UDS-RTC101: A hands-on workshop on the real-time control of urban drainage systems

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Xylem

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UDS-RTC101: Workshop Outline:

Introduction

- Today's workshop and stormwater systems
- Modeling, RTC workflow, and tools

Hands-on Examples

- Using pyswmm
- Using pystorms

-- *Break* --

Questions and Re-orient to Big Picture

More(!) Hands-on Examples

- Equal-filling degree controller, Scenario gamma
- Bayesian optimization, Scenario gamma

Future Directions

As storms are becoming more frequent and stronger for longer, urban watersheds are being stressed beyond capacity…

Duluth, MN 2012

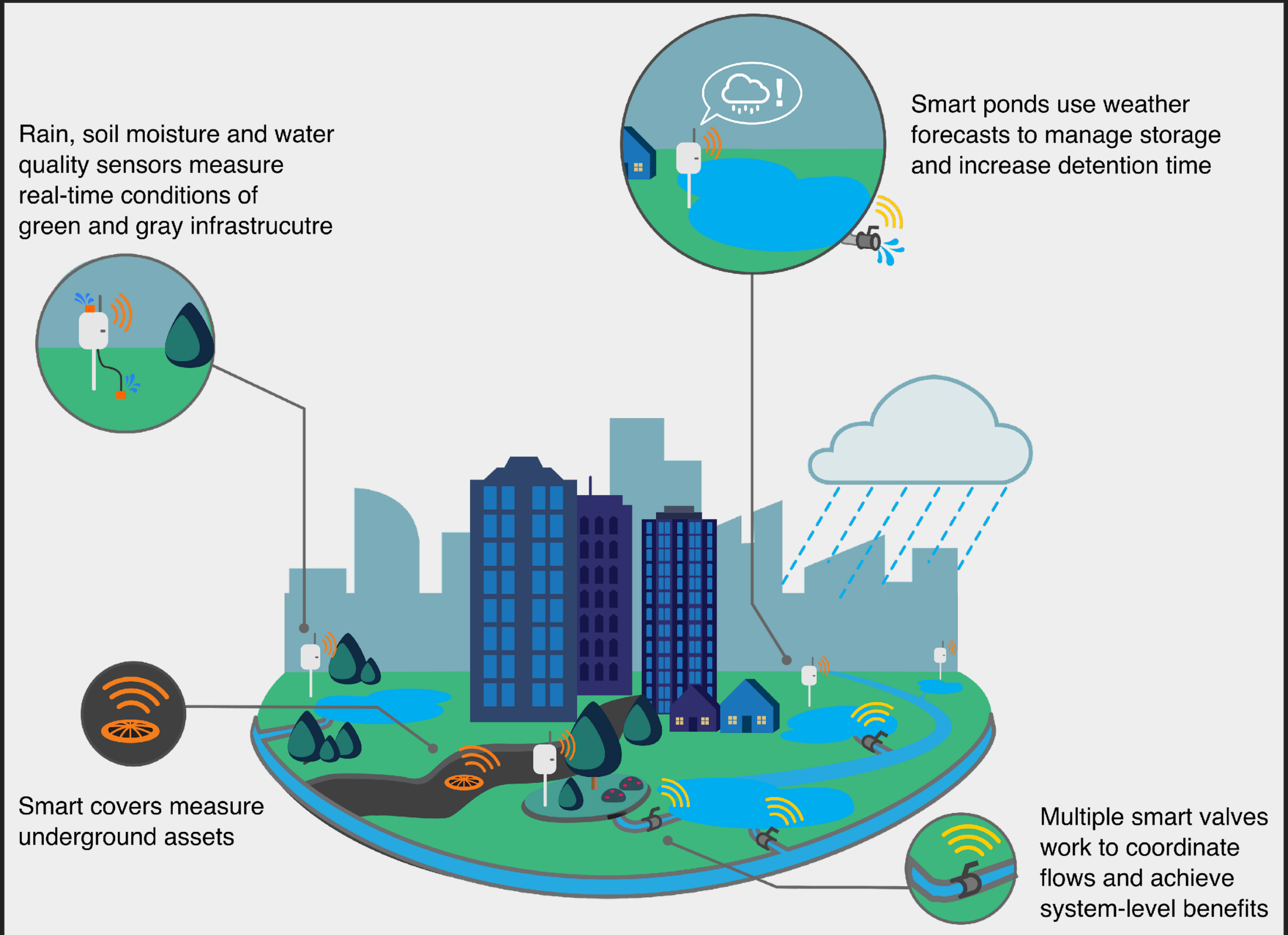
As storms are becoming more frequent and stronger for longer, urban watersheds are being stressed beyond capacity…

Detroit, MI 2014

…current solutions have been costly, large-scale, and *static* interventions.

TARP in Chicago, IL

How can we improve our stormwater systems with technology and methods of today?



(Kerkez et al., ES&T, 2016)

Deployment of distributed control actuators enable potential large-scale system-wide impacts.

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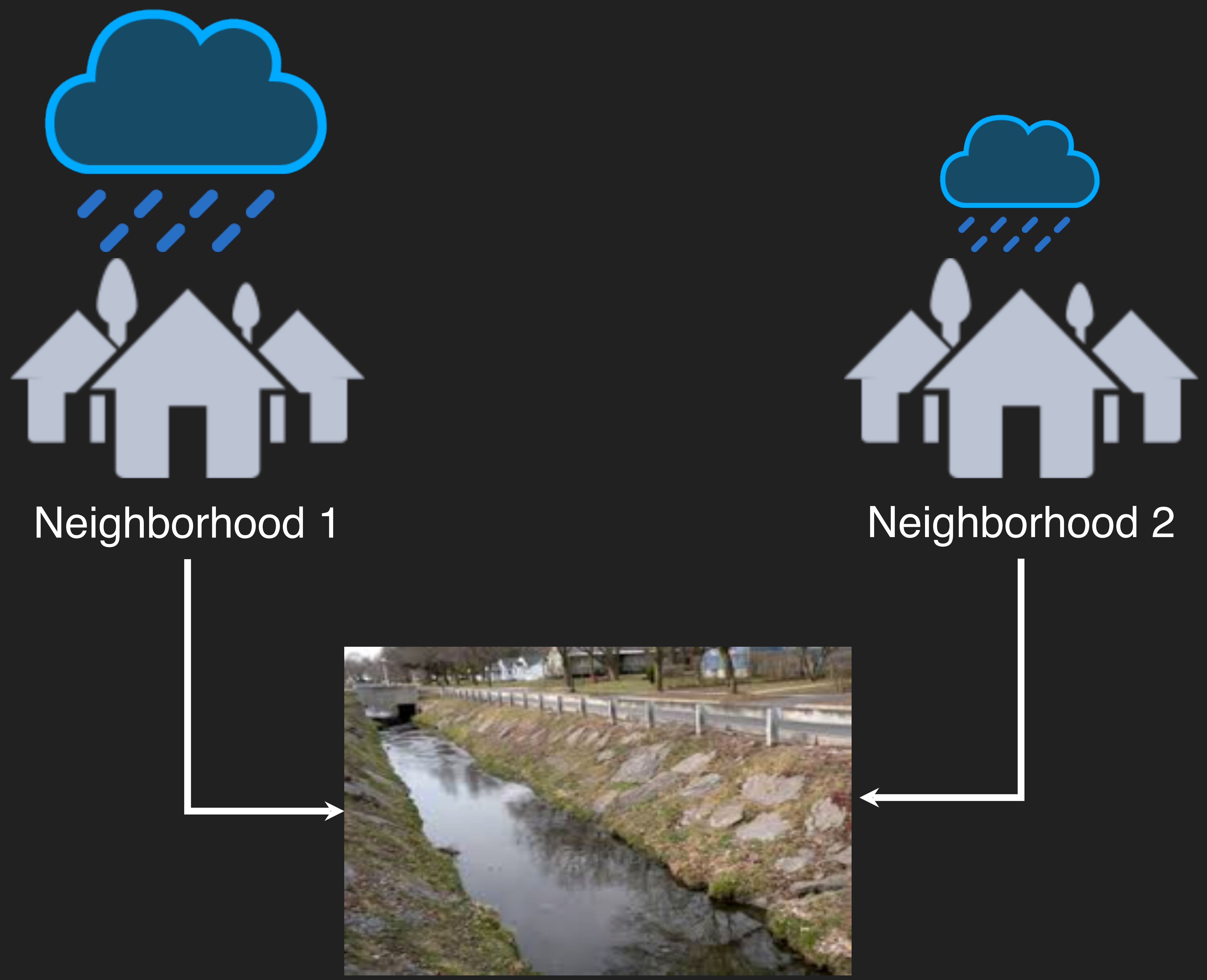

