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— L'eau dans la ville | Urban water

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L'eau dans la ville | Urban water

Simulation-Optimization of Smart Decentralized Network of Rainwater Harvesting Systems for Reducing Urban Drainage Flows

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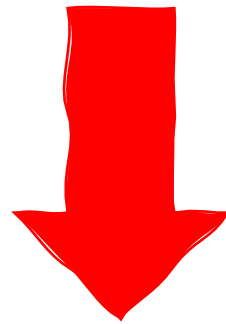
 **DTU**
Denmark
Technical
University

Introduction

Dual Benefit of Rainwater Harvesting

Supply water while reducing urban drainage flows

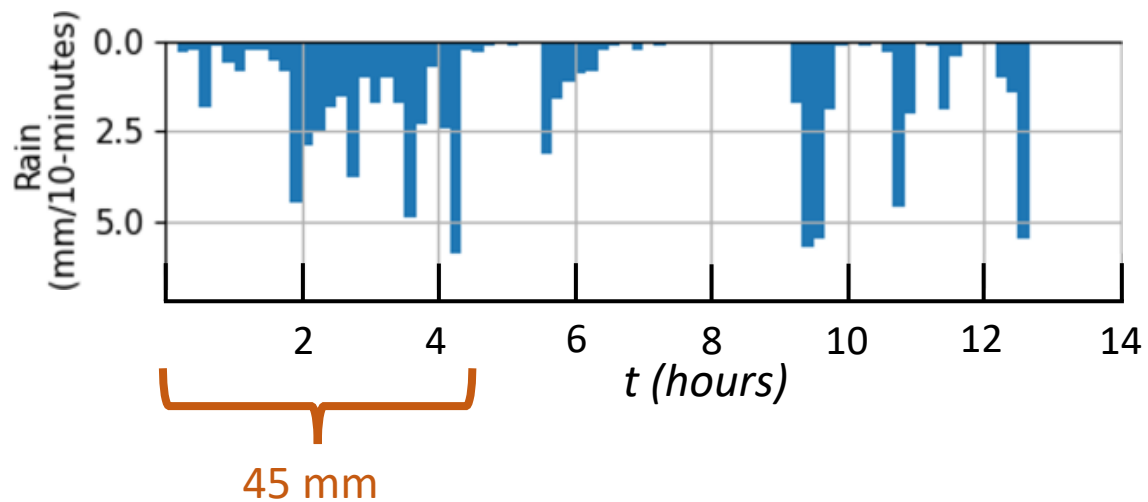
Runoff mitigation during significant events



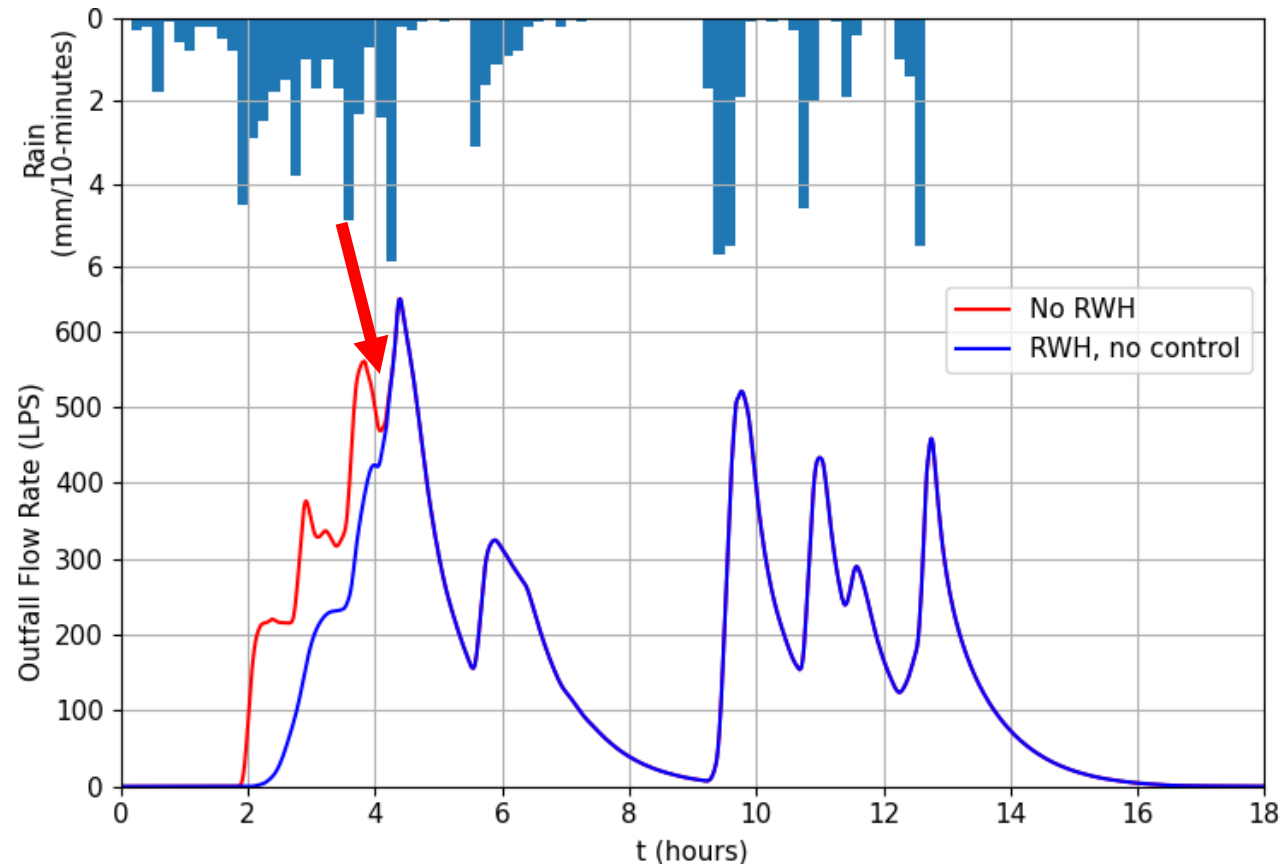
Performance During Significant Events

Feb 25-26, 2010:

85 mm in 13 hours



Performance During Significant Events



Develop a simulation-optimization methodology for generating control policies of a network of RWH systems for achieving two objectives:
reducing urban drainage flows and maximizing rainwater availability

Requirement

- Achieve both by using a simple optimization scheme without multi-objective optimization

