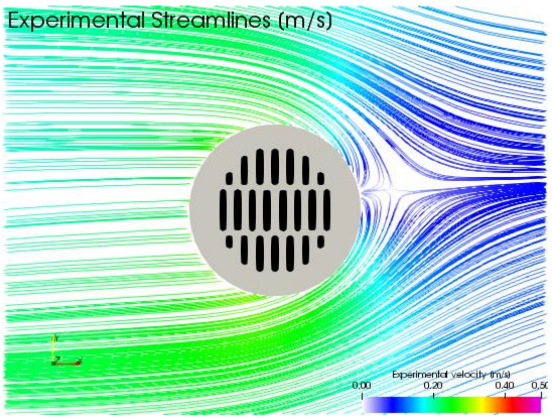
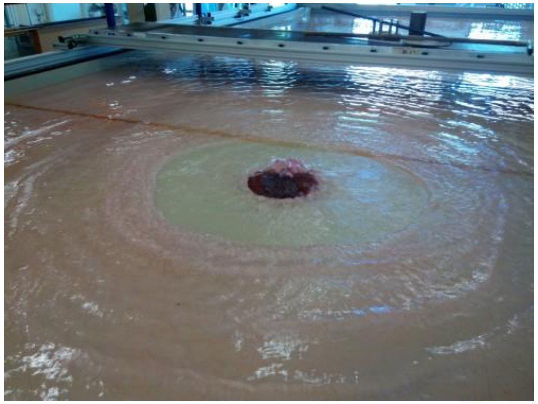
# Improving Urban Flood Modelling towards Water-Wise Cities and Smart Water Systems



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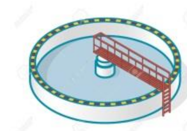
***Xi'an University – China*** – September 2018

# Water systems that…

- Deliver drinking water; 
- Ensure that wastewater is collected, treated properly and efficiently; 
- Ensure that rainwater and stormwater is drained safely out of the city; 

## WE NEED TO PLAN THEM…

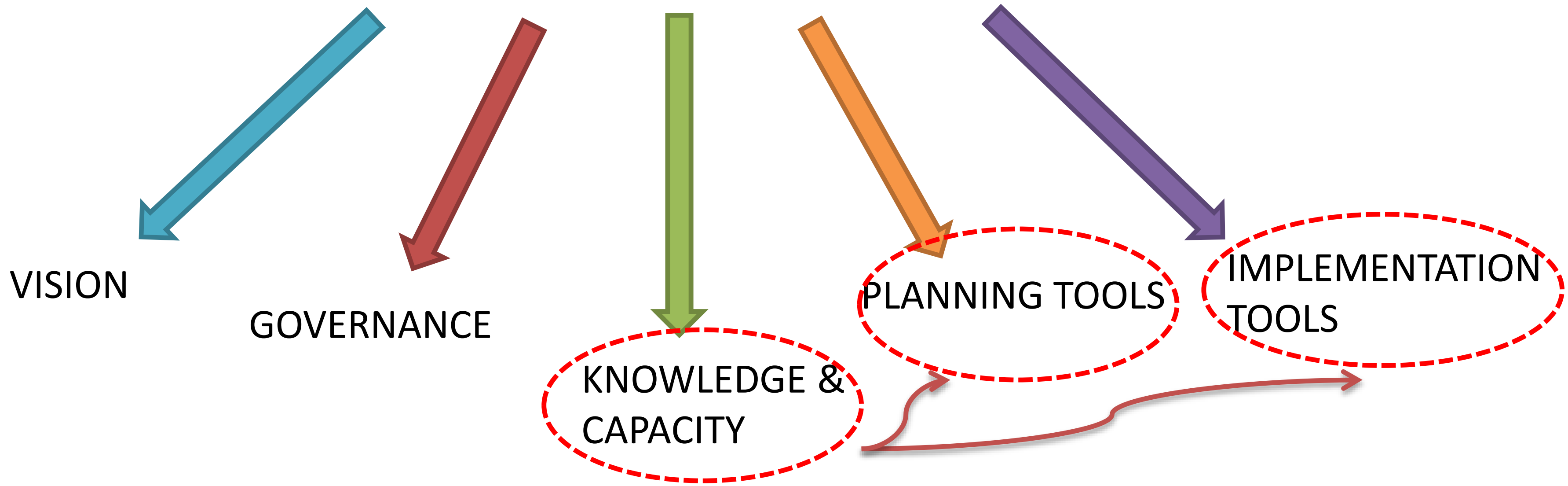
- IN THE CONTEXT OF THE WHOLE CITY
- IN THE WAY WE DESIGN OUR NEIGHBOURHOODS
- HOW WE INTRAGRATE THEM ALL AT THE BASIN SCALE

*looking at what’s happening upstream and downstream the city*

# Towards Water-Wise Cities

Cities are rapidly expanding and water resources are under increasing pressure.

We need to find ways to do more with less, **while ensuring that cities are resilient to floods, droughts and the challenges of growing water scarcity**. Transitioning cities to address these challenges has never been more urgent.



# The 17 IWA PRINCIPLES FOR WATER-WISE CITIES

| | | | |
|---|---|---|---|
| REPLENISH WATERBODIES AND THEIR ECOSYSTEM | REDUCE THE AMOUNT OF WATER AND ENERGY USED | REUSE RECOVER AND RECYCLE | USE A SYSTEMATIC APPROACH INTEGRATED WITH OTHER SERVICES |
| INCREASE THE MODULARITY OF SYSTEMS AND ENSURE MULTIPLE OPTIONS | ENABLE REGENERATIVE WATER SERVICES | DESIGN URBAN SPACES TO REDUCE FLOOD RISKS | ENHANCE LIVEABILITY WITH VISIBLE WATER |
| MODIFY AND ADAPT URBAM MATERIALS TO MINIMISE ENVIRONMENTAL IMPACT | PLAN TO SECURE WATER RESOURCES AND MITIGATE DROUGHT | PROTECT THE QUALITY OF WATER RESOURCES | PREPARE FOR EXTREME EVENTS |
| EMPOWERED CITIZENS | PROFESSIONALS AWARE OF WATER CO-BENEFITS | TRANSDISCIPLINARY PLANNING TEAMS | POLICY MAKERS ENABLING WATER WISE ACTION |
| LEADERS THAT ENGAGE AND ENGENDER TRUST | | | |

- Regenerative Water Services
- Water Sensitive Urban Design
- Basin Connected Cities
- Water-Wise Communities

URBAN FLOODING

Worldwide problem

Expected to increase in the future due to…

Climate change
(short duration heavy rainfall events will become more frequent)

Increase of urbanisation

Conditions of existing sewer systems

# Objectives of flood modelling?

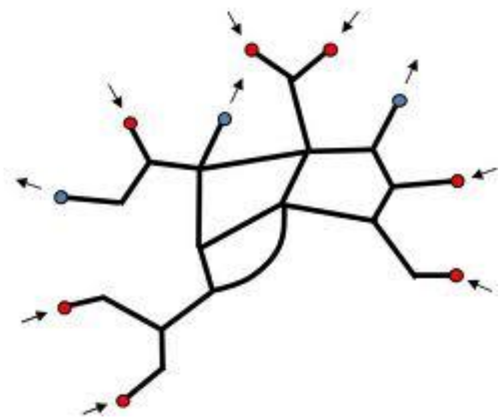
- Sewer system re-design / optimisation
- Major system design
- Damage assessment
- Flood risk attribution
- Hazard maps
- Real-time management