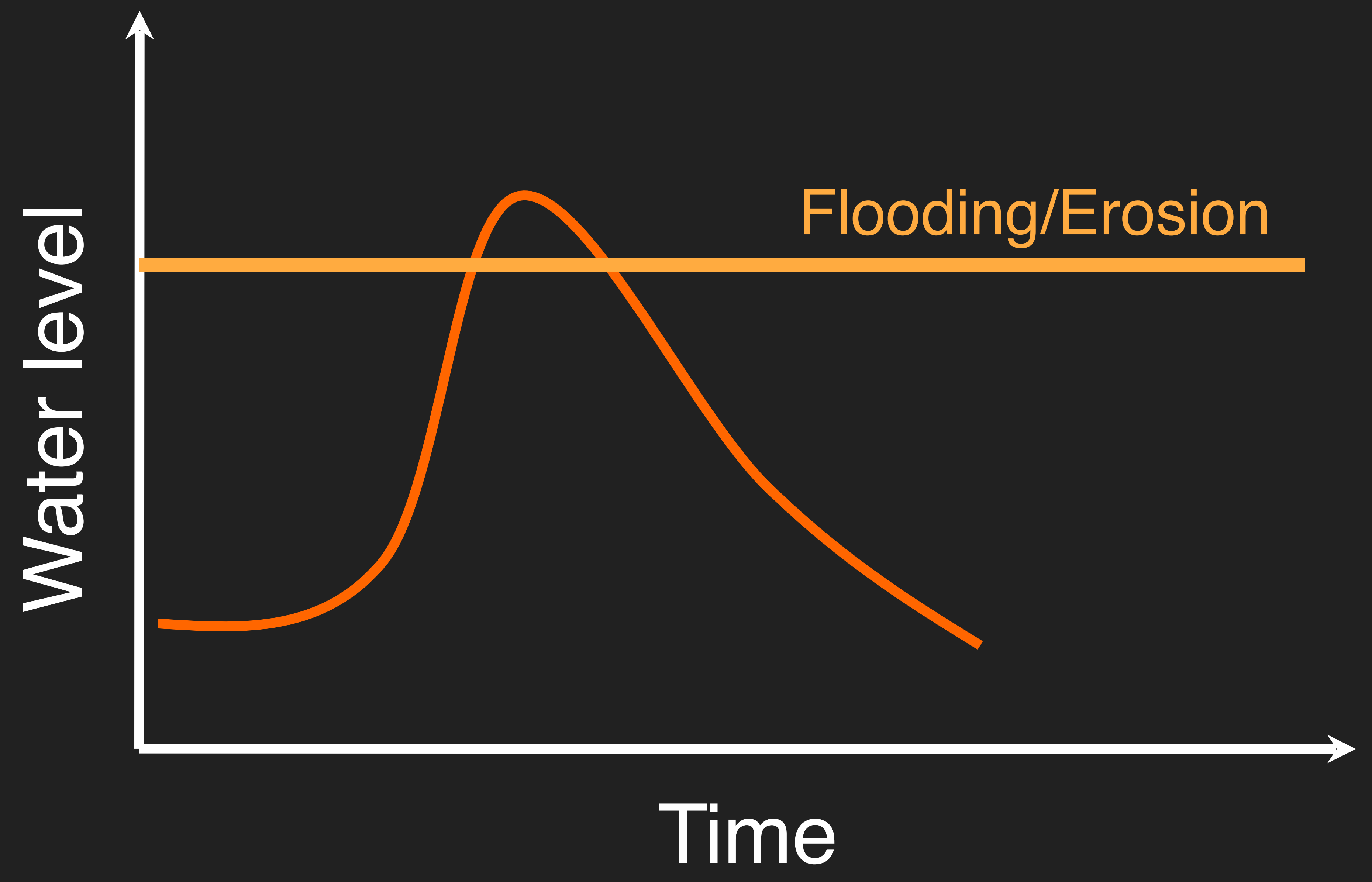

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