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Requirement

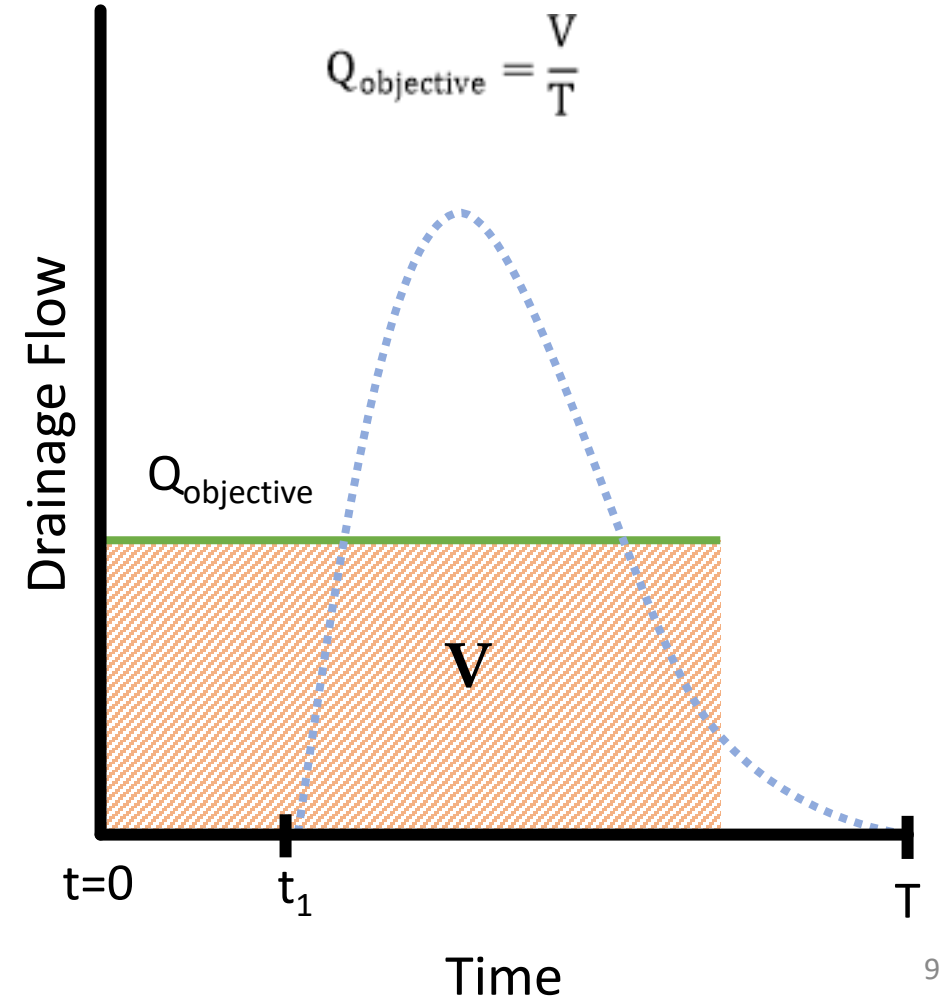
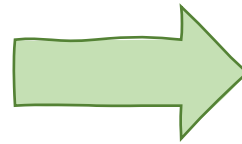
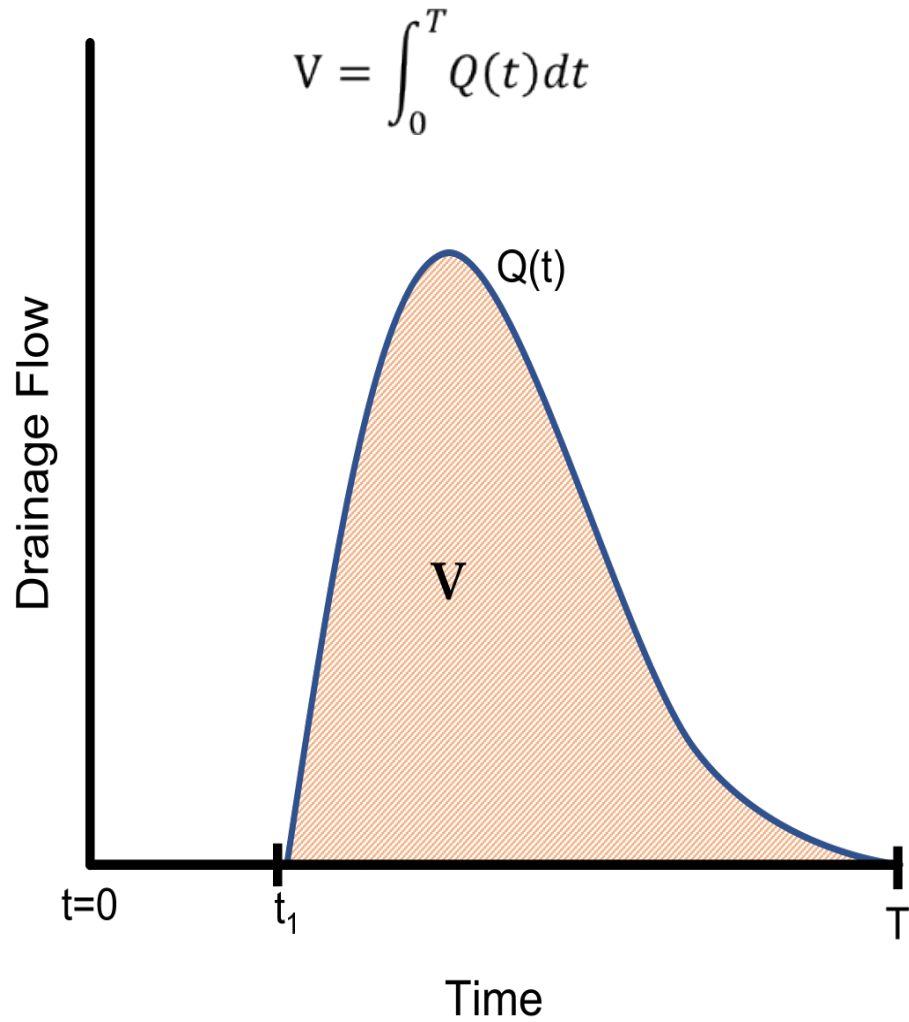
- Achieve both by using a simple optimization scheme without multi-objective optimization

Challenges

- Water availability and flow reduction often compete
- Radar-based nowcasts have errors and change quickly
- Rain events' duration is longer than forecast horizon
- Long optimization runtime – irrelevant control policies

Simulation-Optimization Method

Concept

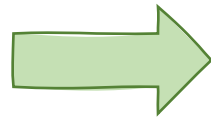
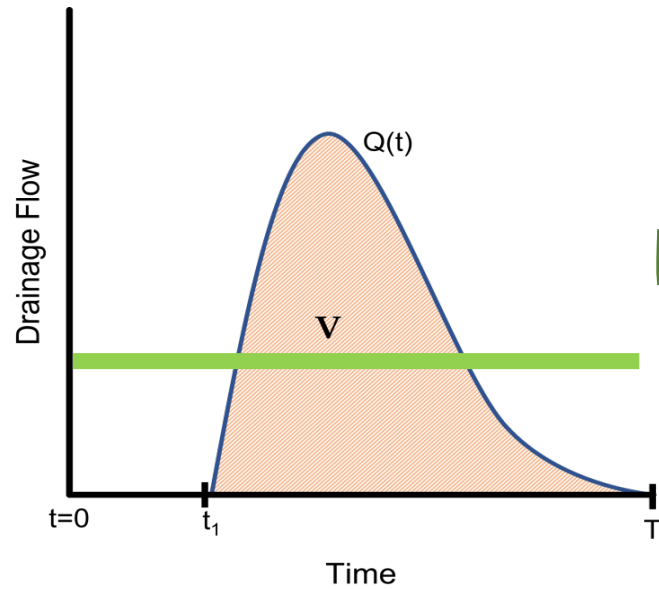