- Support to rescue services
- Uncertainty analysis
- Pollution, health problems
- Climate change impacts
- Effects of urban growth

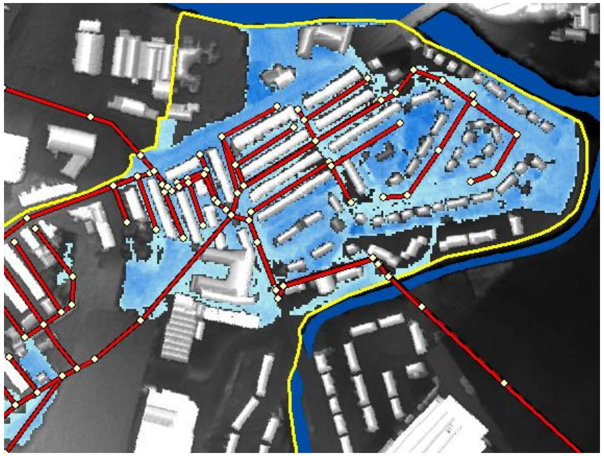
All these objectives require the **estimation of flow exchange between sewer and floodplain (especially associated with flooding events)**

Surface water flooding is recognised as the **hardest type of flooding to predict and defend against** (*Pitt Review*)

# Urban Flood Models



Pipe Network –
*1D St. Venant Equations*



Pipe Network –
*2D St. Venant Equations*

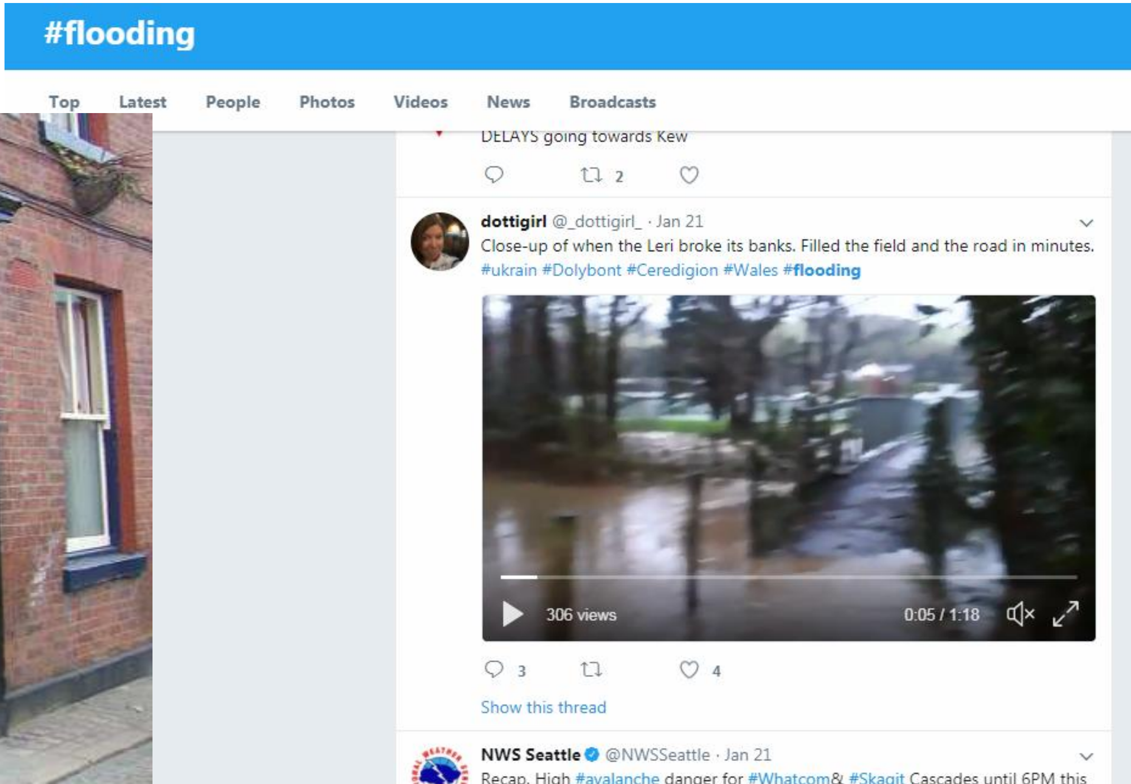
Gully/ Manhole 'Linkage' –
*Empirical/Semi Empirical Equations*

**Inputs/Parameters**

Rainfall runoff, pipe network, digital elevation model, roughness and energy loss parameters…….

# Verification

- How do we know models are telling the truth?
  - Comparison with Sewer Flow Data
  - Measured surface extents?
  - Photos?