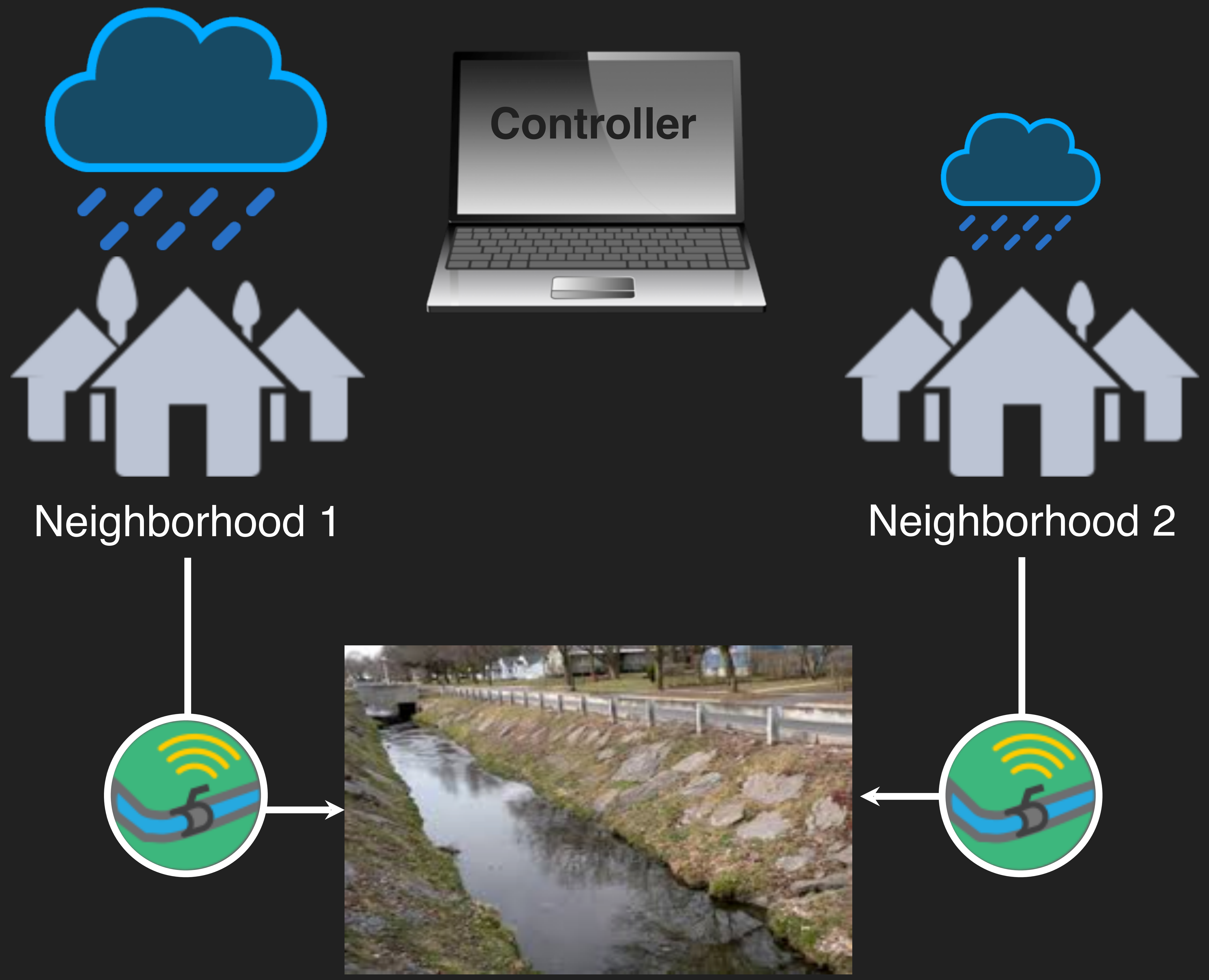
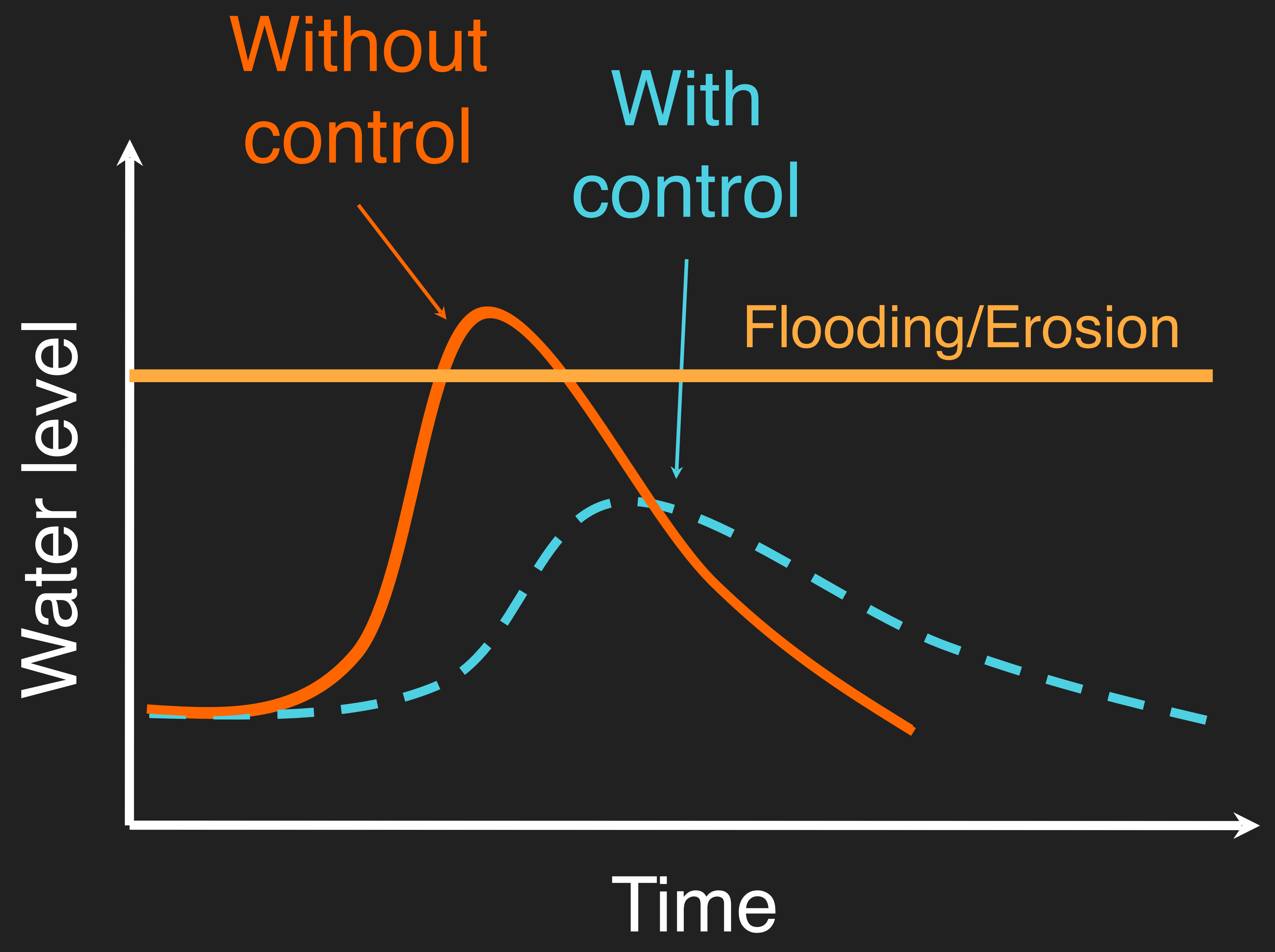
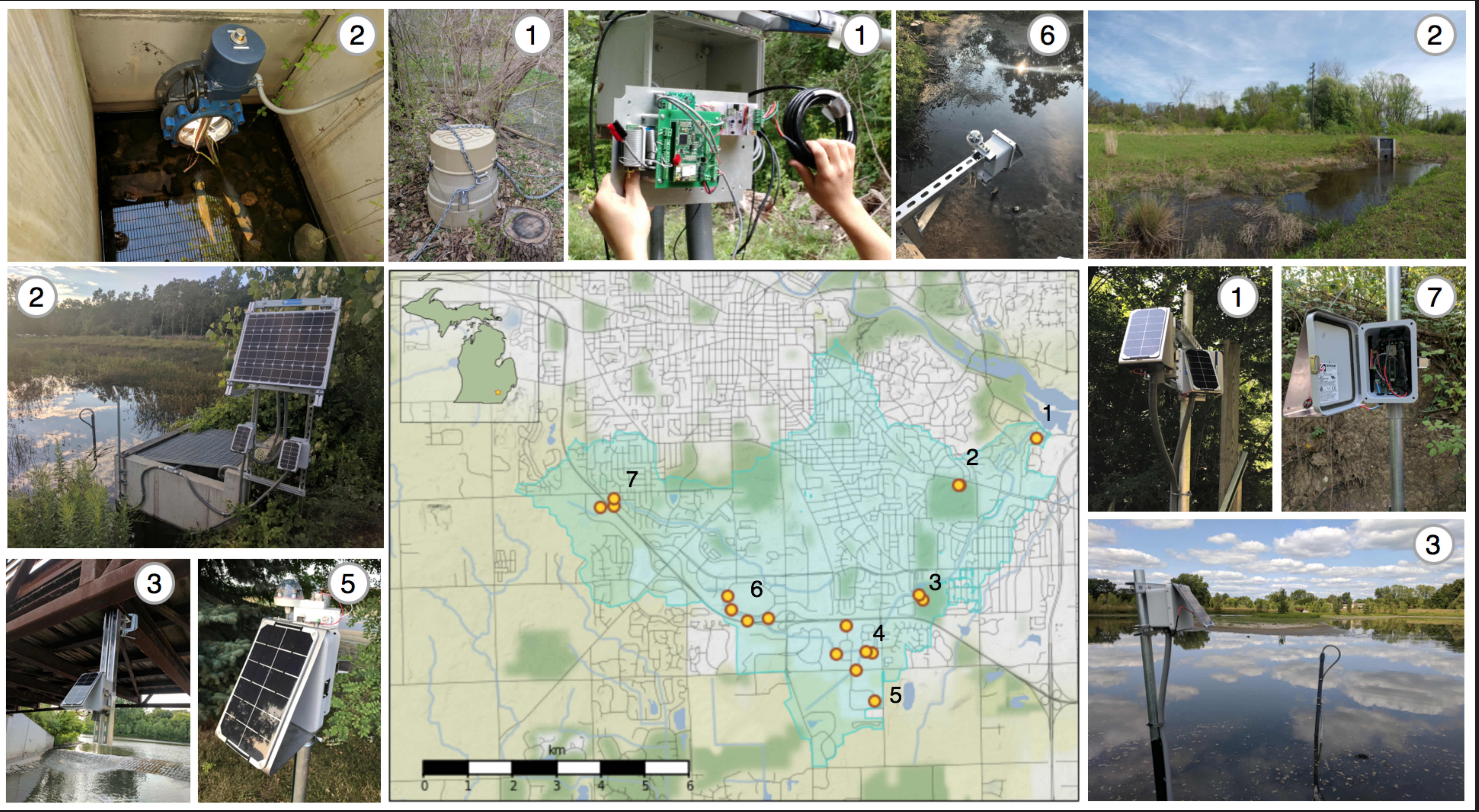