Simulation-Optimization

Forecast



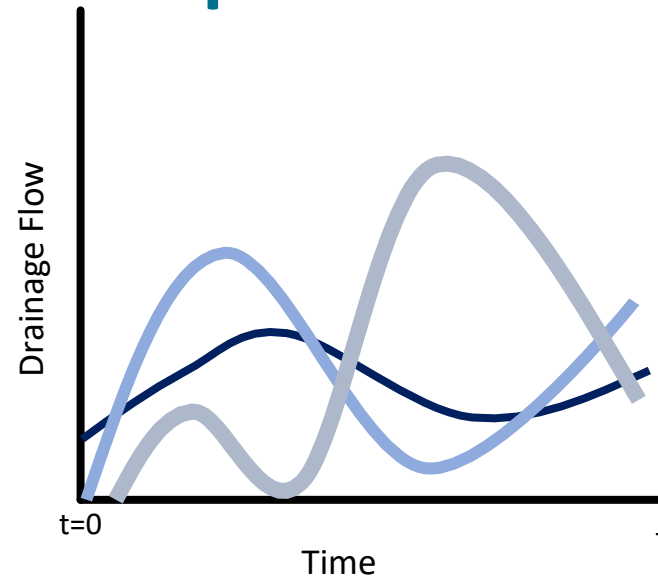
Prediction



Forecast



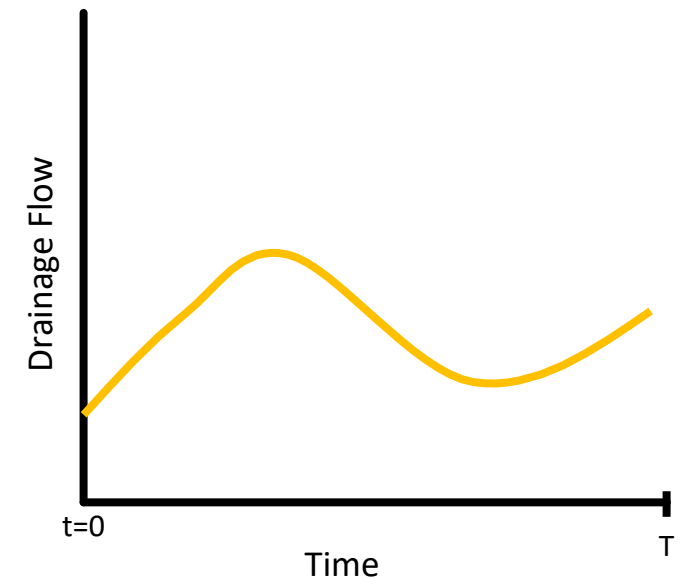
Optimization



Measured



Control



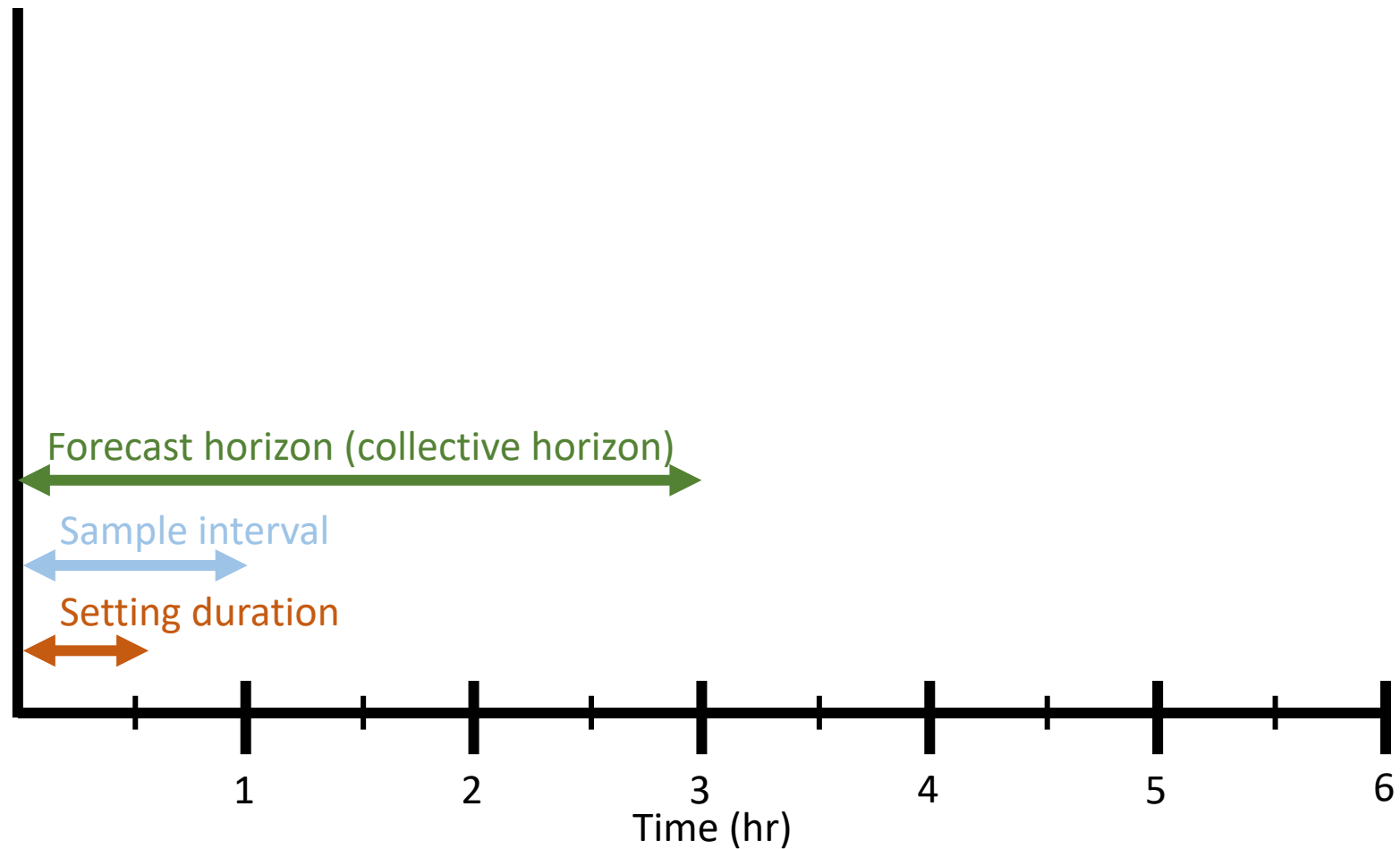
$$\min \sum_{t=0}^T |Q(t) - Q_{objective}|$$

Optimization

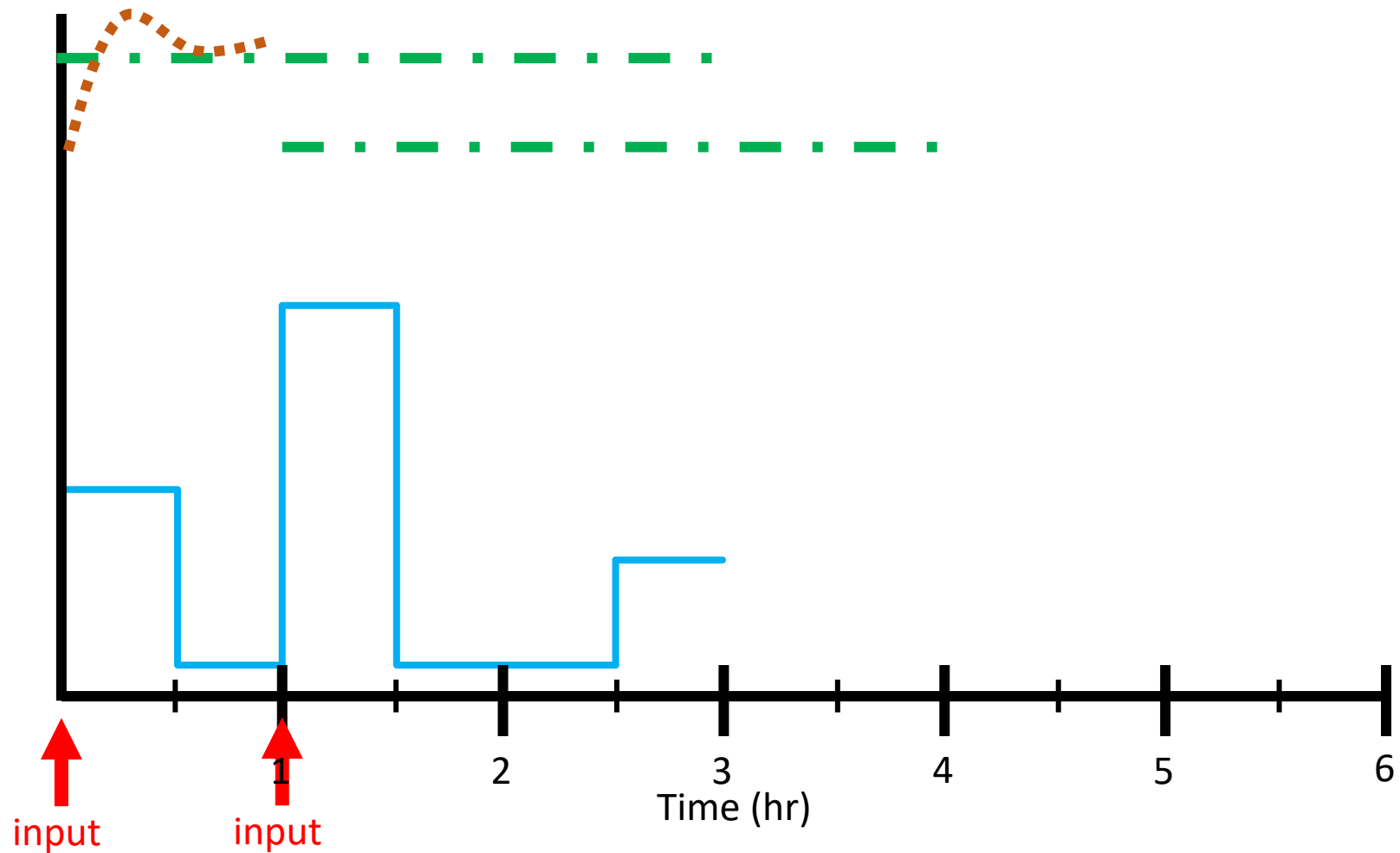
- Genetic algorithm as optimization method
- Decision variables – valve opening %
- Internal kinematic wave model for flow routing

