud} = \begin{cases} (2.1 \pm 1.1 \times 10^{-3})R + (2 \pm 0.3) & R \leq 1,000 \ (N = 17) \\ (6.79 \pm 0.68 \times 10^{-10})R^3 + (3.5 \pm 0.48) & 1,000 < R \leq 2,400 \ (N = 24) \\ (2.4 \pm 0.1) \times 10^{12} R^{-3.337} + (0.31 \pm 0.17) & 2,400 < R \leq 10,000 \ (N = 39) \\ 5.05 \sqrt{f/8} & R > 10,000 \text{ (Taylor's Equation)} \end{cases}$$



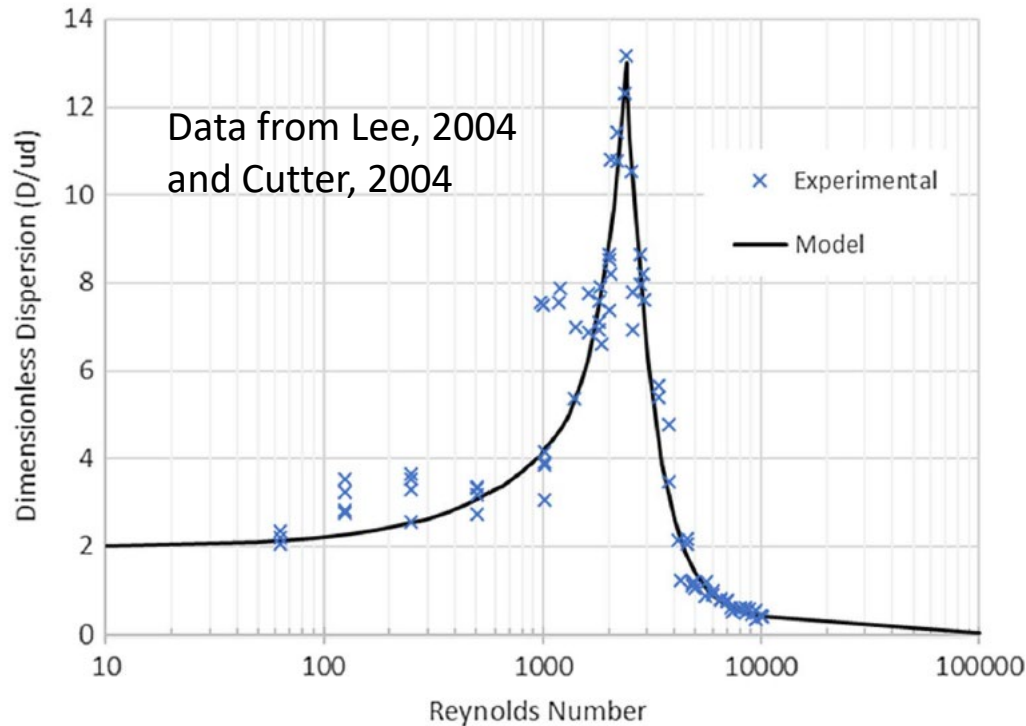
Observed dispersion during sampling

Lytle, et al. (2021) Water Research 197, 117071



Uncertainty in flow rate with advection-dispersion-reaction model

Burkhardt, et al. (2020) JWRPM 146(12): 04020094.



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Burkhardt, et al. (2020) JWRPM 146(12): 04020094.

Most fixtures in homes are only allowing
~1 – 2 gpm (3.8 – 7.6 Lpm) through

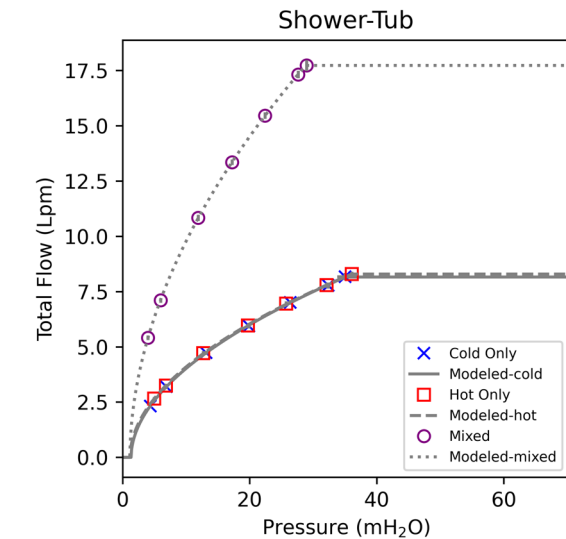
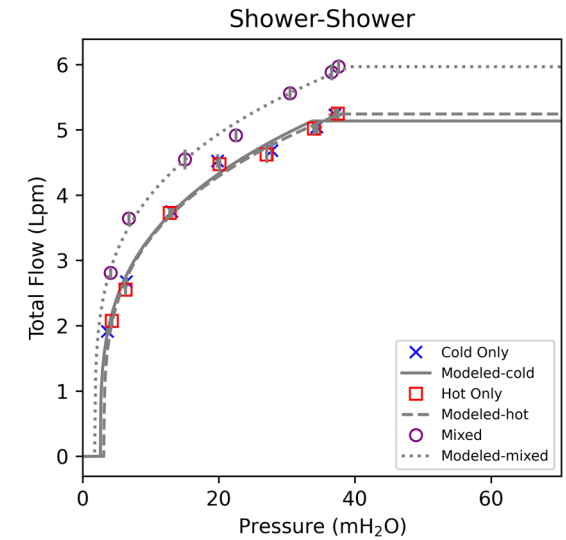
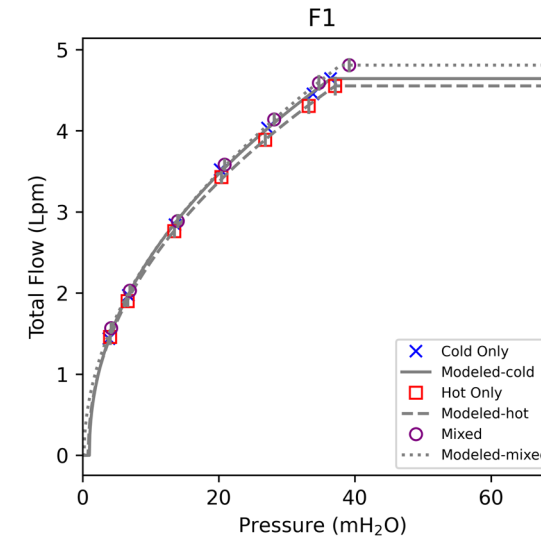
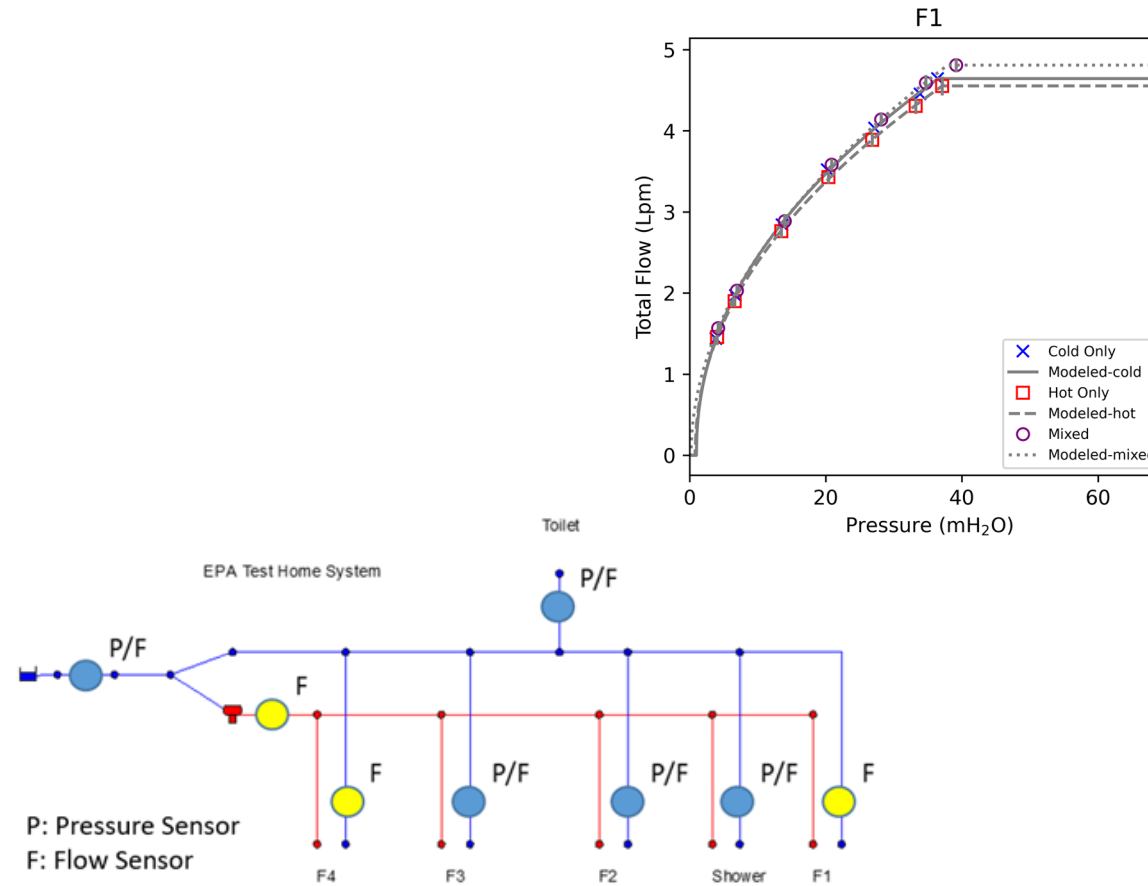
Flow Rates for $Re=2,500$

Pipe Size	GPM	LPM
½" (12.7 mm)	0.4	1.5
¾" (19 mm)	0.6	2.3

Flow Rates for $Re=20,000$

Pipe Size	GPM	LPM
½" (12.7 mm)	3.2	12
¾" (19 mm)	4.7	18

What is the actual flow rate in PPSs? What is pressure's impact?



Burkhardt, et al. (2023a) Submitted AWWA Water Science



Developed EPANET compatible Lagrangian approach

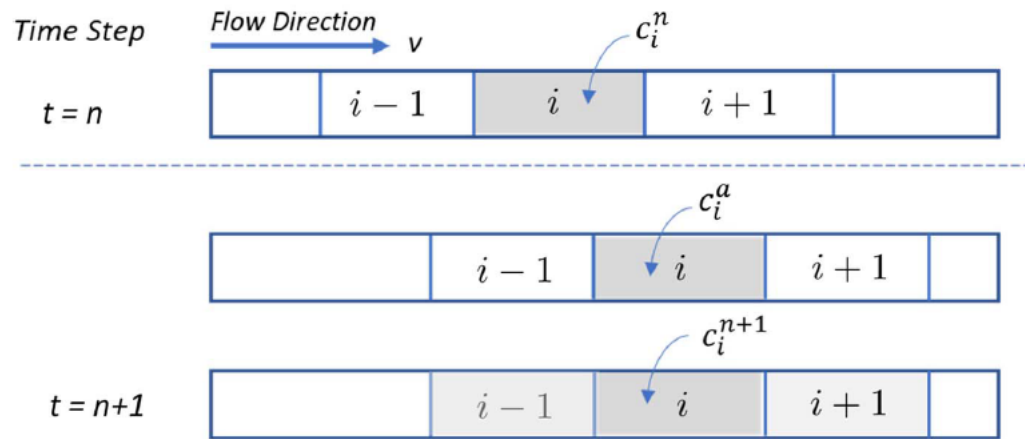


Fig. 1. Nonuniform pipe discretization and Lagrangian transport.

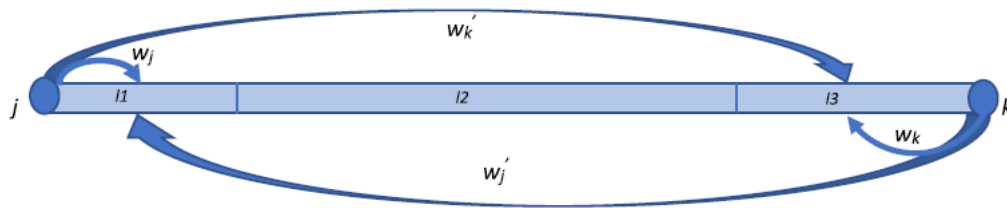


Fig. 3. Impact of a pipe's junction concentrations on its segment concentrations.

Can run entire network, rather than segmenting only dead-end sections

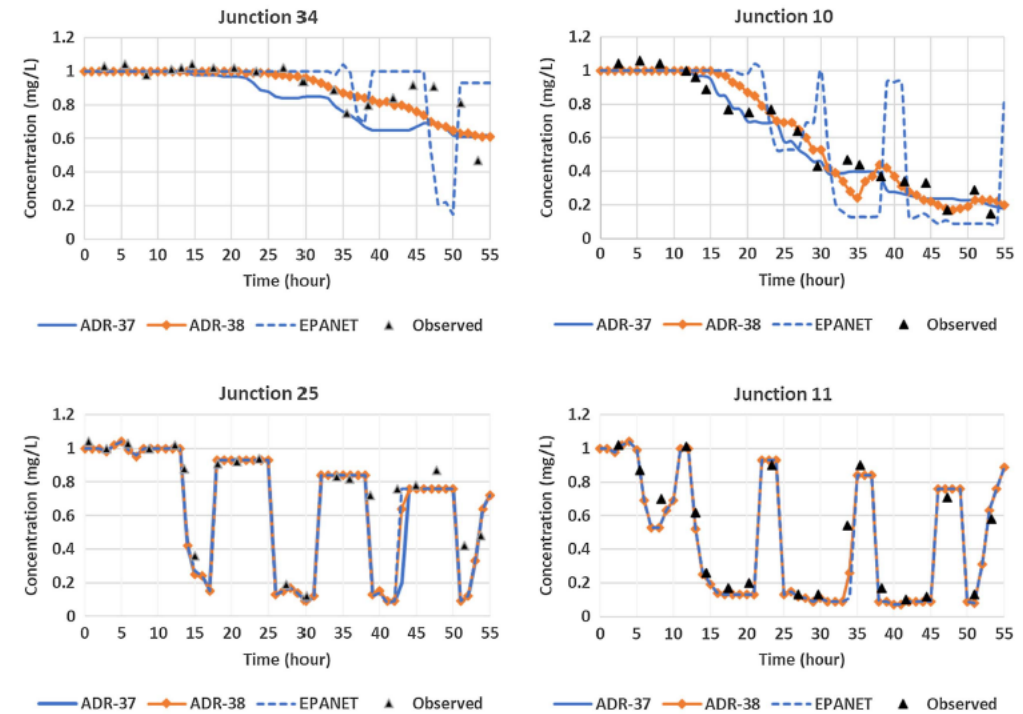


Fig. 8. Simulated fluoride tracer concentrations against field measurements at four junctions within Cherry Hill/Brushy Plains network.

Shang et al. (2021), JWRPM 147(9): 04021057.

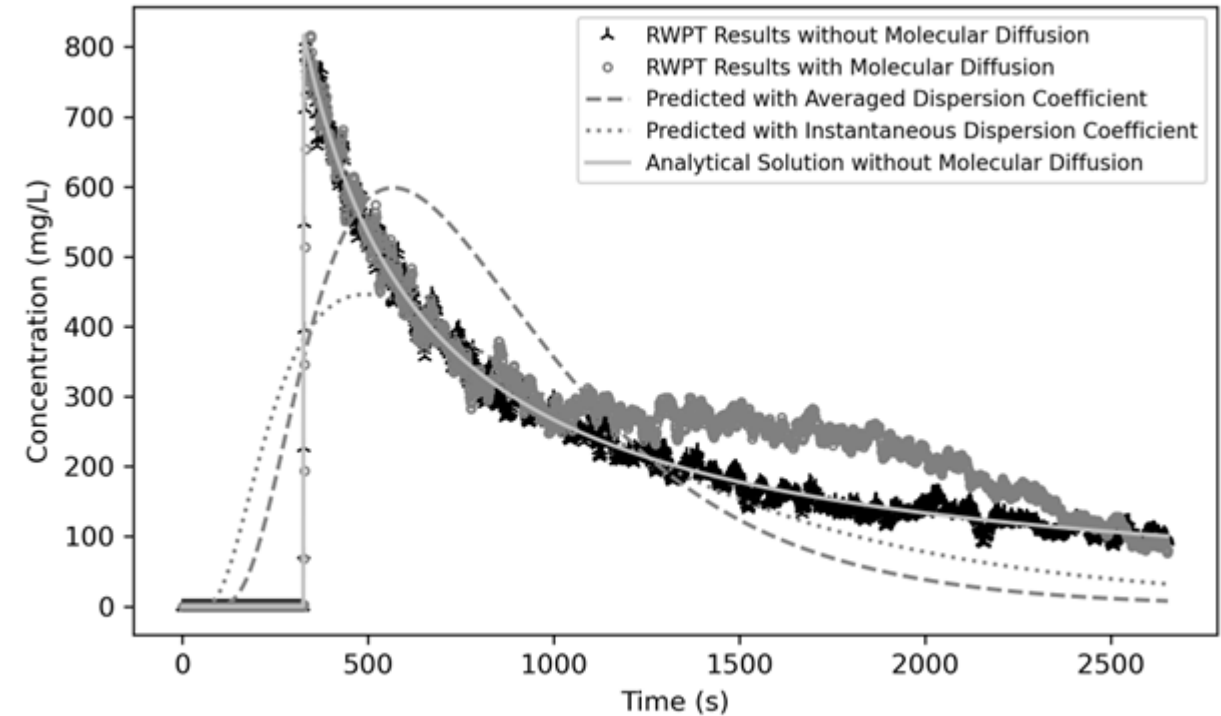
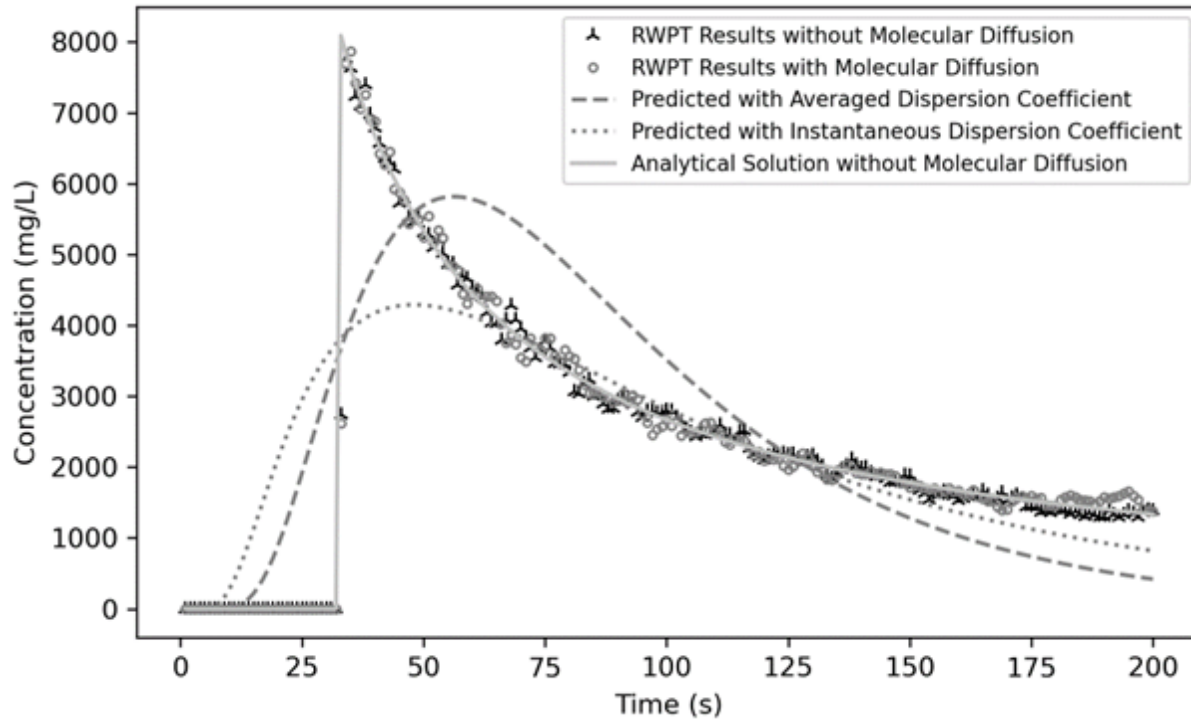


Wanted faster model than 3D CFD, that was more accurate than 1D advection-dispersion in EPANET-MSX

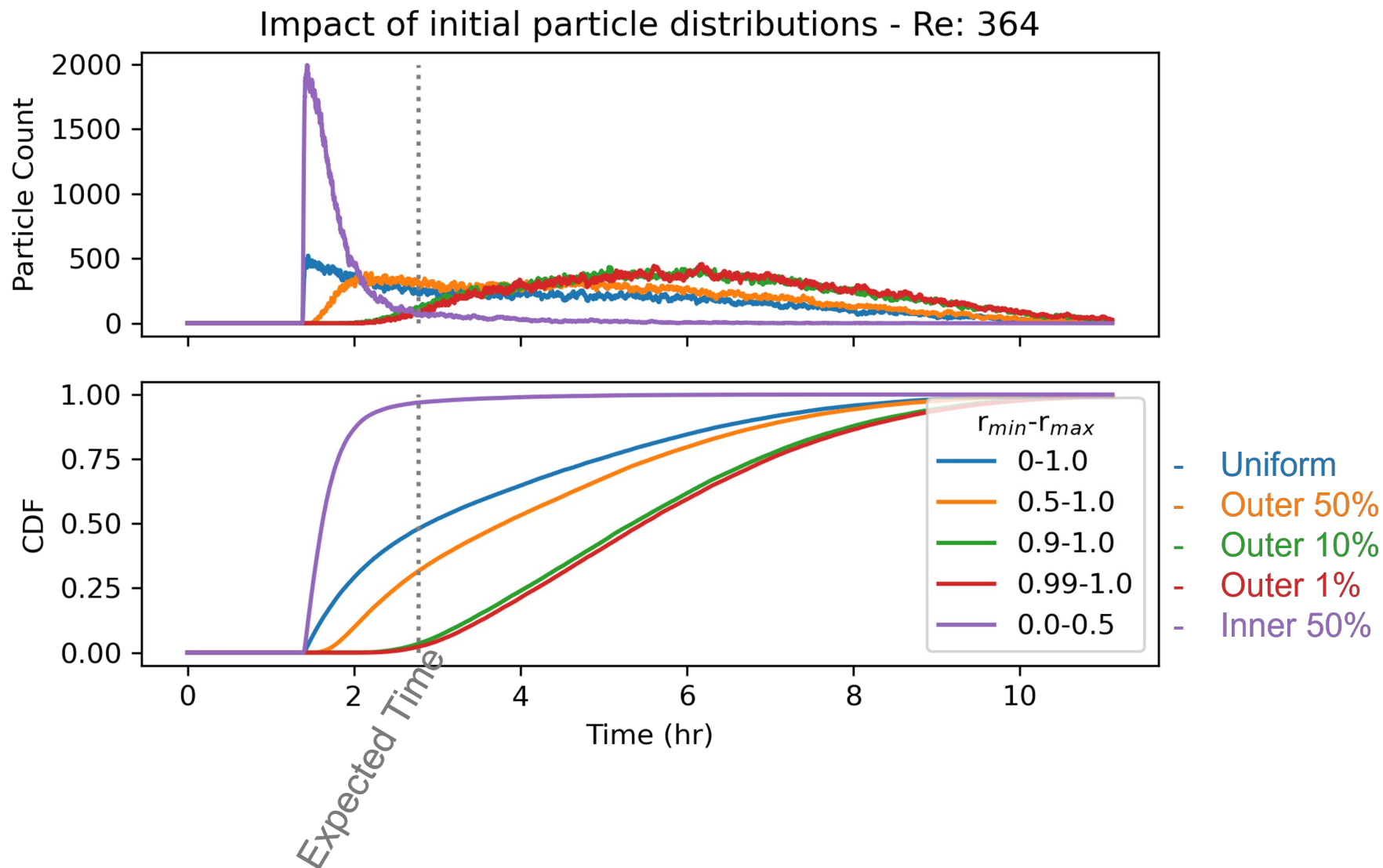
$L = 6.5 \text{ m}$, $R = 0.02 \text{ m}$, $U = 0.098 \text{ m/s}$

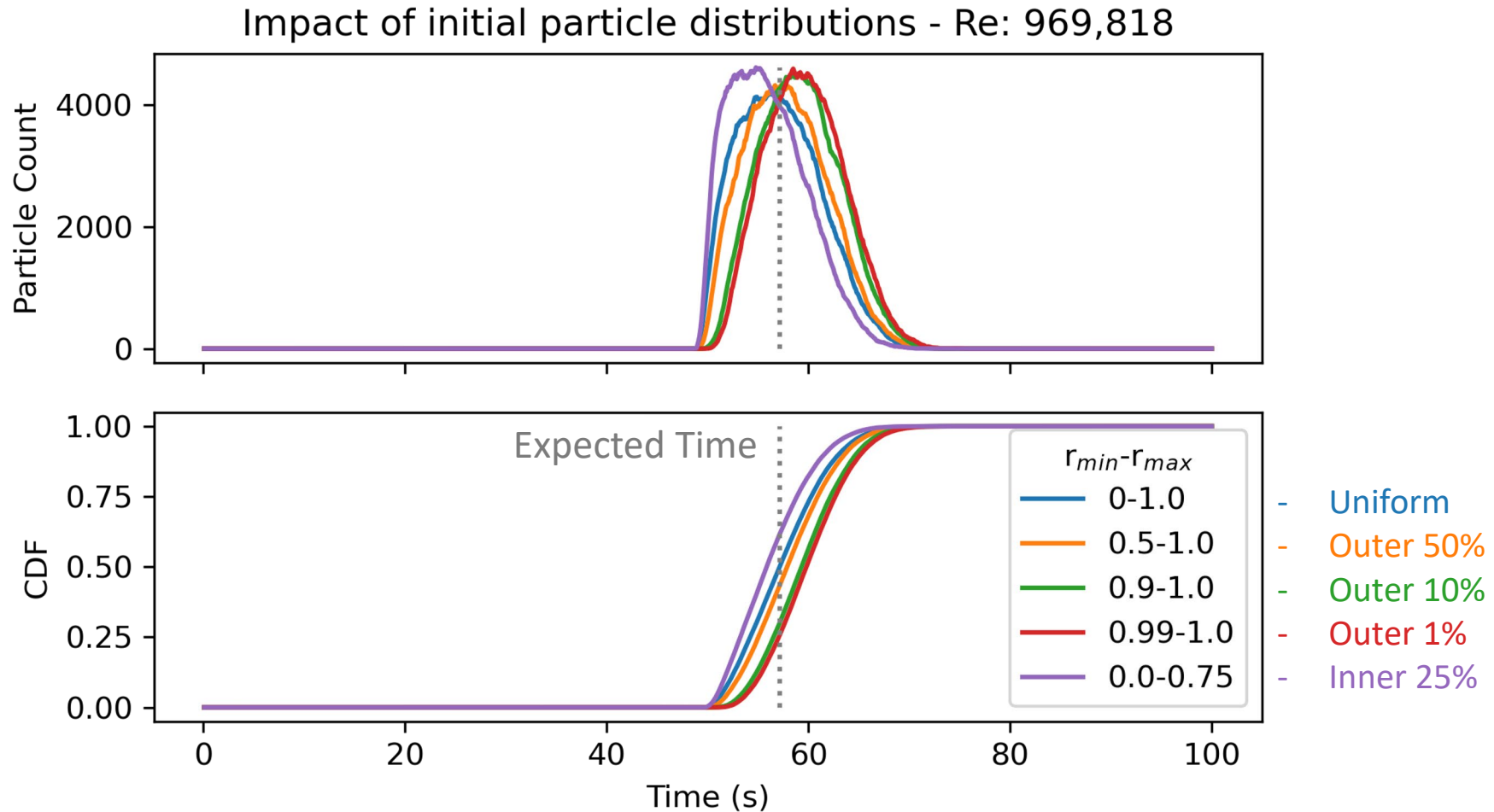
$Re = 363$

$L = 65 \text{ m}$, $R = 0.02 \text{ m}$, $U = 0.098 \text{ m/s}$



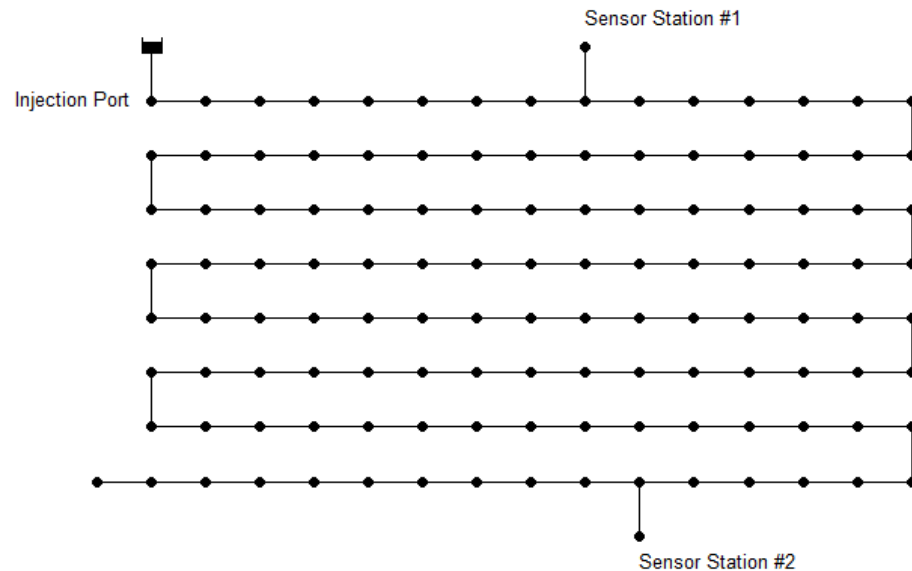
Shang, et al. (2023), Journal of Hydraulic Engineering





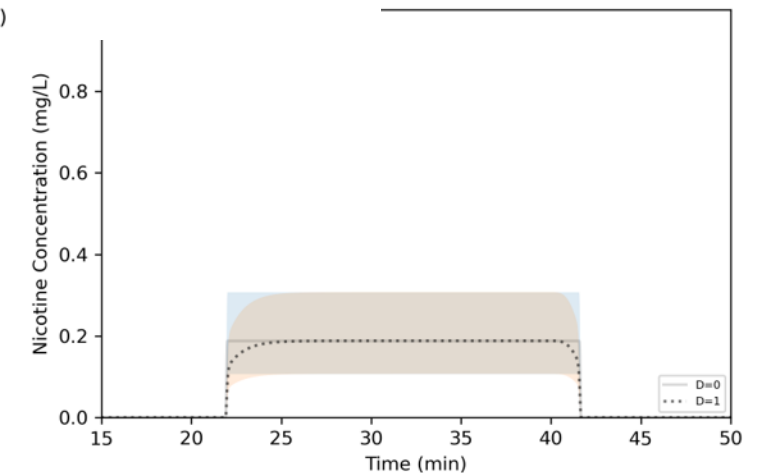
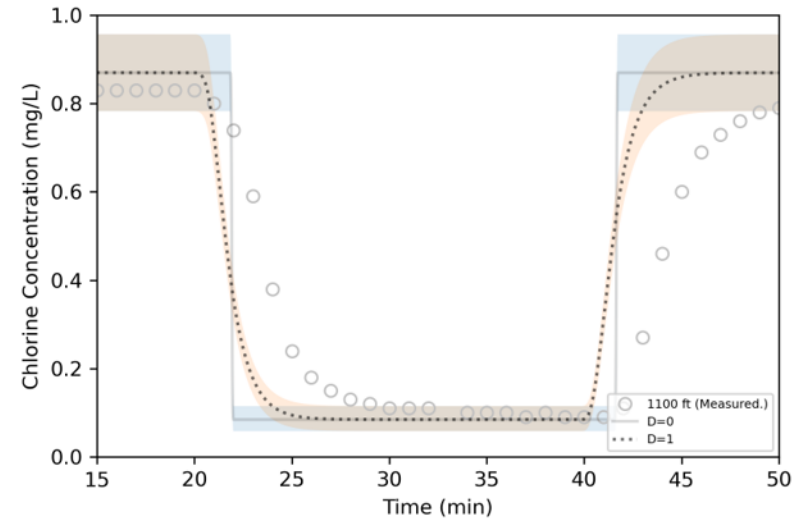
Lagrangian approach integrated into EPANET-MSX 2.0

Model with and without dispersion, with associated reaction



1,200 ft pipe, 3" diameter, 22 gpm

Burkhardt, et al. (2023b) Submitted J. Env. Mod. & Soft.





- Flushing Study
 - Contaminate and flush out the single-family home simulator
 - Model system to test effectiveness of flushing protocols and compare with experimental data
- Effective 1D Dispersion Study
 - Monitor conductivity sensor response associated with a contaminated slug under various PPS relevant flow rates
 - Introduce tees and elbows to assess their impact on effective 1D dispersion in PPSs, focusing on relevant lengths and flow rates
 - Goal is to provide better dispersion coefficients for PPS modeling



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Models Used

<https://github.com/USEPA/EPANETMSX>

<https://github.com/USEPA/EPANET2.2>

https://github.com/USEPA/msx_tools

<https://github.com/USEPA/WNTR>