With modular and versatile components, cyber-physical networks can be scaled-up and allow for system-level control.

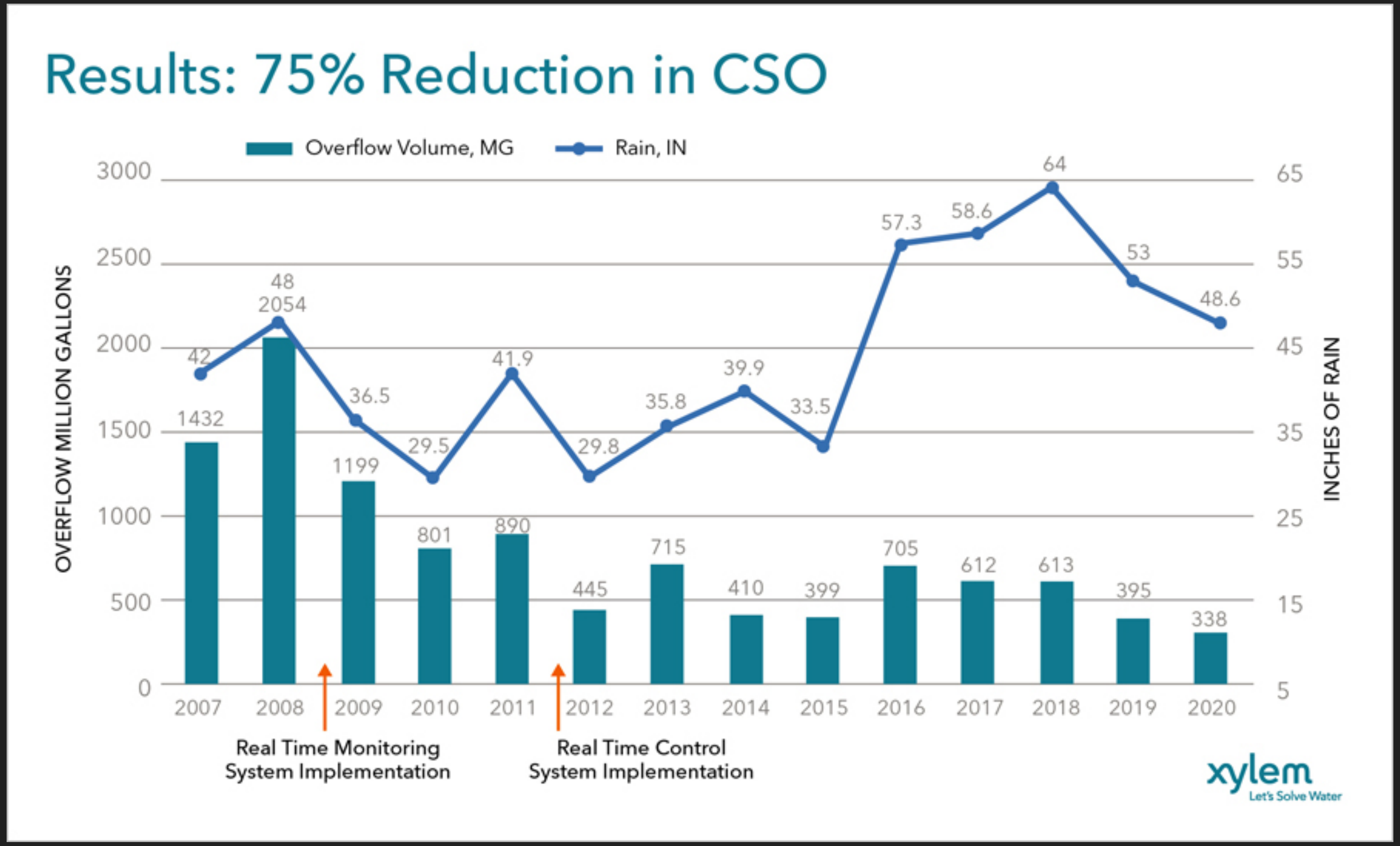


This is actually happening in cities across the world.