Model Predictive Control

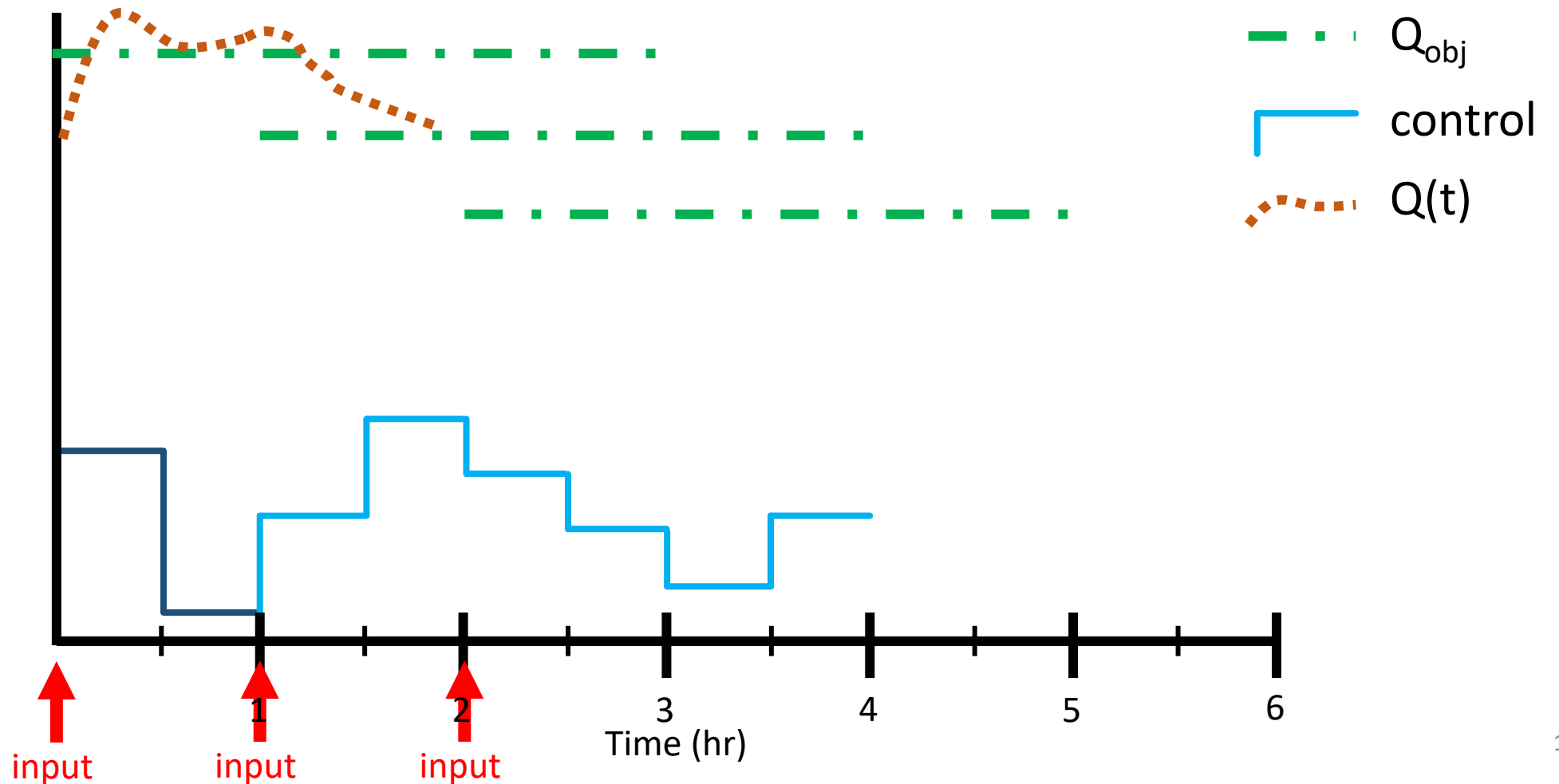
Model Predictive Control



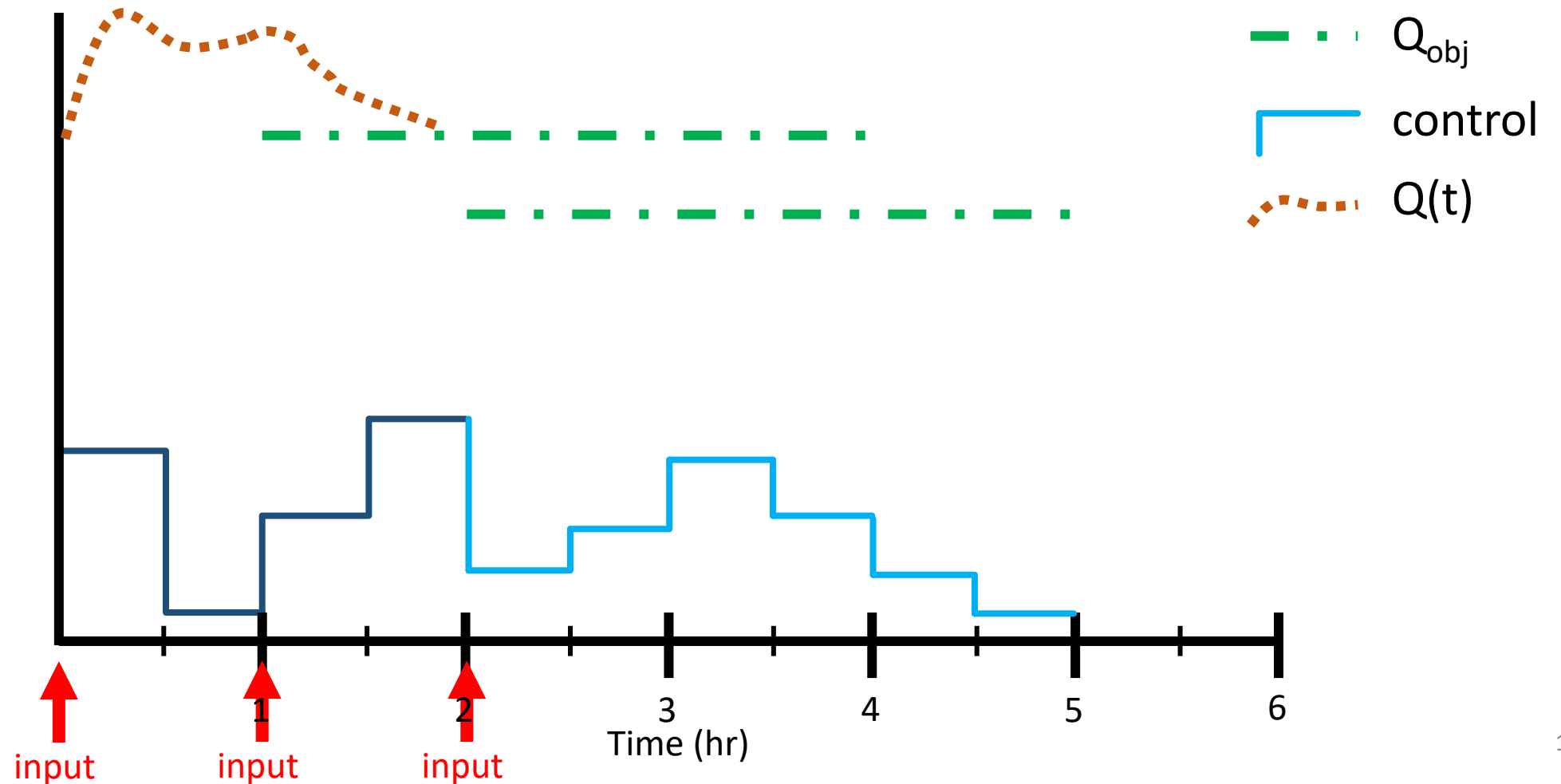
Model Predictive Control



Model Predictive Control



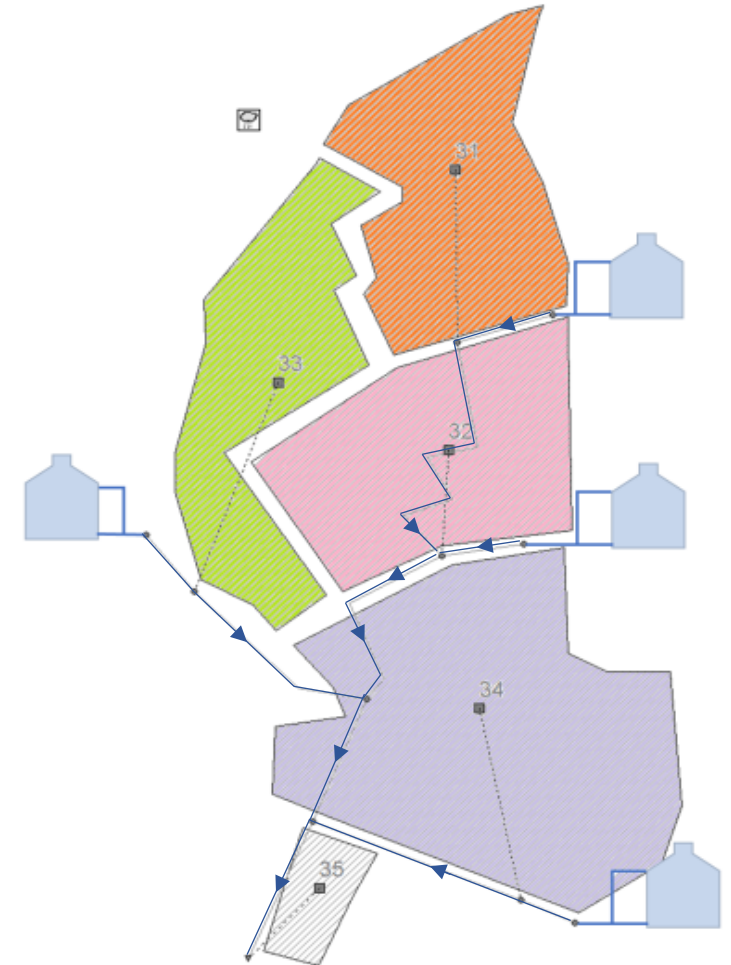
Model Predictive Control



Catchment and Rainfall Inputs

Catchment

- “Retrofitting” an existing catchment:
19 ha, 140 residential buildings,
10 m³ tanks
- Rooftop area – independent model
- subcatchment-based control



Rainfall and Forecast

Rainfall and forecast

- 73 events – at least 40 mm, 6 hr inter-event time
- Synthetic forecast data – 3 hr forecast horizon, depth and temporal errors
- Simulations with two datasets – perfect and synthesized forecast