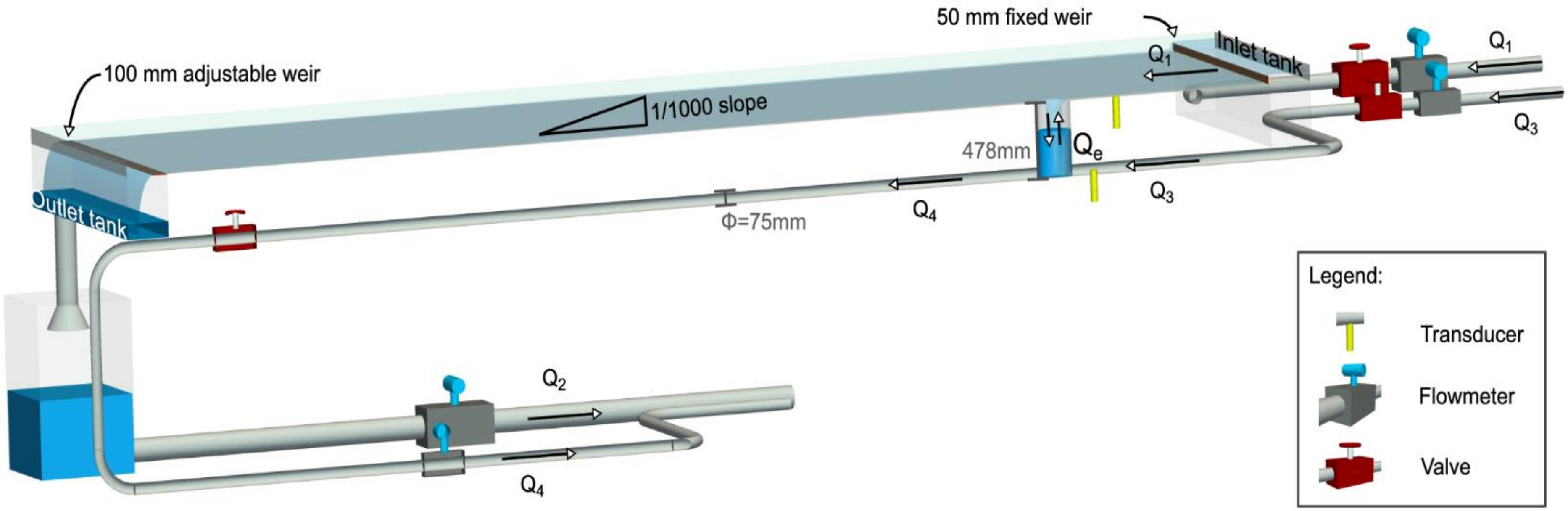



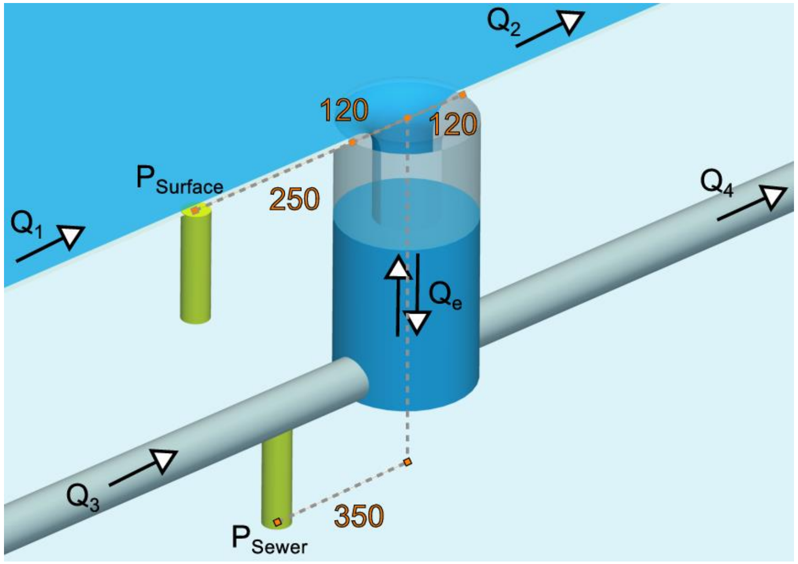
# Aim

- Develop a laboratory facility to provide good quality verification data for urban flood models
  - Evaluate some current assumptions within models
  - Provide better data to enhance future model development and testing

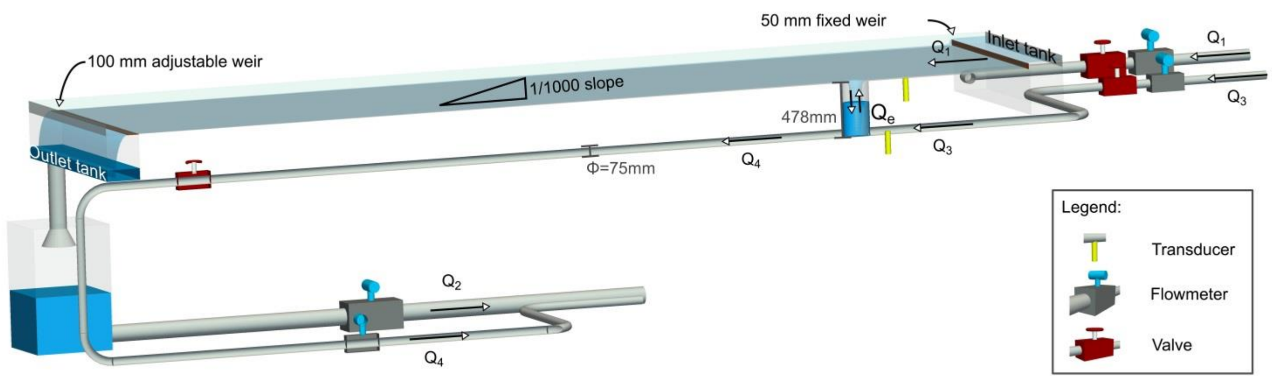
- Laboratory approach can provide high resolution data in controlled conditions, at the cost of scale + boundary effects

# Experimental facility



# Sub-surface/surface interactions




**Inflow into unsurcharged sewer**

$$-Q_e = \frac{2}{3} C_w \pi D_M (2g)^{1/2} (h_s)^{3/2}$$

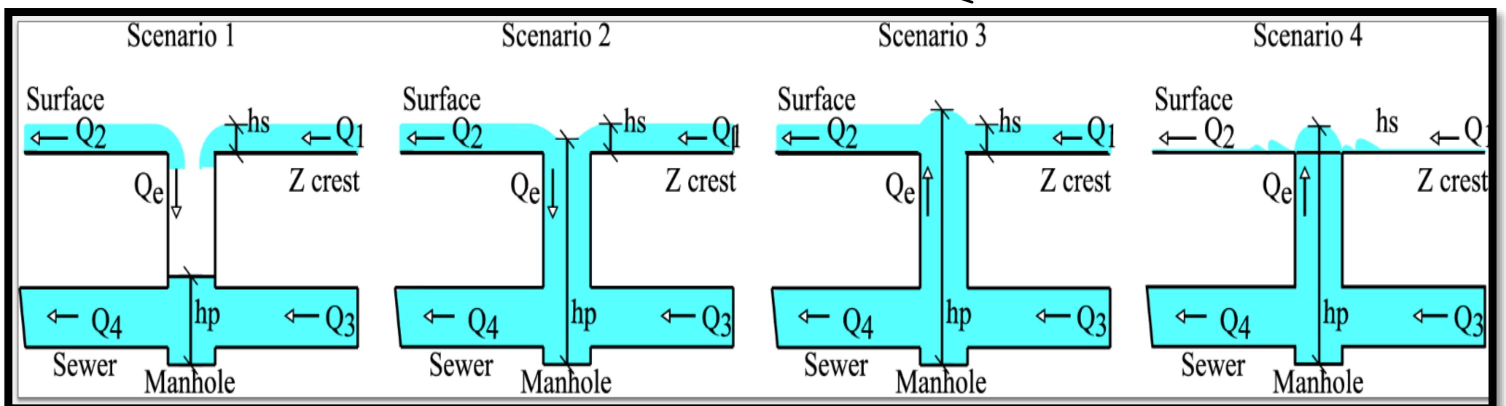
**Inflow into surcharged sewer**

$$-Q_e = C_w \pi D_M (2g)^{1/2} (h_s)\left(h_s + z_{crest} - h_p\right)^{1/2}$$

**Outflow over wet floodplain**

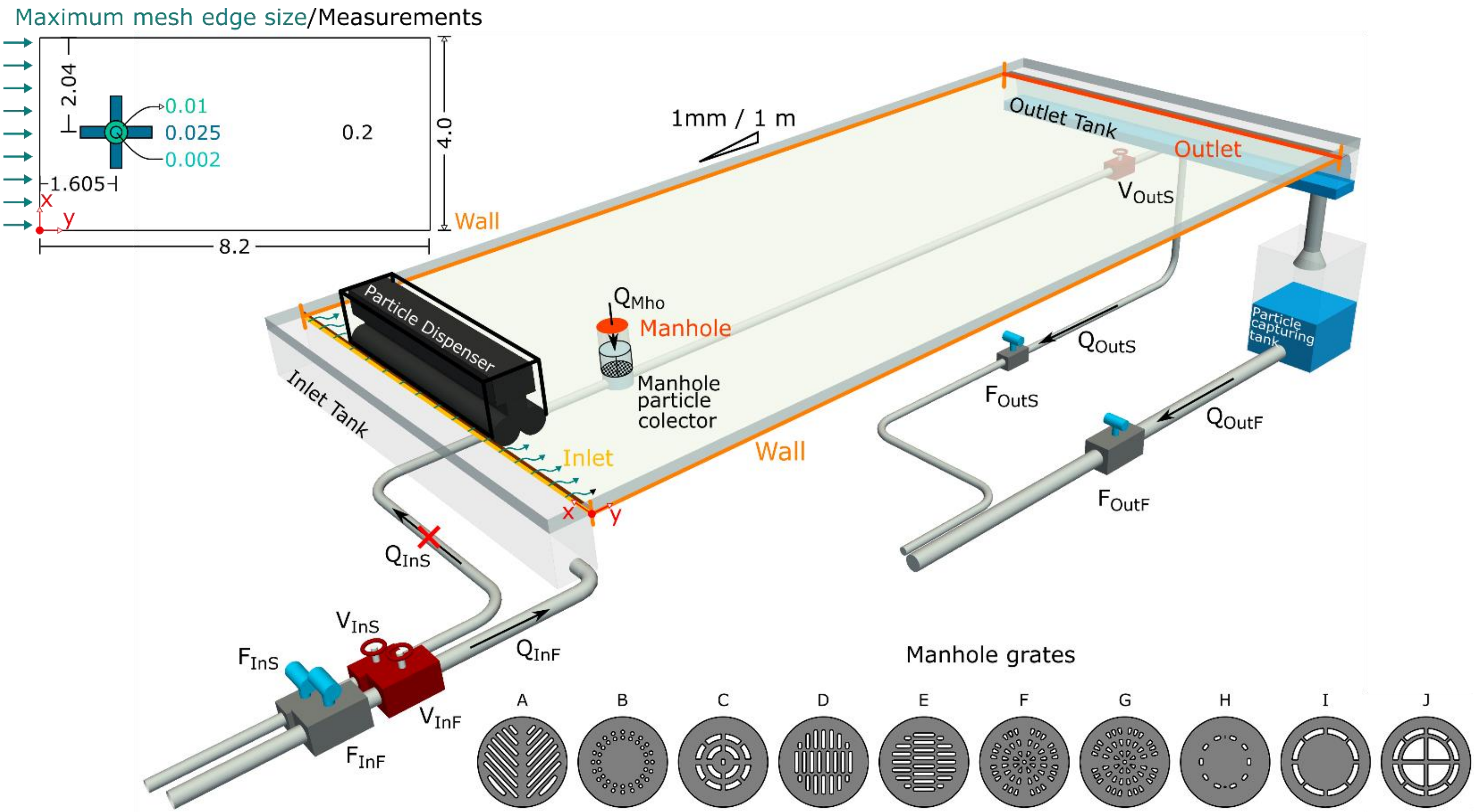
**Outflow over dry floodplain ($h_s$=0)**

$$Q_e = C_o A_M (2g)^{1/2} \left(h_p - (h_s + z_{crest})\right)^{3/2}$$




✓ ✓ ✓ ✓

# Sub-surface/surface interactions



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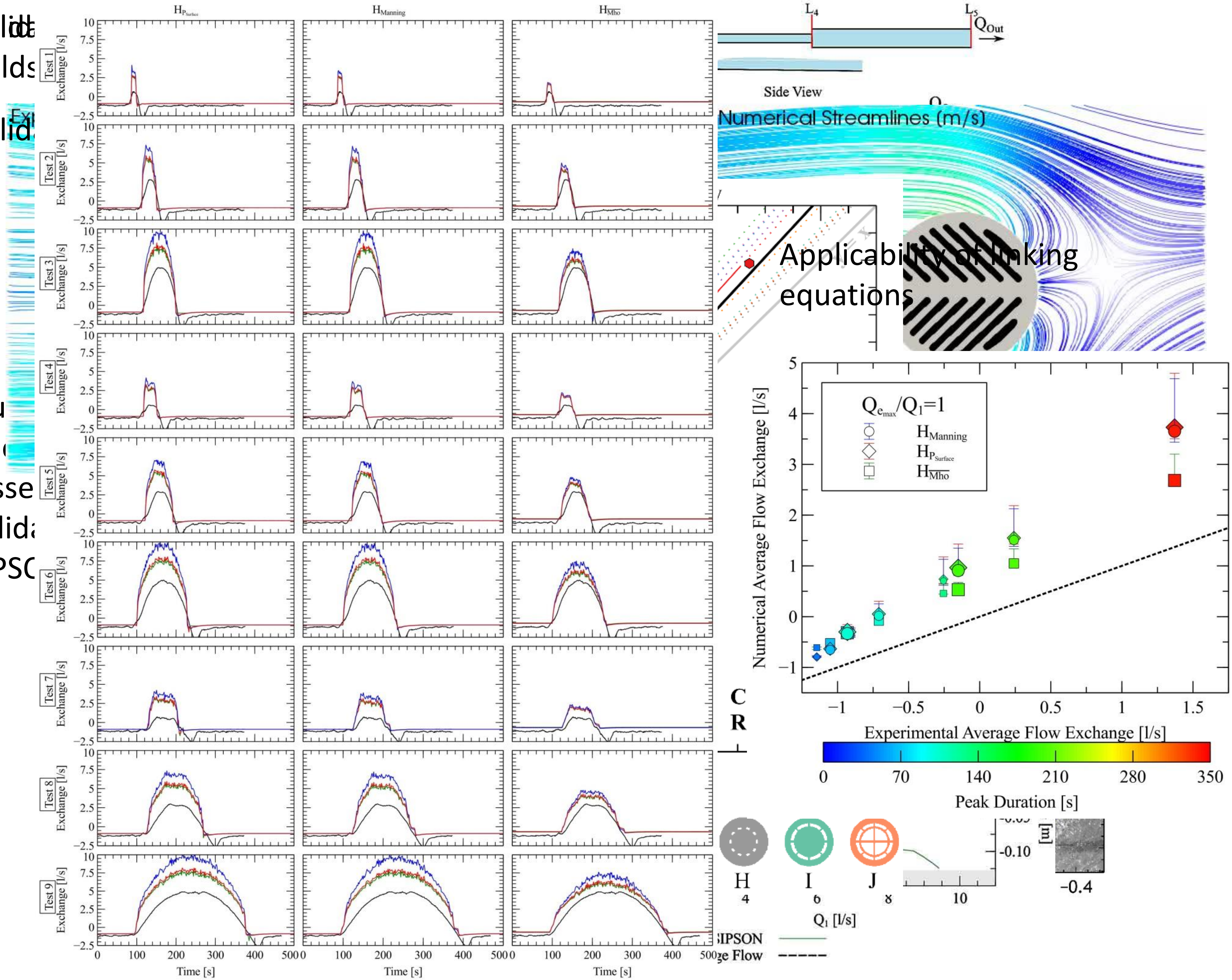
Applicability of linking equations



# Outputs

- Validation of the applicability of weir and orifice equations
- Linking equations are sensitive to calculations of relative head within pipe and surface systems.
- In unsteady surcharging conditions, significant head losses are encountered over and above those in steady state flow
- In non-surcharging conditions, energy loss coefficients are unaffected by the presence of a manhole lid
- In surcharging conditions, the coefficients (and hence energy losses) are lower when the lid is removed
- Energy loss coefficient associated with the overflow is not dependent on the blockage in the pipe or the flow conditions on the surface.
- This behaviour is a consequence of the increasing proportion of flow which is transferred to the surface encountering higher turbulent losses as the flow moves from the sewer into the surface

# Where to find them…

OUTPUT (1) M.Rubinato, R.Martins, G.Kesserwani, J.Leandro, S.Djordjevic, J.Shucksmith. **Experimental calibration and validation of sewer/surface flow exchange equations in steady and unsteady flow conditions**. *Journal of Hydrology*, 2017, 552, 421-432, https://doi.org/10.1016/j.jhydrol.2017.06.024

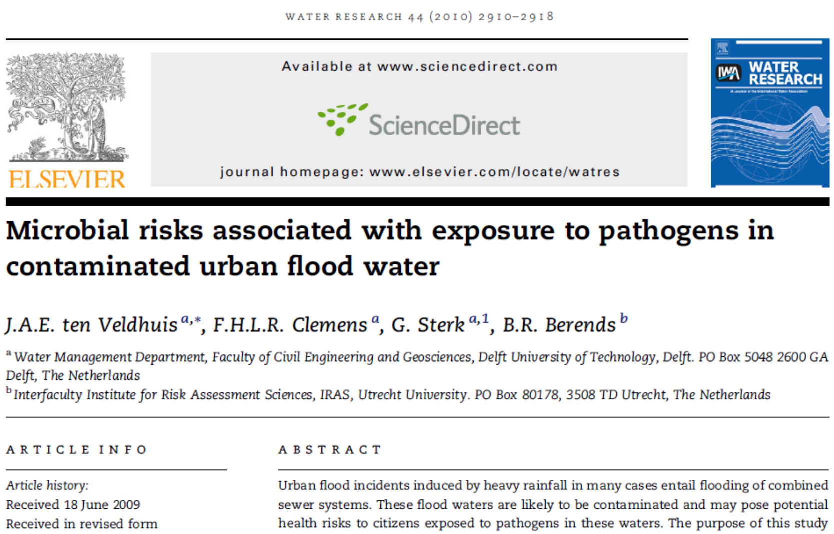
OUTPUT (2) R . Martins, G. Kesserwani, M. Rubinato, S. Lee, J. Leandro, S. Djordjević & J. D. Shucksmith (2017) **Validation of 2D shock capturing flood models around a surcharging manhole**, *Urban Water Journal*, http://dx.doi.org/10.1080/1573062X.2017.1279193 .

OUTPUT (3) M.Rubinato, R.Martins, J.Shucksmith (2018) **Quantification of energy losses at a surcharging manhole**. *Urban Water Journal*, http://dx.doi.org/10.1080/1573062X.2018.1424217 .

OUTPUT (4) M.Rubinato, S.Lee, R.Martins, J.Shucksmith (2018) **Surface to sewer flow exchange through circular inlets during urban flood conditions**. *Journal of Hydroinformatics*, DOI: 10.2166/hydro.2018.127 .

OUTPUT (5) R. Martins, G. Kesserwani, M. Rubinato, S. Lee, J. Leandro, S. Djordjević & J. D. Shucksmith (2018) **On the Characteristics of Velocities Fields on the Vicinity of Manhole Inlet Grates during Flood Events**, *Water Resources Research* https://doi.org/10.1029/2018WR022782 .

# Health Risks of Urban Floods



WATER RESEARCH 44 (2010) 2910–2918

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WATER RESEARCH

**Microbial risks associated with exposure to pathogens in contaminated urban flood water**

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ARTICLE INFO

*Article history:*
Received 18 June 2009
Received in revised form

ABSTRACT

Urban flood incidents induced by heavy rainfall in many cases entail flooding of combined sewer systems. These flood waters are likely to be contaminated and may pose potential health risks to citizens exposed to pathogens in these waters. The purpose of this study

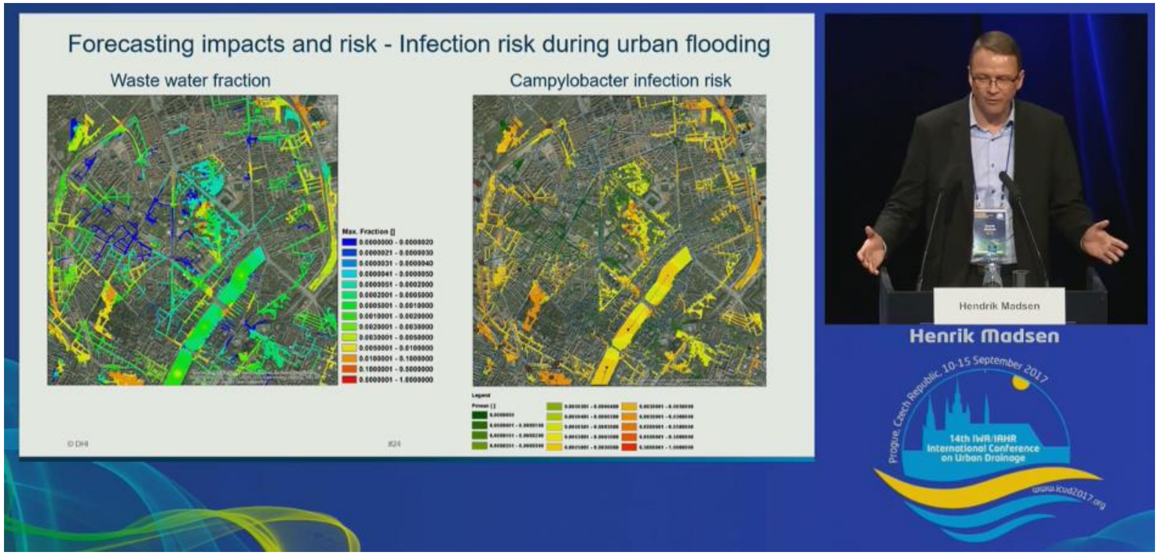
*Water Research, 2010*


*The Sun, 200?*

- Urban floods (especially those in areas with combined sewers) contain high levels of pathogens and other harmful bacteria
- Direct and indirect contamination risk, risk to vulnerable sites

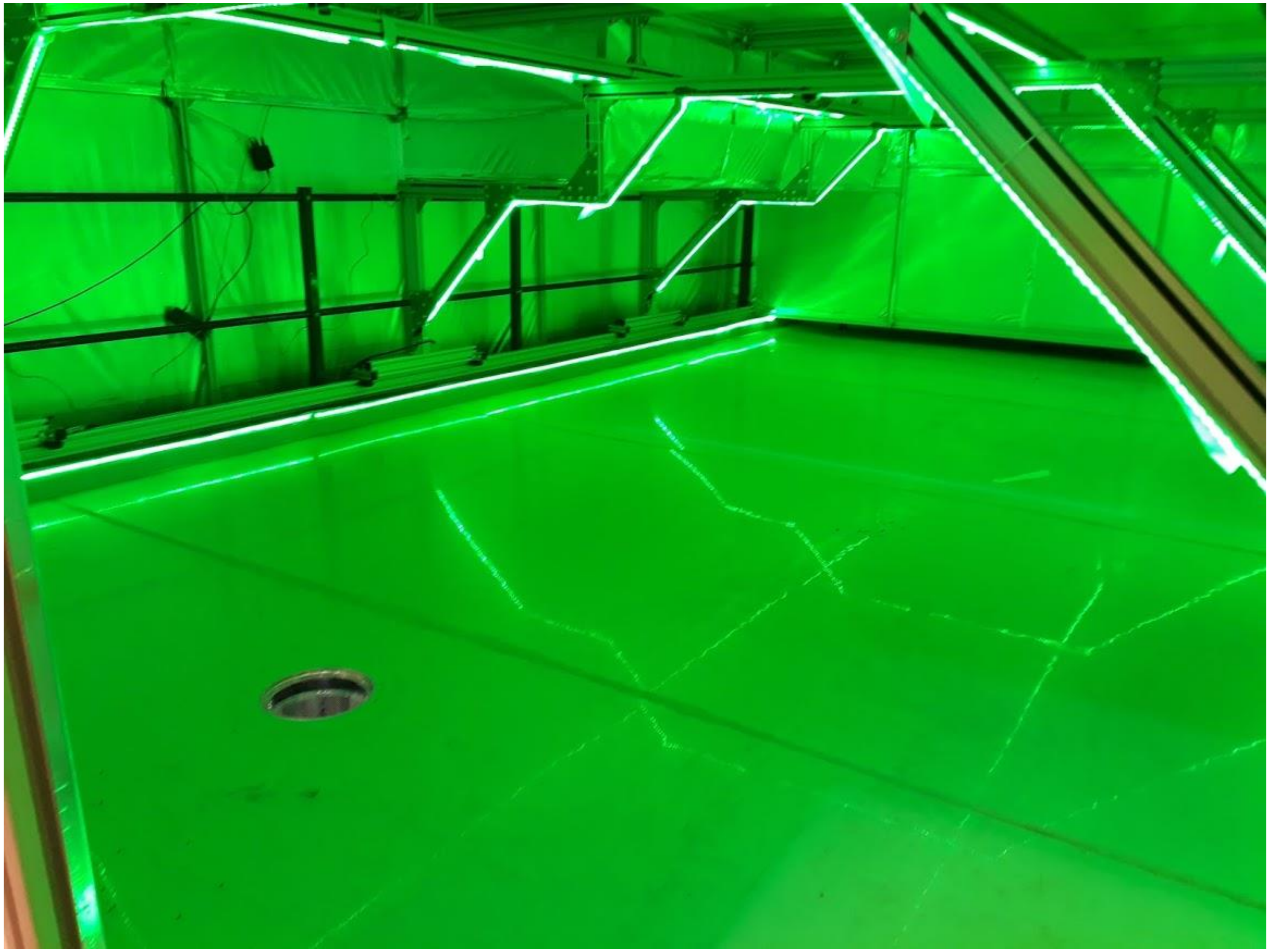
- Is it possible to develop modelling capability to include this?

# International Conference on Urban Drainage 2017, Prague

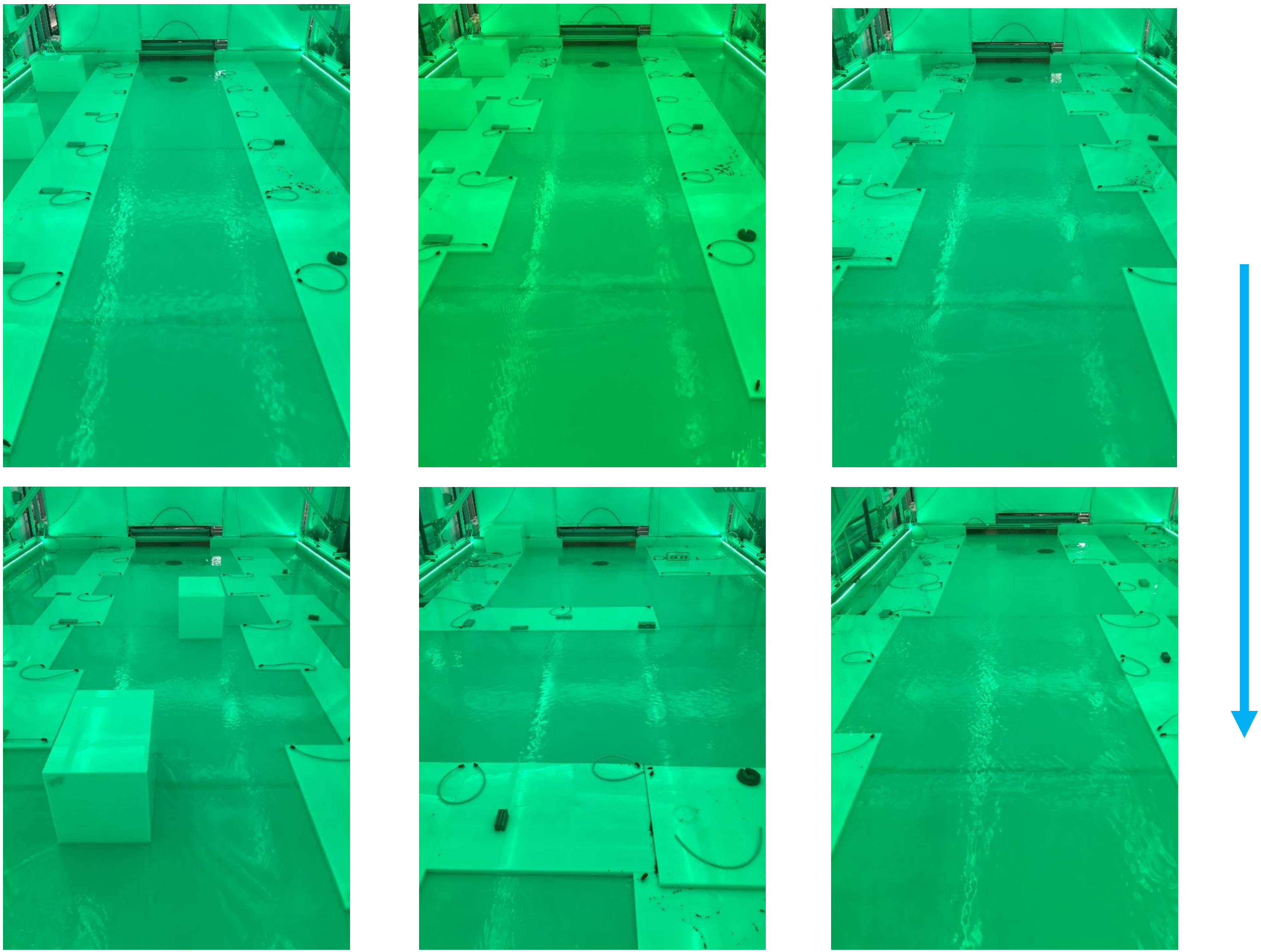



- Presentation at ICUD 2017 from Head of Innovation at DHI
- Contaminant transport model added to flood model
- Calibration/Verification data?

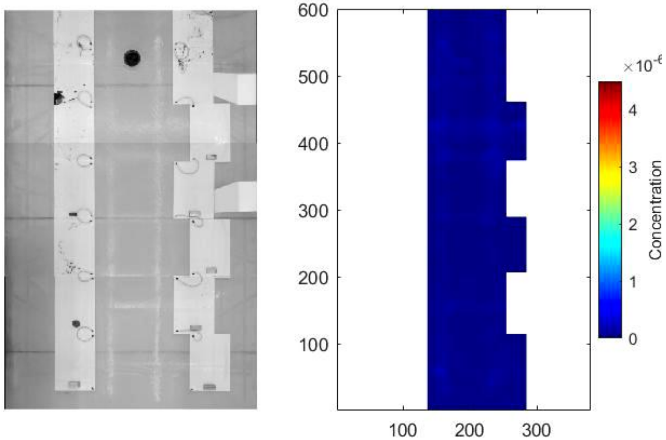
# The illuminated facility



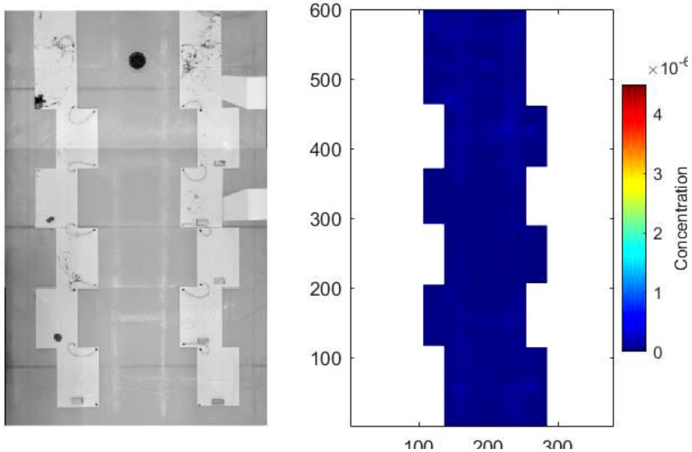
# Configurations tested (downstream view)



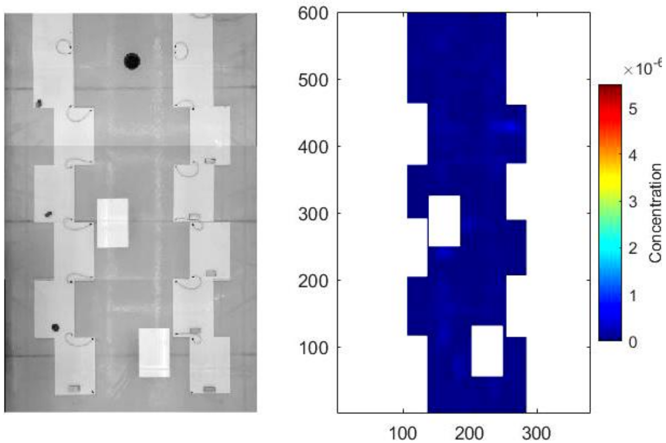
Conf2



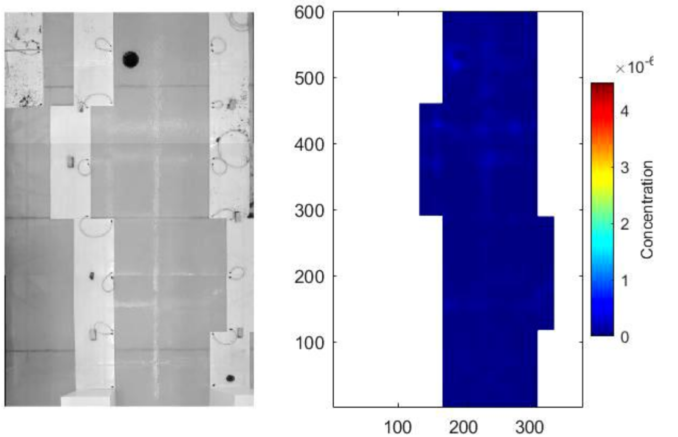

Conf3




Conf4

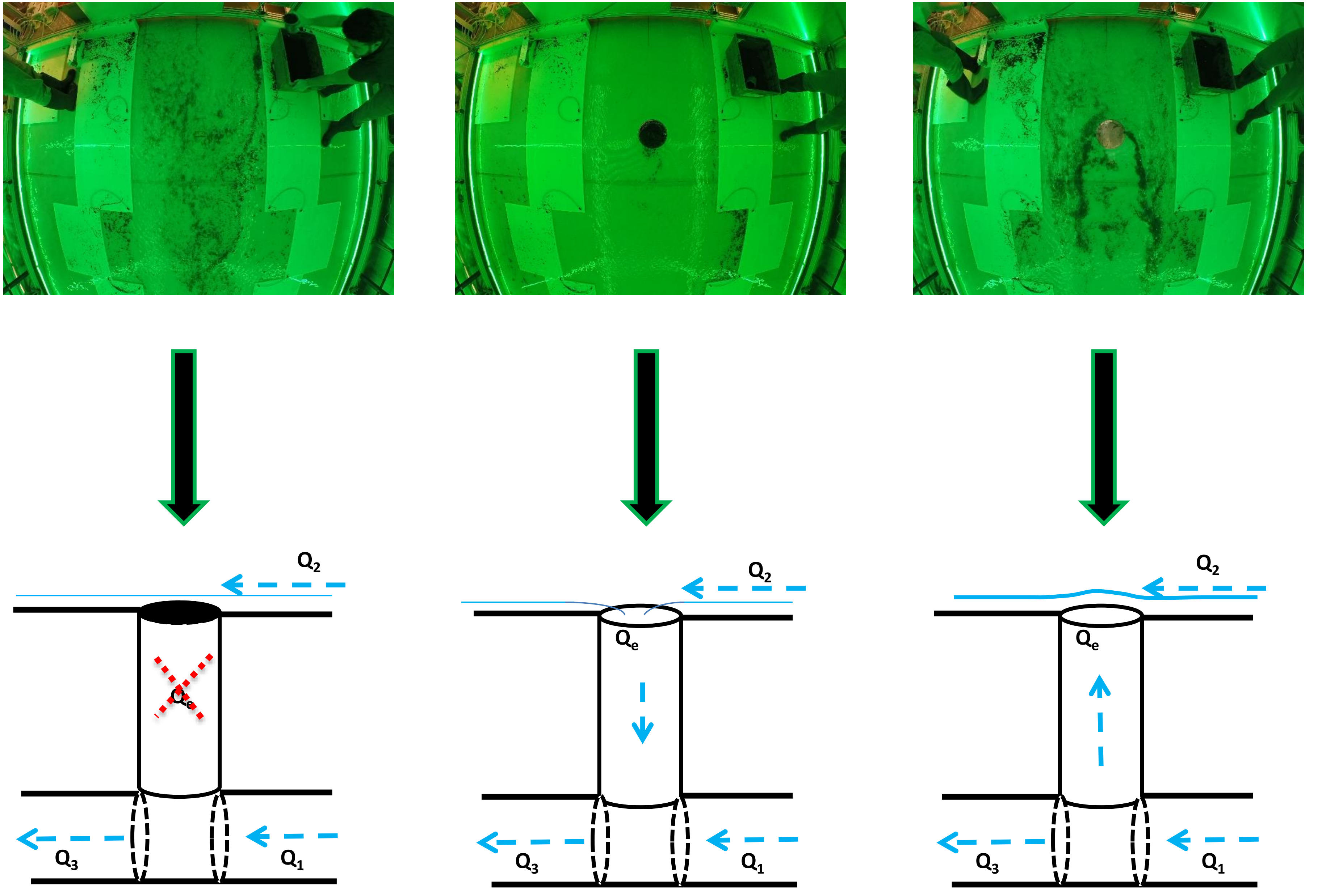



Conf6




PRELIMINARY RESULTS:

- small inconsistencies around the reflection points to be improved;
- the parking slots on there own don't seem to have much effect, its only when they are coupled with the obstacles, or the manhole is close to the edge of the roadway that the impact becomes important.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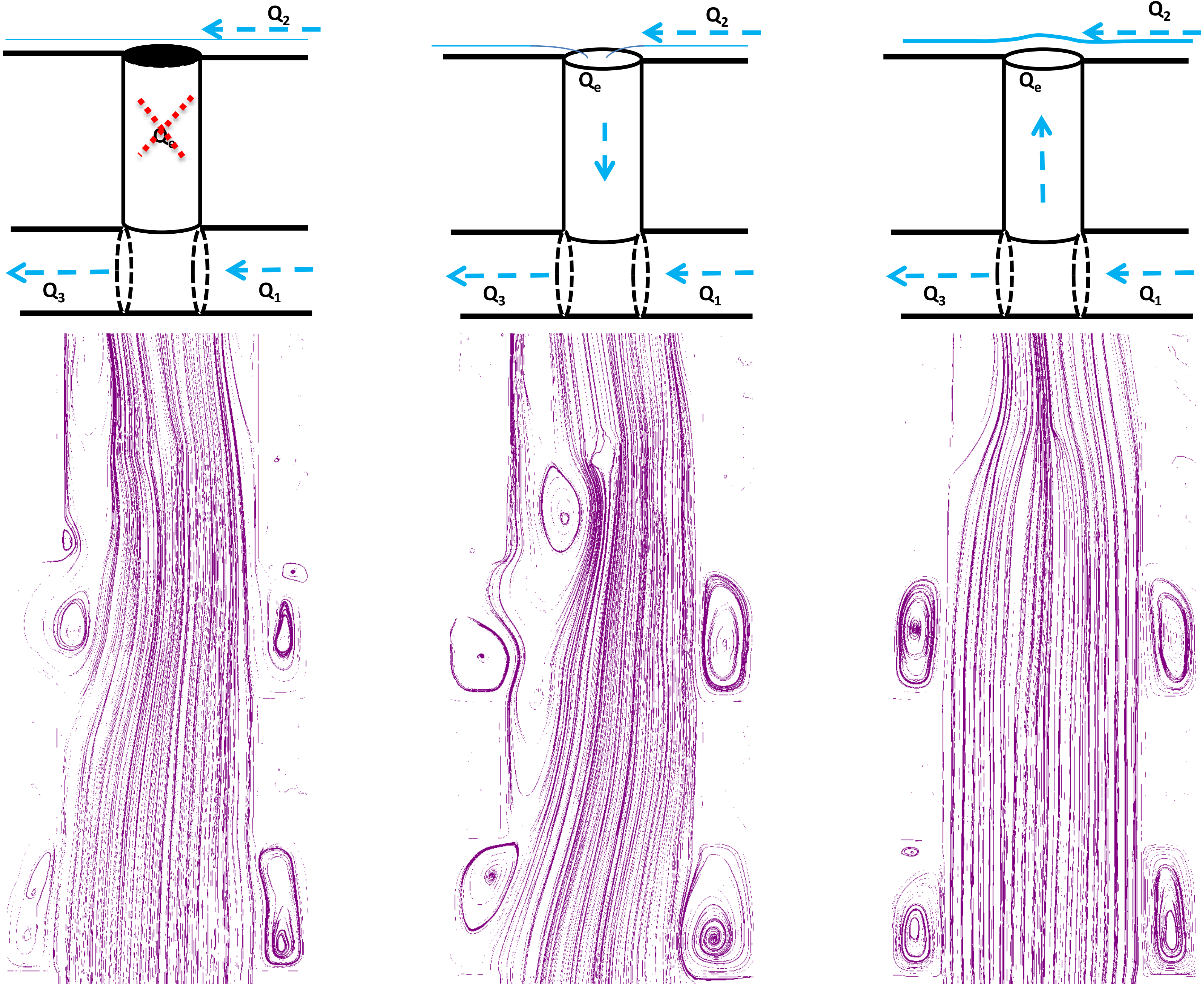
Q2
Qe
Q3
Q1



Q2
Qe
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Q1
Q2
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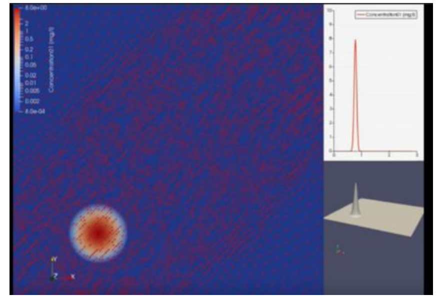
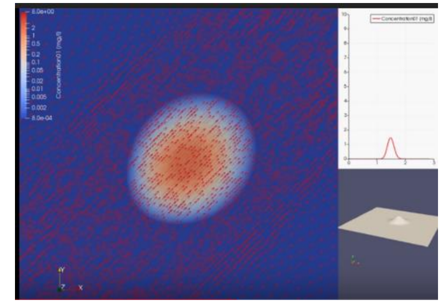
Q3
Q1
Q2
Qe
Q3
Q1

# FUTURE STEPS





## SHORT TERM:

- Calibrate the ADE model developed and investigate the spread of pollutants in floodwater in urban areas
- Assess the ability of a typical 2D model tailored to solve the depth-averaged Shallow Water Equations (SWE) on a non-uniform 2D mesh to represent the surface flow pattern during urban floods by comparing numerical simulations and laboratory experiments

## LONG TERM:

- Increase awareness of the health impacts of urban flooding
- Develop health impact models
- Continue to support numerical modellers and improve the accuracy of flood modelling

# Thanks a lot for your attention

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*This research is supported by EPSRC grant EP/K040405/1*

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All datasets collected are available in OPEN ACCESS