City of South Bend, Indiana

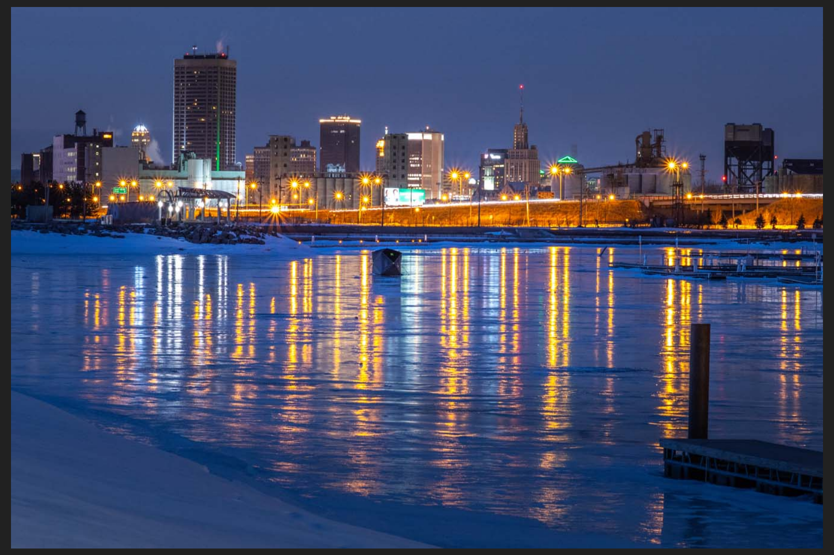
In the combined sewer system:

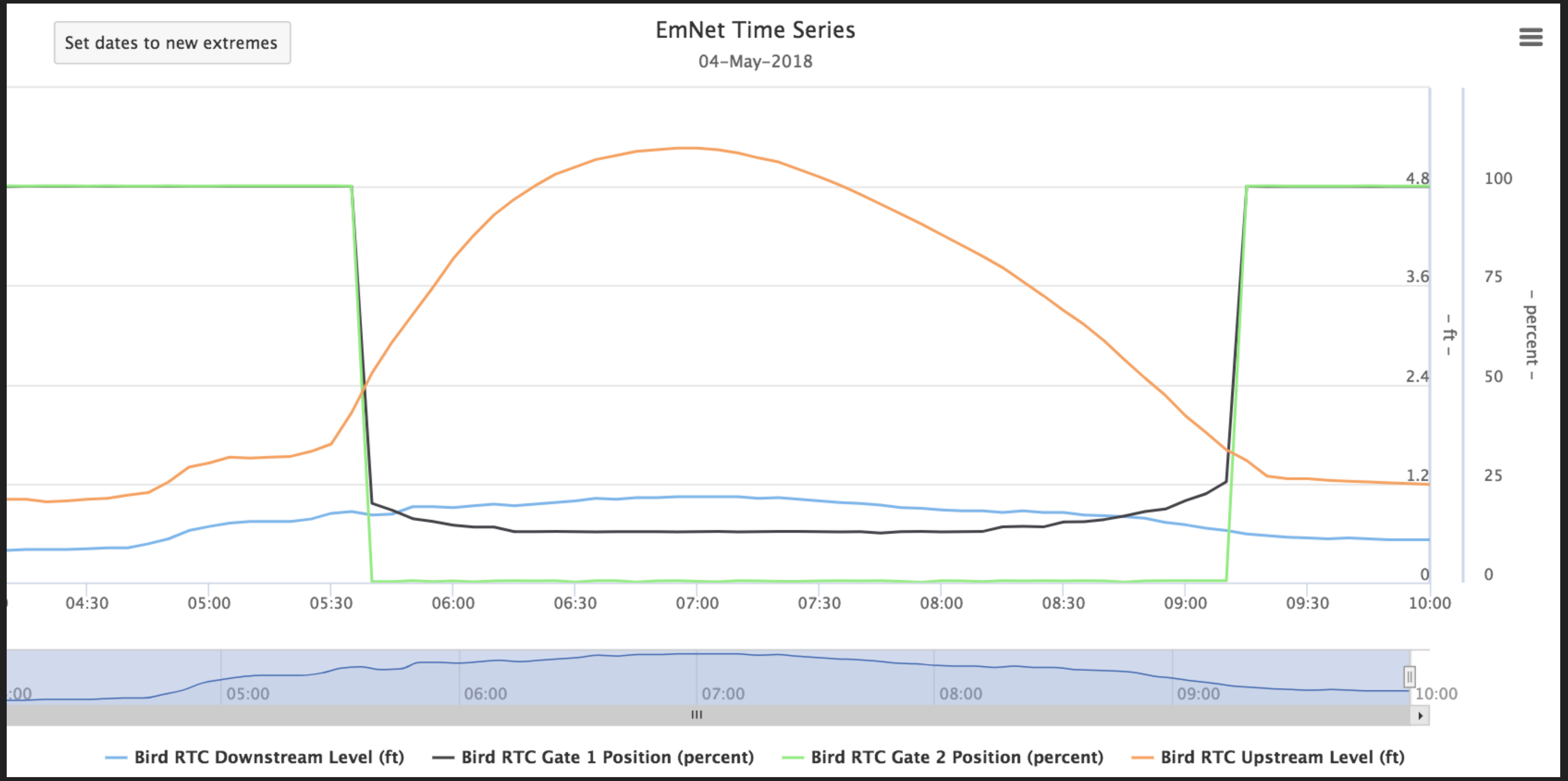
- 165 monitoring sites
- 13 automated gates and valves



Buffalo, New York

Real-time decision support system for combined sewer management.





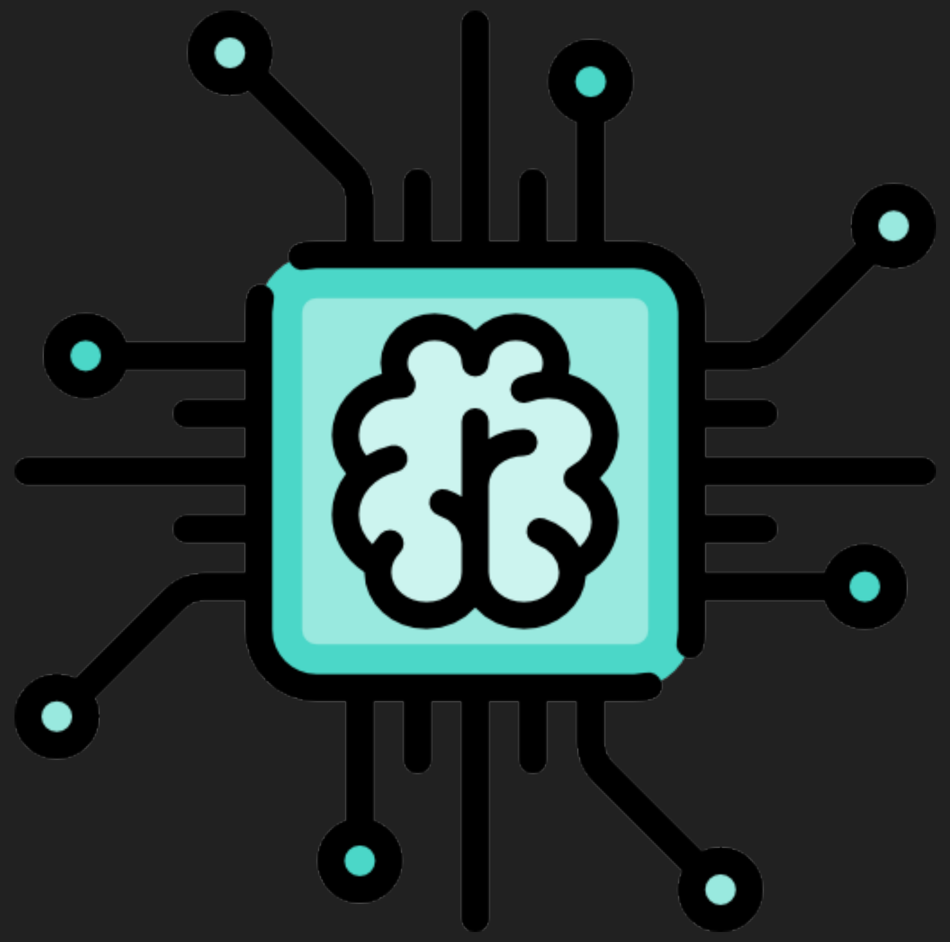
"the first three sites alone have reduced Buffalo's CSO volume by **450 million gallons over the 12 months**"

(Xylem, xylem.com)

System-wide and multi-objective control is being enabled by exploring other domains.

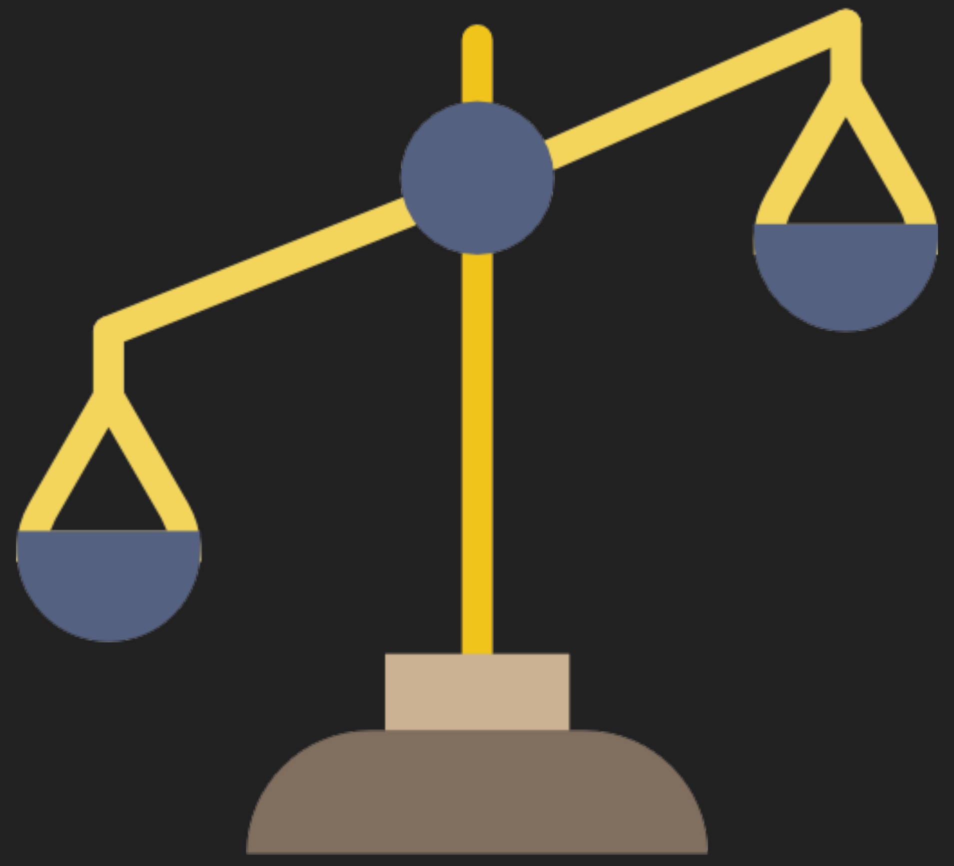
Rule-Based

- If …, else …



Heuristic

- Equal-filling degree
- Reinforcement learning



Optimization

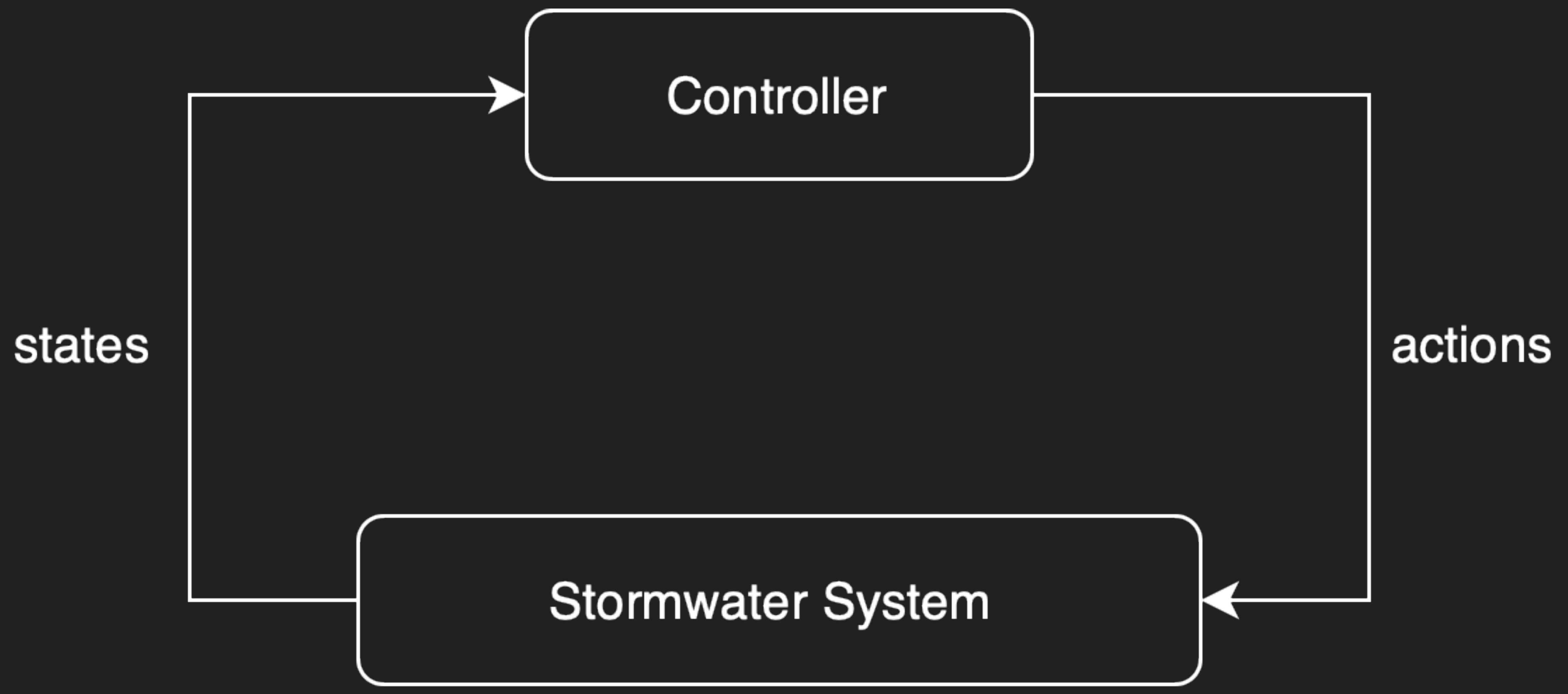
- Genetic algorithms
- Model-predictive control

Stormwater Control Modeling Stack

pyswmm and pystorms

Feedback Control Loop: Stormwater System

$$controller : state_t \rightarrow actions_t$$



$$state_t = \begin{bmatrix} depth_i \\ flows_j \\ rainfall_k \end{bmatrix}$$

$$actions_t = \begin{bmatrix} valve_1 \\ pump_1 \end{bmatrix}$$

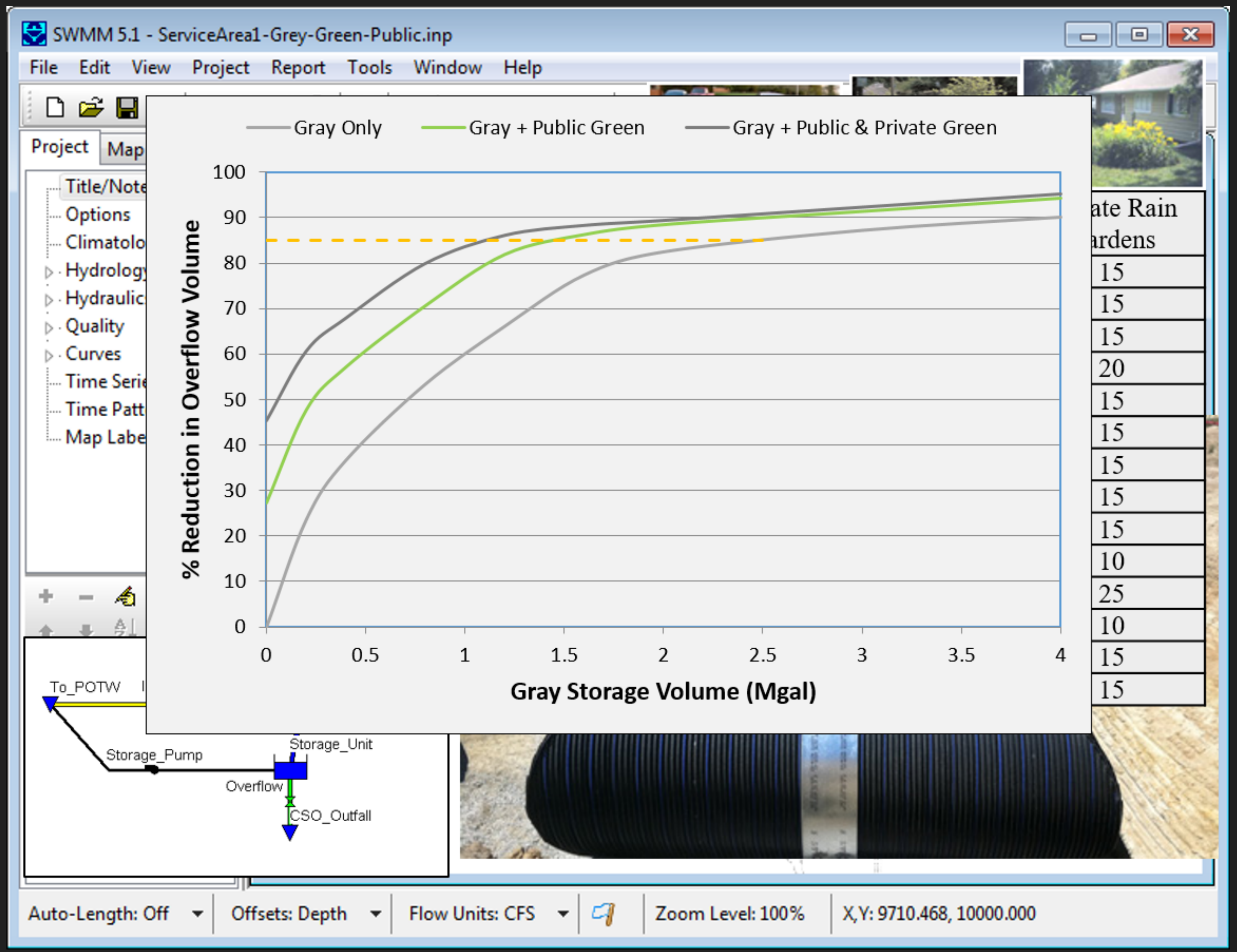
To truly validate the performance of a stormwater control approach we would have to apply it in a physical stormwater system

A dojo for simulating stormwater control

I know a new control algorithm!!!

pyswmm

What is pyswmm? what does it do?



1. pyswmm enables to control EPA-SWMM's simulation using python and run it in an interactive fashion.

2. pyswmm lets us stop the simulation mid-way, query the states, modify valve settings, and progress the simulation.

3. This interactive simulation enables us interface EPA-SWMM with python scientific stack and develop new features like modeling pollutant interactions.

4. The best part about pyswmm is that it is open-source and free to use and modify.

```python
import pyswmm

input_file = "./pyswmm_saves_the_world.inp"

with pyswmm.Simulation(input_file) as sim:
  for step in sim:
    # < your awesome code here >
    pass
```

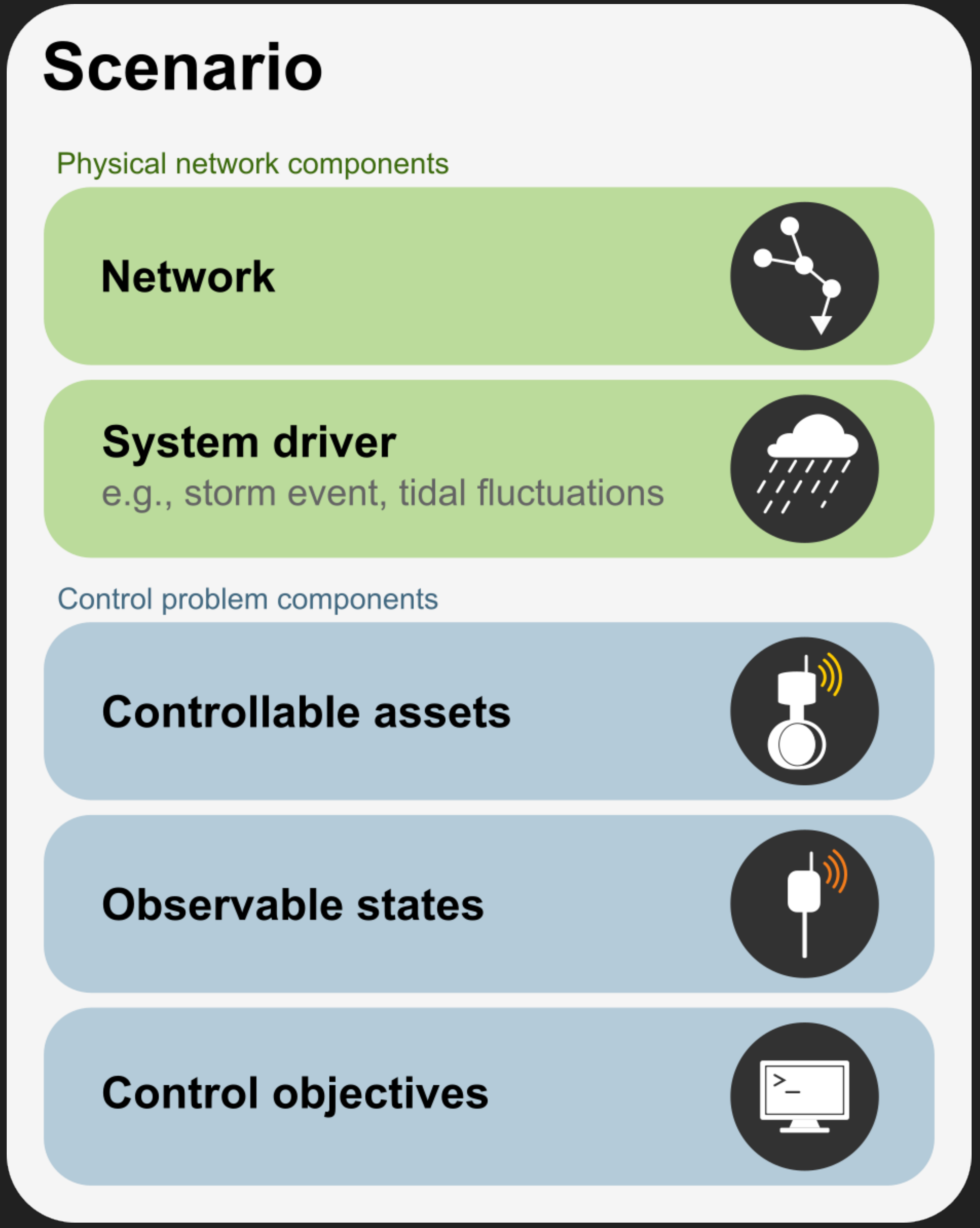
What is pystorms? what does it do?

1. pystorms is a curated collection of stormwater networks coupled with an API for prototyping and evaluating control algorithms.

2. pystorms abstracts the control of stormwater systems as scenarios.

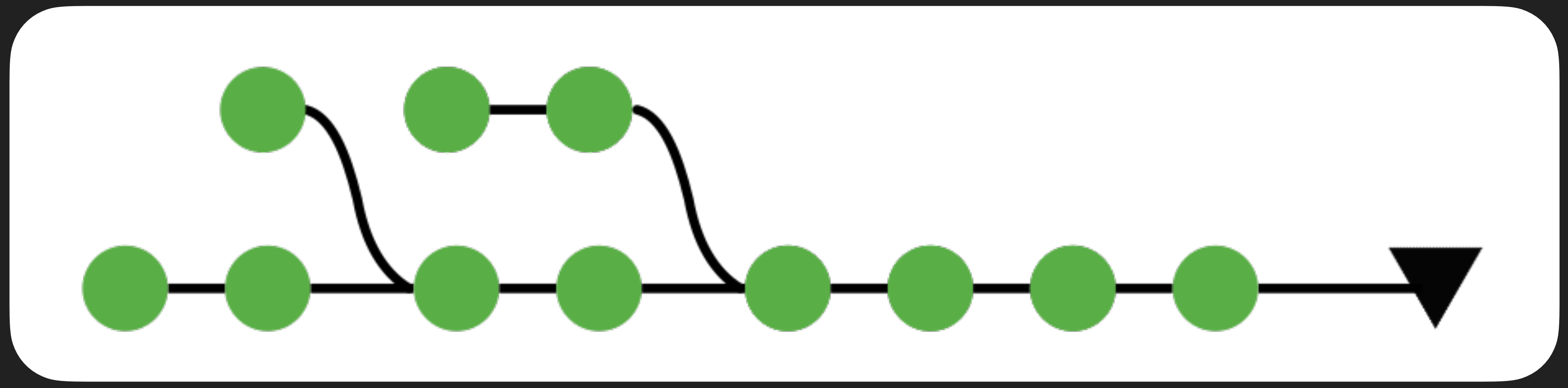
3. pystorms has a diverse set of stormwater control scenarios ranging from a simple two basin system to a real-world inspired combined sewer systems.

4. pystorms uses EPA-SWMM as its simulation engine, but it is designed to be agnostic to the underlying simulation engine.



What is pystorms? what does it do?

Scenario Gamma



25 year 6 hour event

All the 11 basins in the networks

Water levels in 11 basins

Maintain the flows and water levels in the network below a desired threshold.

Scenario

Physical network components

- **Network**
- **System driver**
  e.g., storm event, tidal fluctuations

Control problem components

- **Controllable assets**
- **Observable states**
- **Control objectives**

Future Directions

Increase the accessibility of the stormwater control field.

- With lowered or removed barriers to entry, we can have more individuals and groups contributing and innovating.

Expand the way we evaluate the performance of stormwater control.

- Multi-objective (e.g., flooding, water quality)
- Event-based performance vs. real-time tracking of performance

Better understand and consider the social impacts of stormwater management and control.

- Is the placement of stormwater management assets, and the risks they pose, equitable across communities?

Great Lakes Protection Fund

NSF

U.S. DEPARTMENT OF ENERGY

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UNIVERSITY OF MICHIGAN

THE UNIVERSITY OF TENNESSEE KNOXVILLE

UNIVERSITY of VIRGINIA

pystorms.org