Results

Performance Indicators

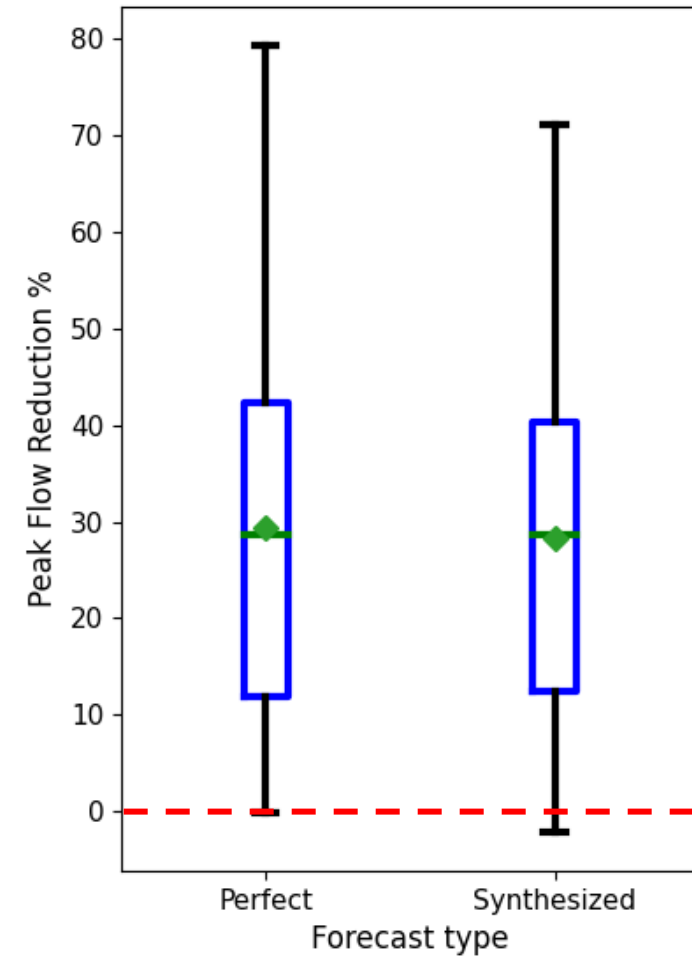
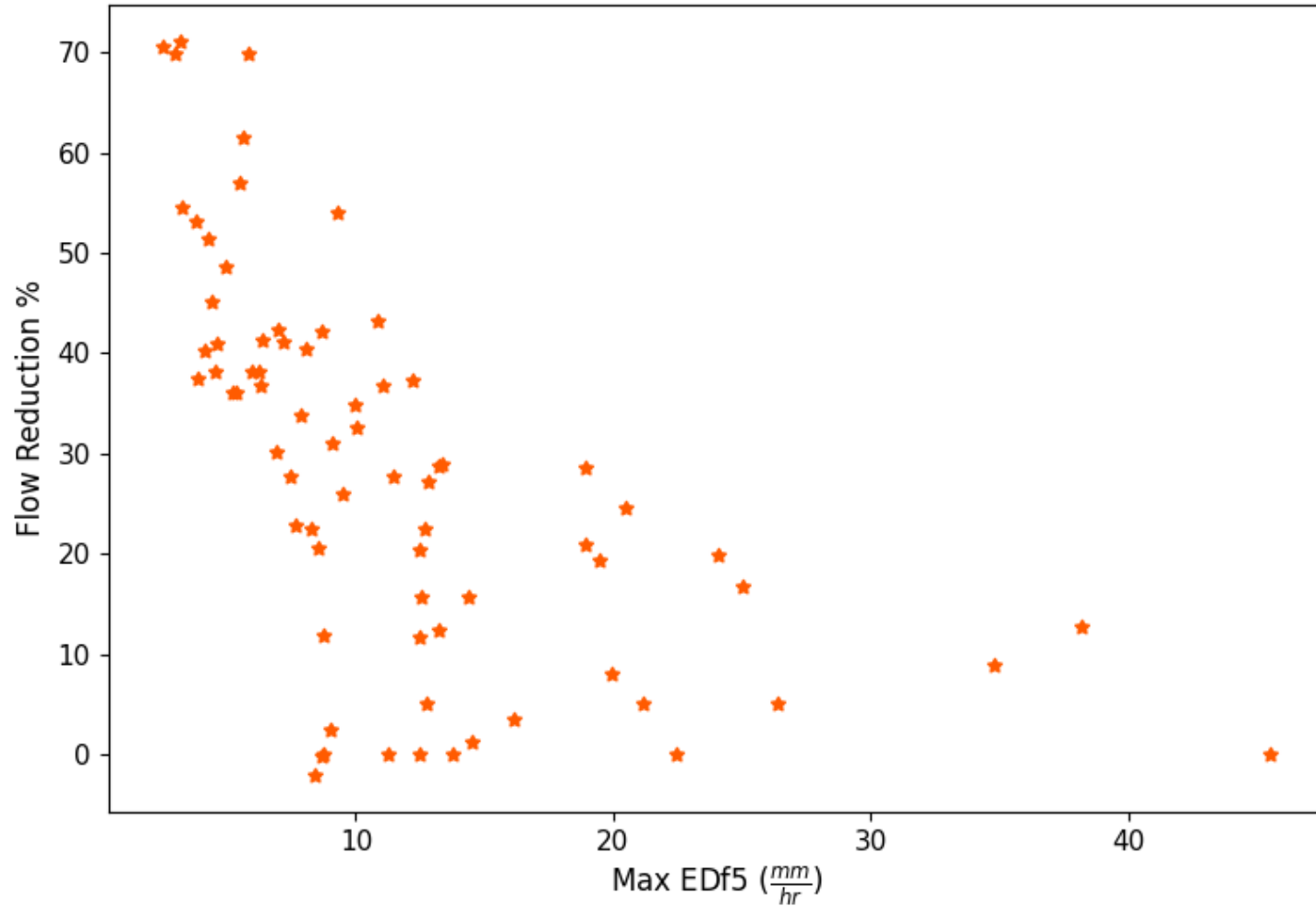
- Peak flow reduction:

$$\frac{\max(Q_{baseline}) - \max(Q_{control})}{\max(Q_{baseline})}$$

- Water availability reduction:

$$\frac{\sum Water_{baseline} - \sum Water_{control}}{\sum Water_{baseline}}$$

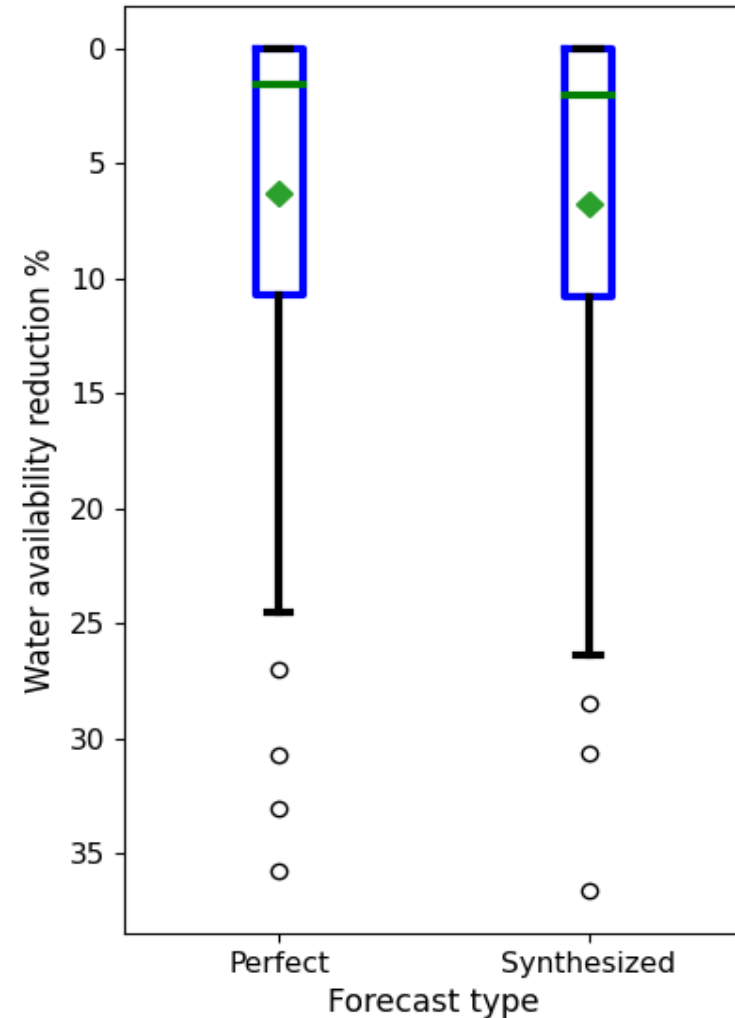
Peak Flow Reduction



Water availability Reduction

25% - 0% reduction

60% - <5% reduction



Performance Examples

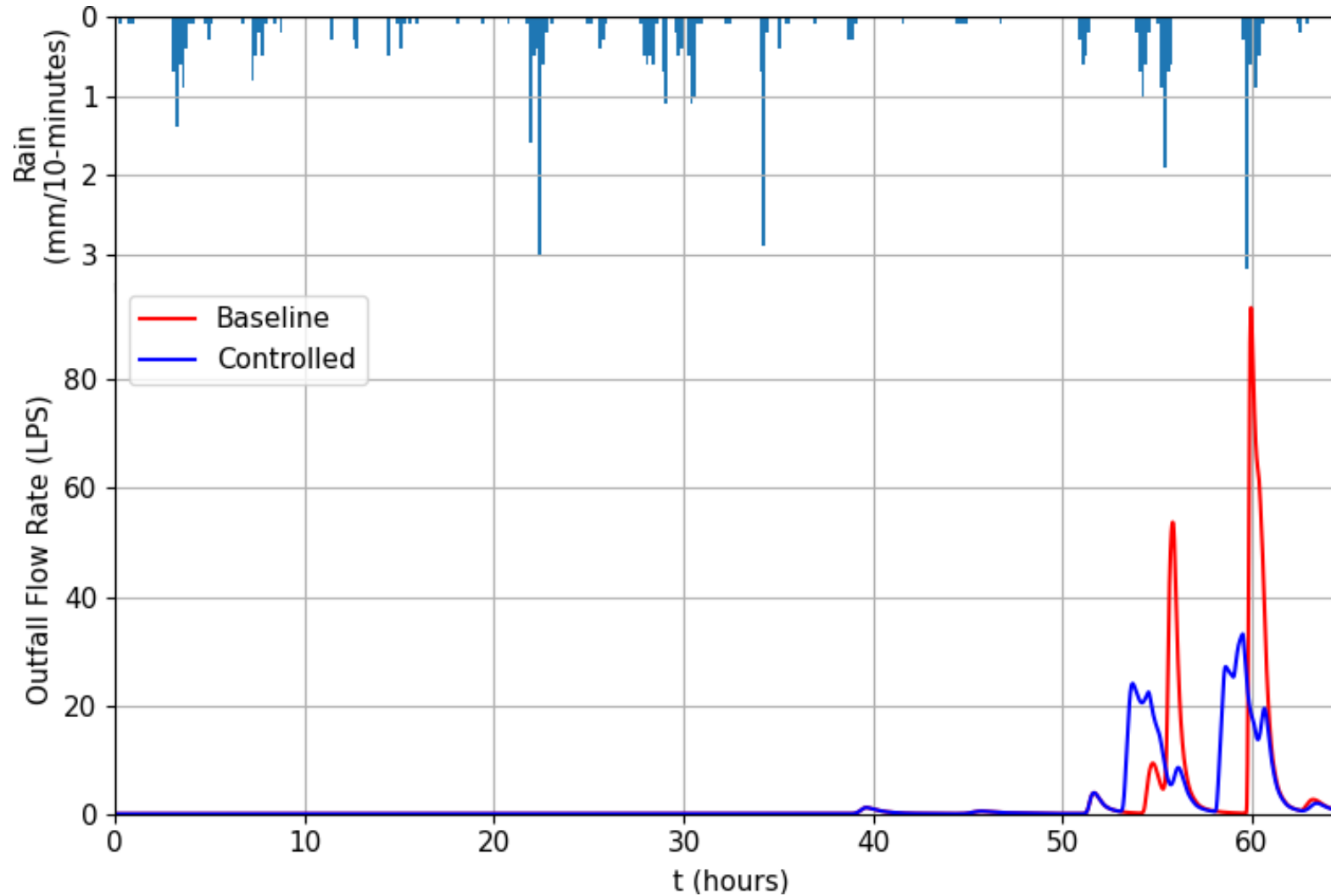
Feb. 2003

Flow reduction – 70%

Water reduction – 0.85%

$ED_{f5} = 2.5 \text{ mm/hr}$

Total depth: 47 mm



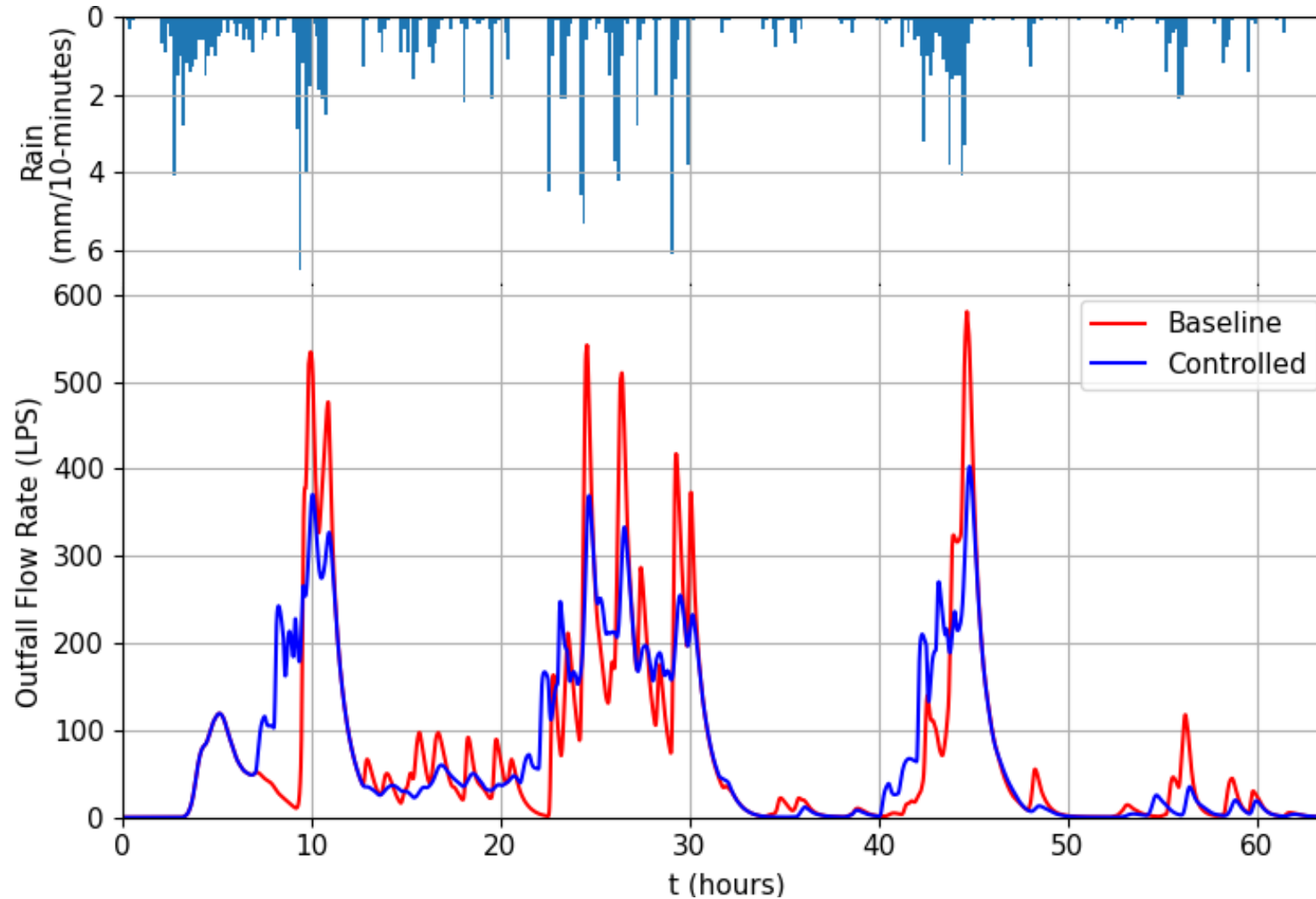
Dec. 2018

Flow reduction – 31%

Water reduction – 1.7%

$ED_{f5} = 9.1 \text{ mm/hr}$

Total depth: 177 mm



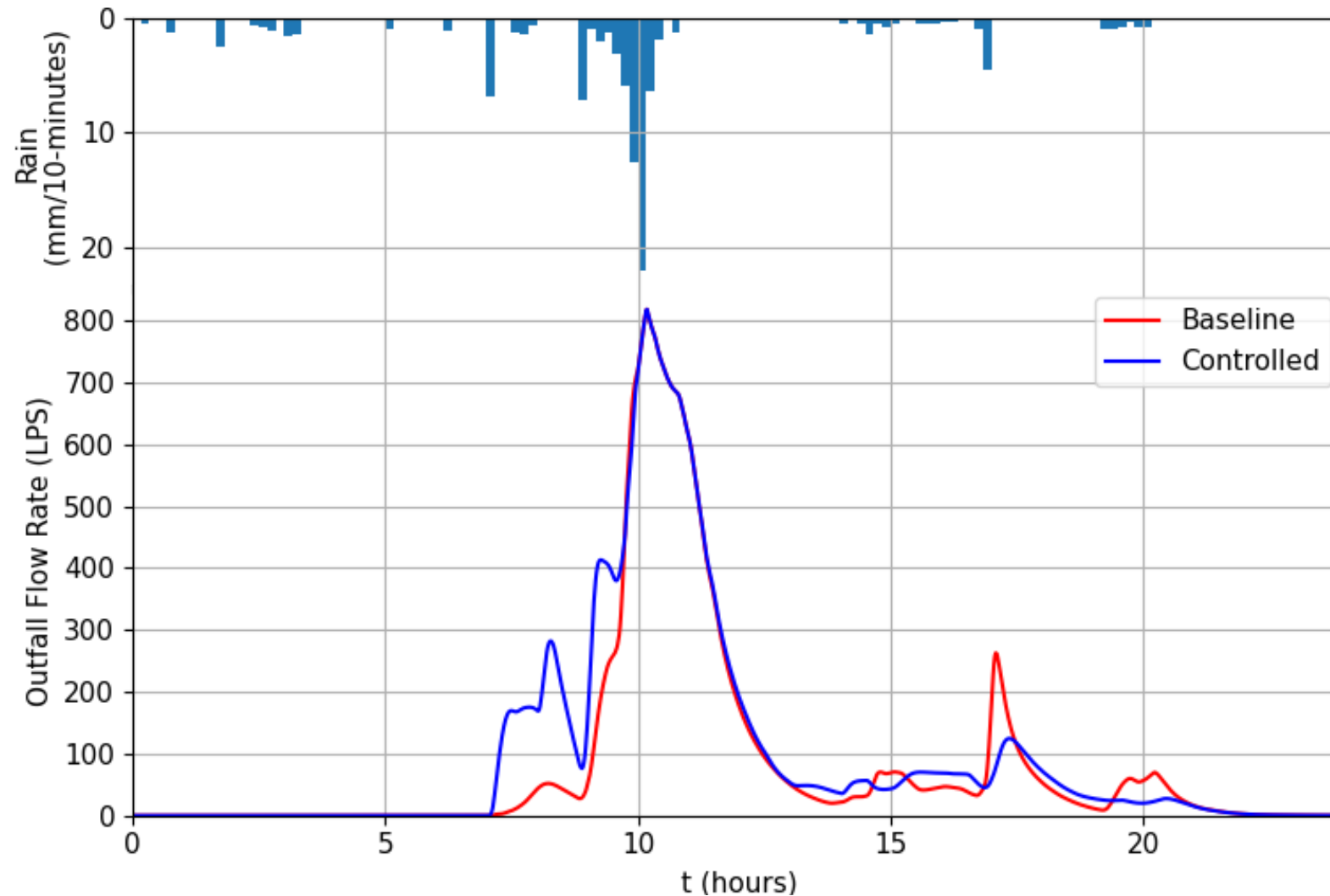
Nov. 2020

Flow reduction – 0%

Water reduction – 0.7%

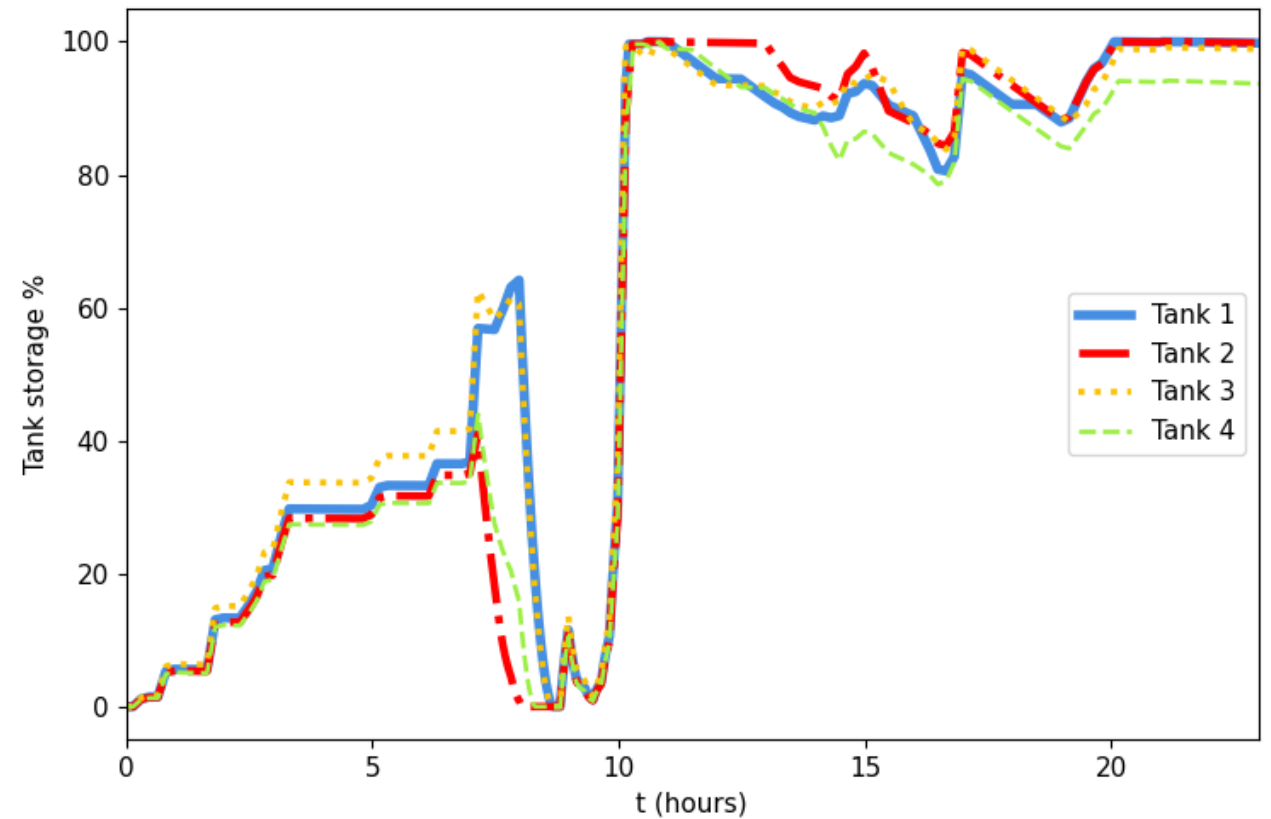
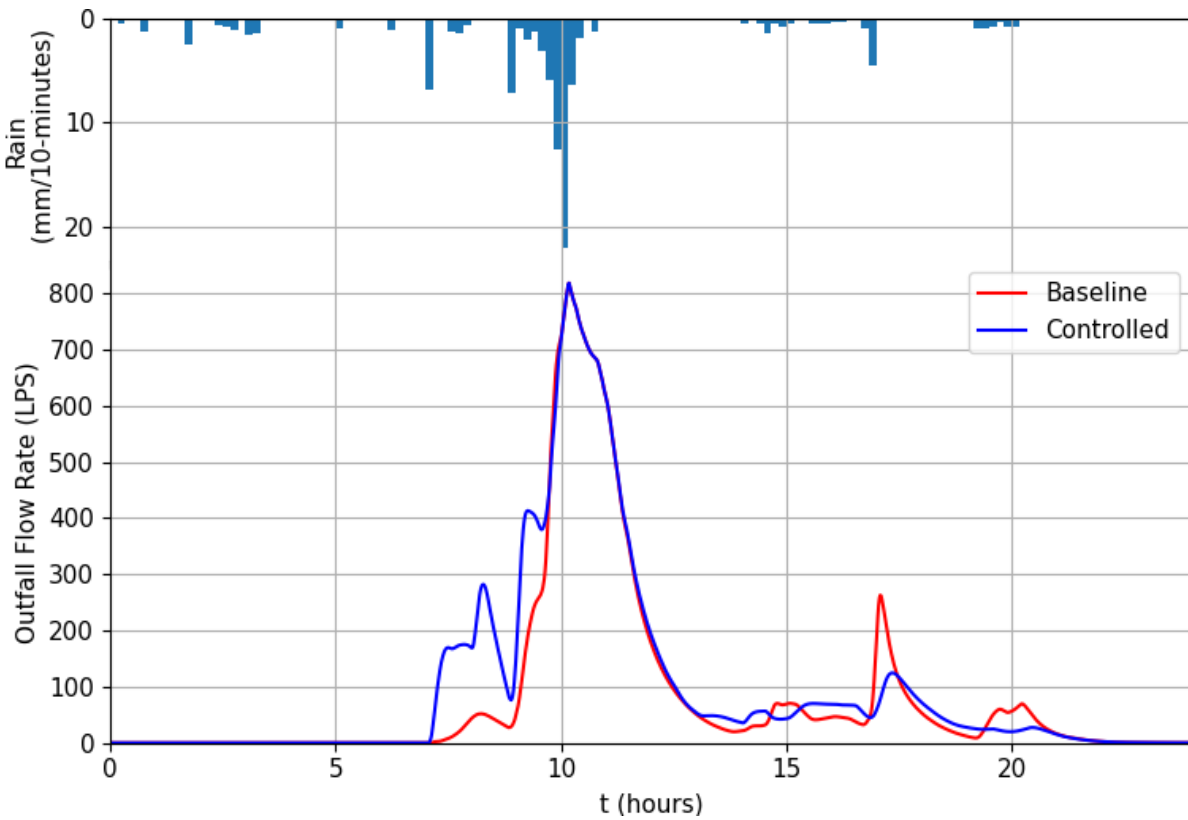
$ED_{f5} = 45.5 \text{ mm/hr}$

Total depth: 105 mm



Nov. 2020

Flow reduction – 0%
Water reduction – 0.7%



Summary

- RWH - Controllable “buffer volume” for urban catchments
- Predictive control is successful in overcoming inherent shortcomings
- Method utilizes forecast to achieve intra-event recovery
- Future research – real nowcasts, intra-event behavior



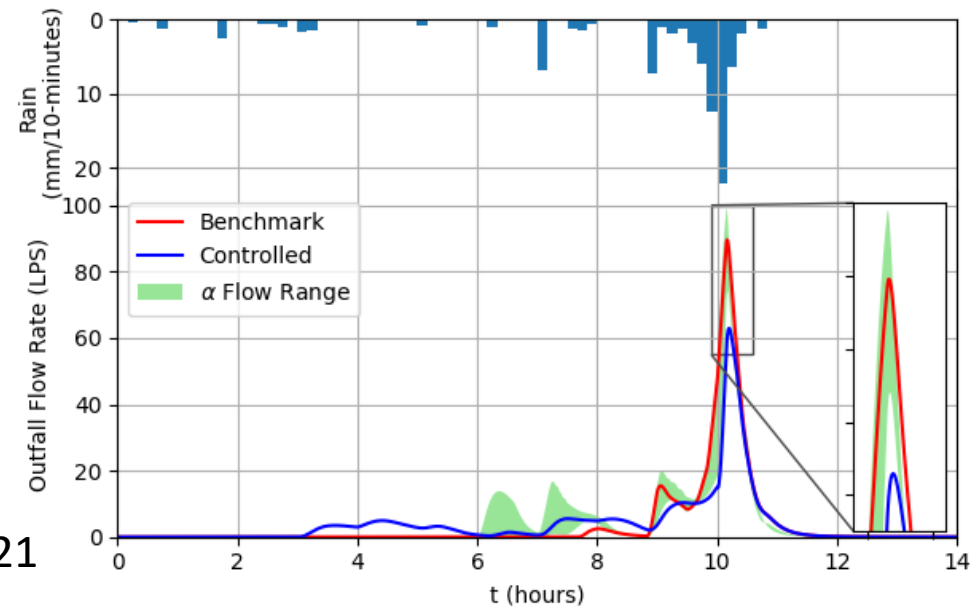
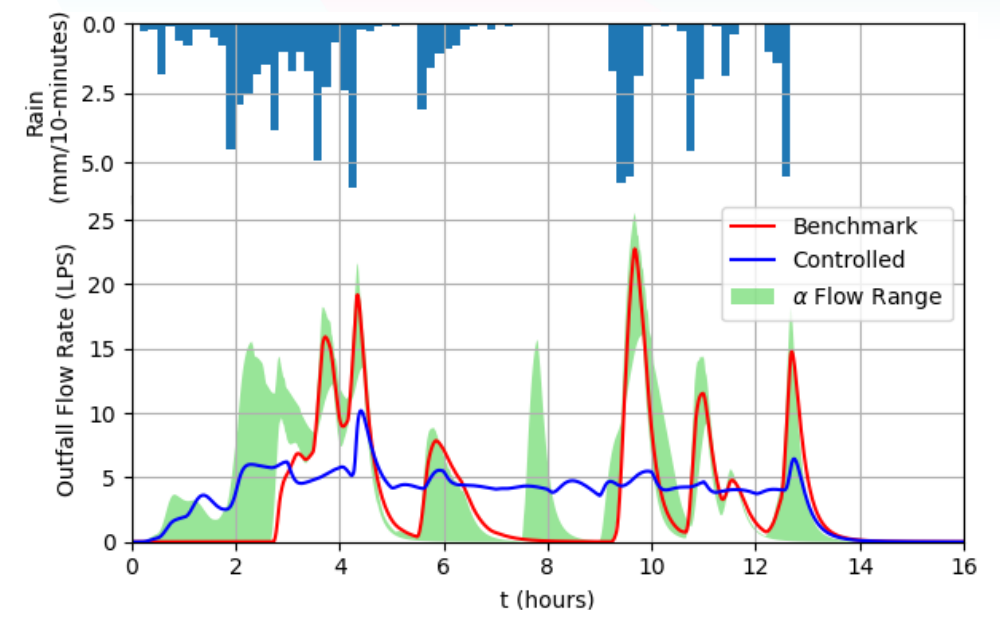
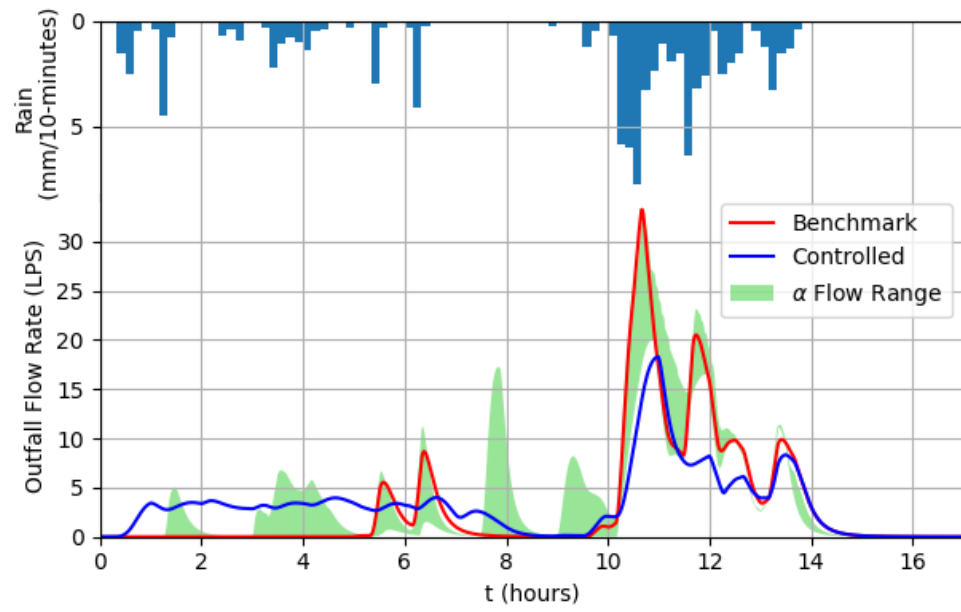
Single building model



RWH network control

Thank you for listening!

Ευχαριστώ για την προσοχή!



Flow routing by using the continuity eq. for open channels:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

Lighthill and Whitham, 1955

$$Q = f(A) = \alpha \cdot A^\beta$$

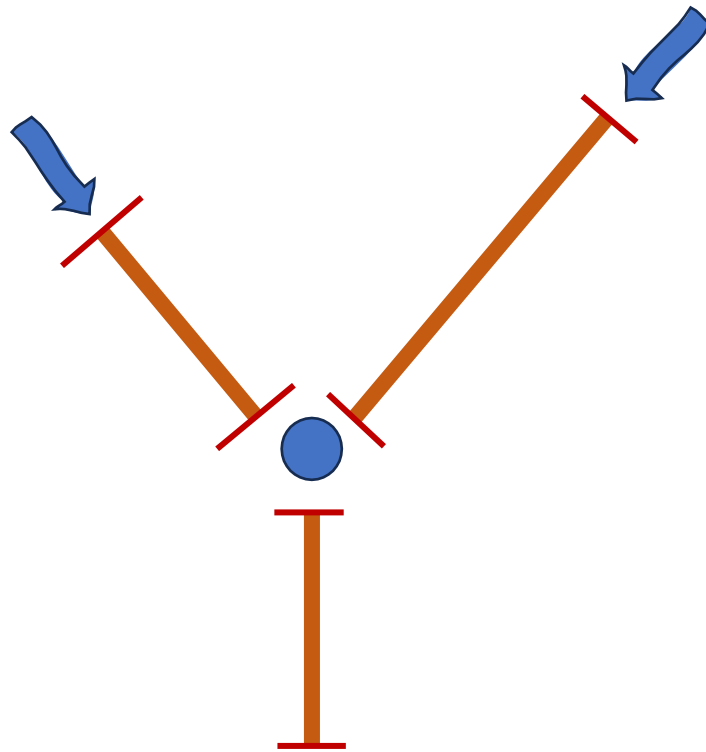
$$\alpha \approx 0.501 \cdot \frac{D^{\frac{1}{6}} \cdot S^{\frac{1}{2}}}{n}, \beta \approx \frac{5}{4}$$

Wong and Zhou, 2002

$$\frac{\partial Q}{\partial A} = \alpha \cdot \beta \cdot A^{\beta-1}$$

$$\alpha \cdot \beta \cdot A^{\beta-1} \cdot \frac{\partial A}{\partial x} + \frac{\partial A}{\partial t} = 0$$

$$\alpha \cdot \beta \cdot A^{\beta-1} \cdot \frac{\partial A}{\partial x} + \frac{\partial A}{\partial t} = 0$$



- Beit Dagan meteo station - 1999-2022
- Min 40 mm, 6 hours inter-event duration (73 events)
- Forecast: 3-hour horizon , depth and temporal errors:

