Open-Storm Detroit Dynamics

Utility-University Team

GLWA Great Lakes Water Authority

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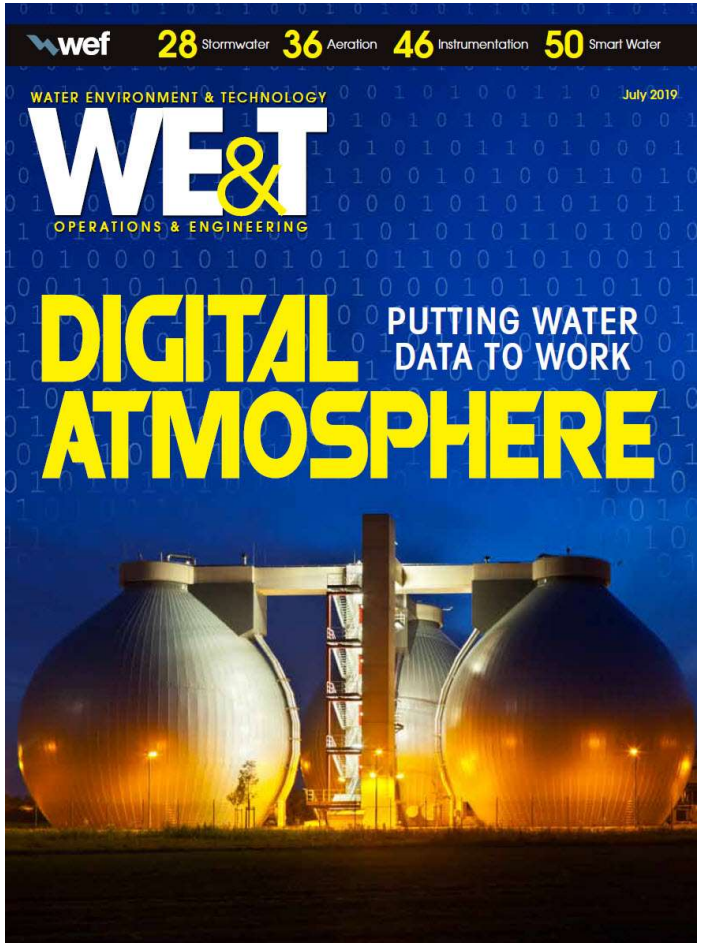
M ENGINEERING

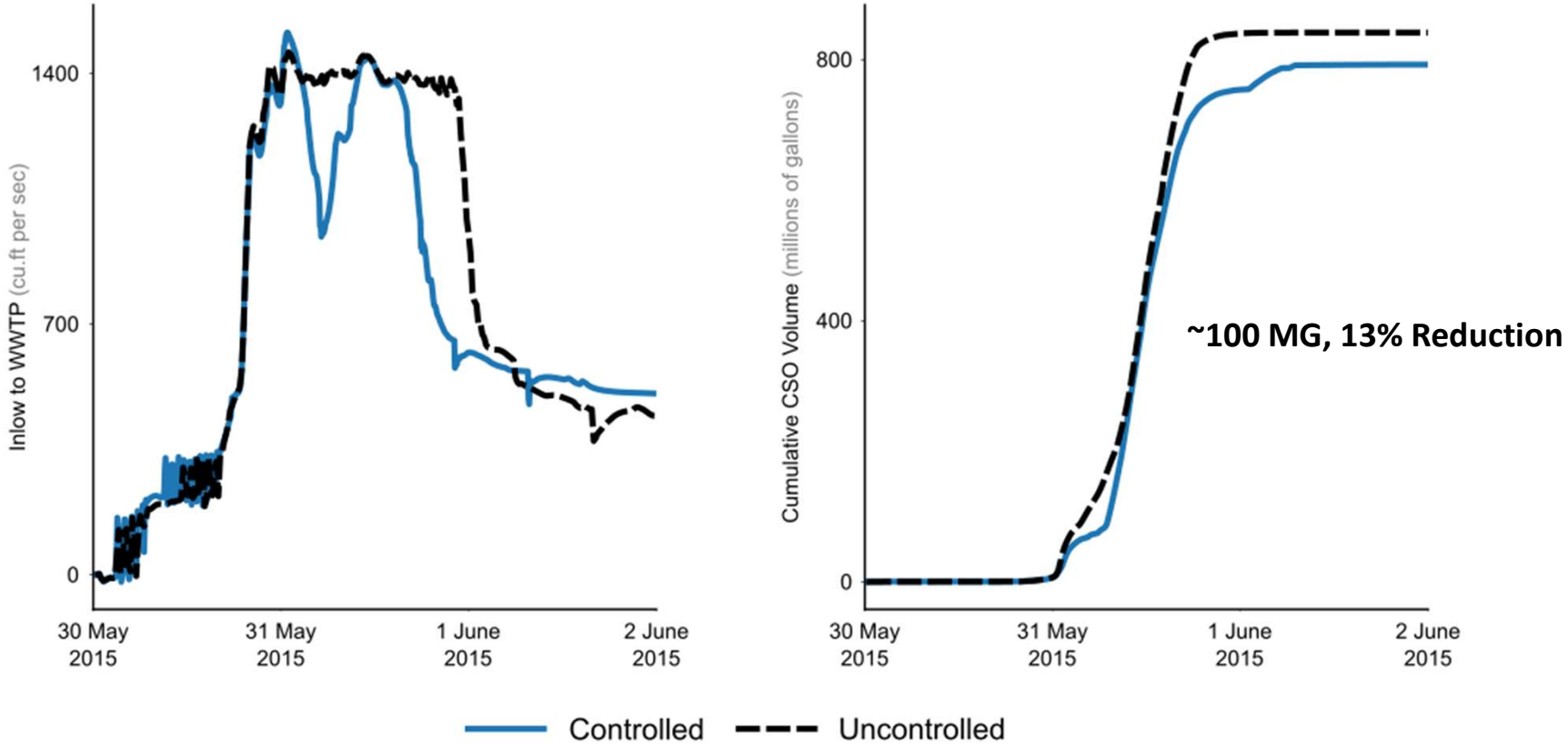
All Information Presented Is Available Online

www.tinyurl.com/OSDetroit

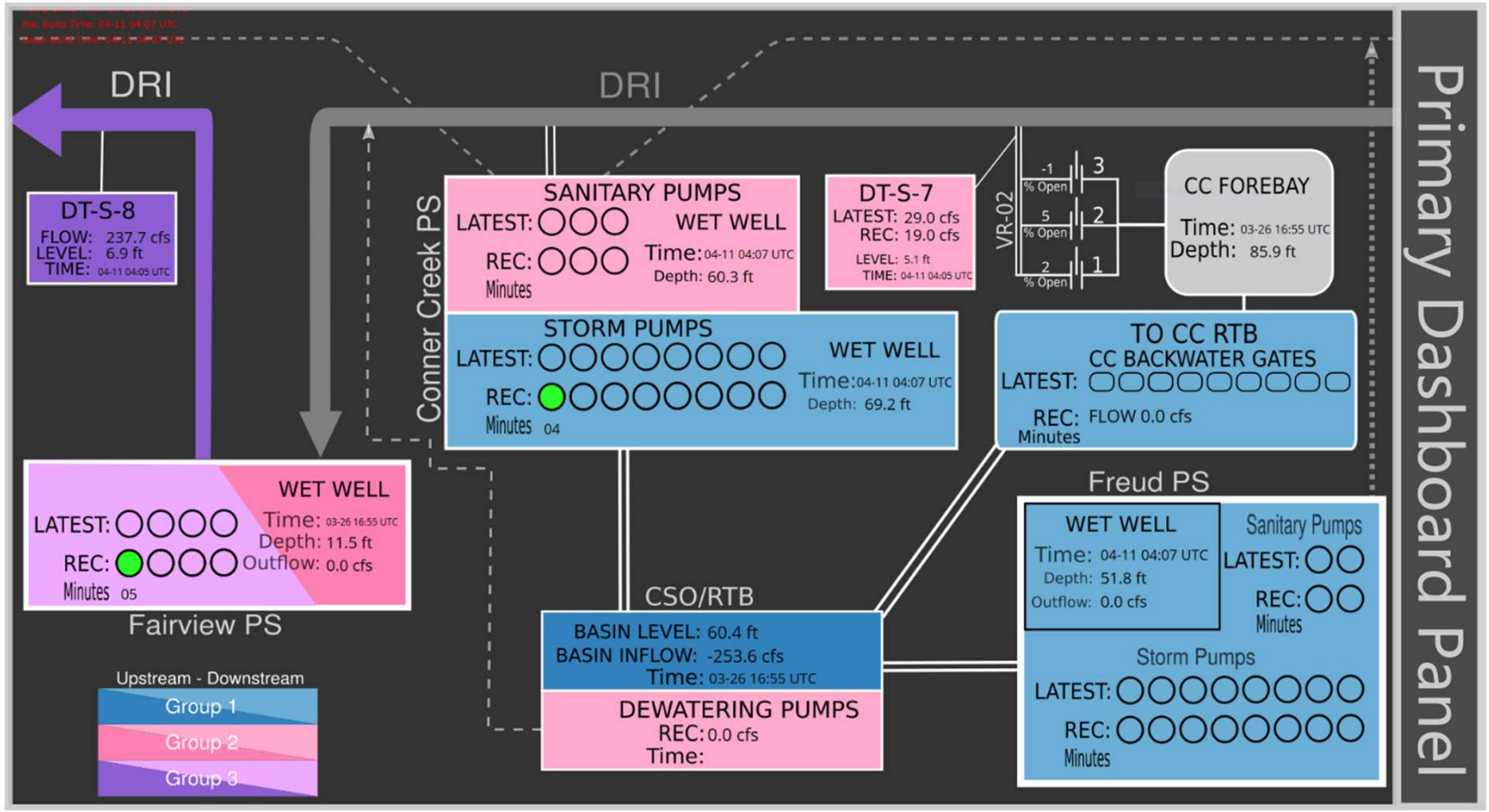
Look for our Article in the July WE&T Issue



Real-time control algorithm study demonstrates potential to reduce CSOs



From Results, Recommendation Dashboard



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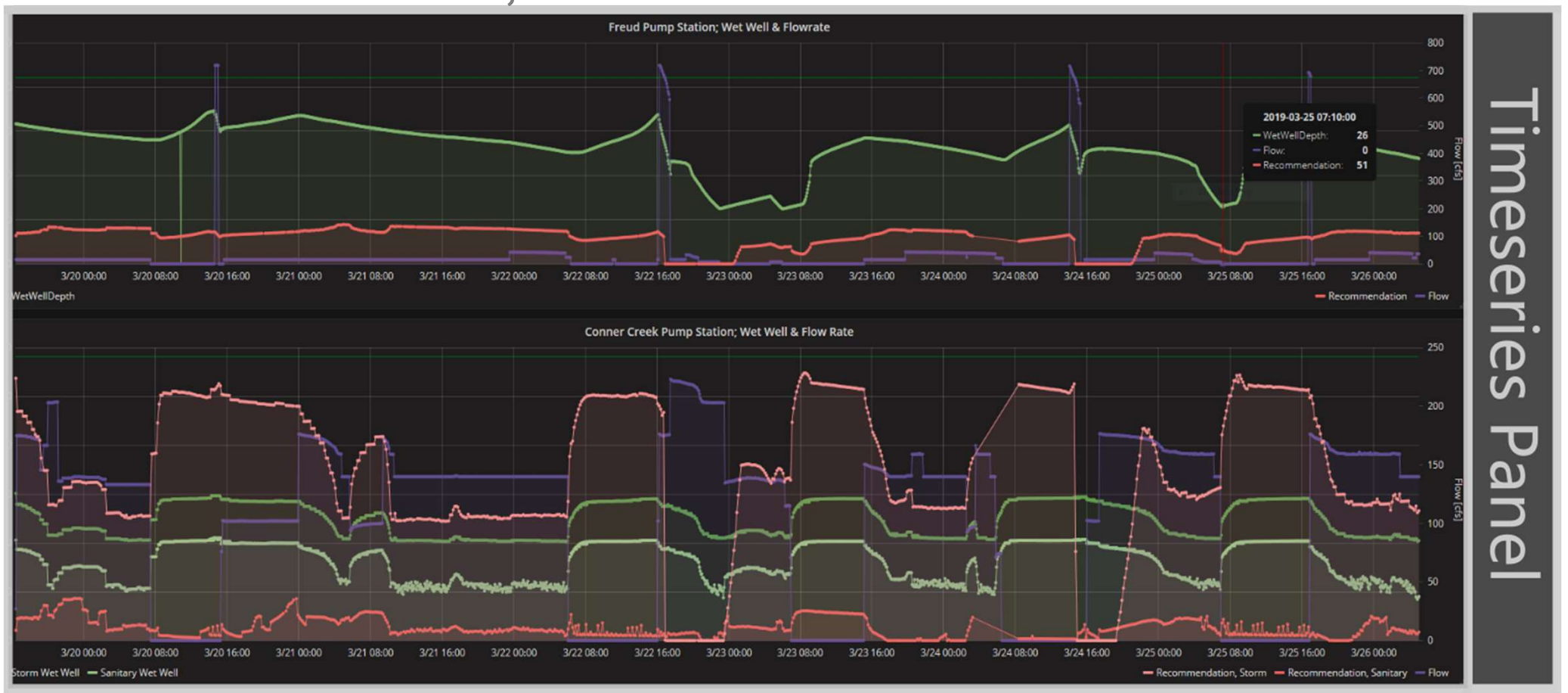


Emphasize the process

- Model for other University-Utility partnerships
- Project Plan
- ‘How to’ guide

GLWA formalizes university partnerships

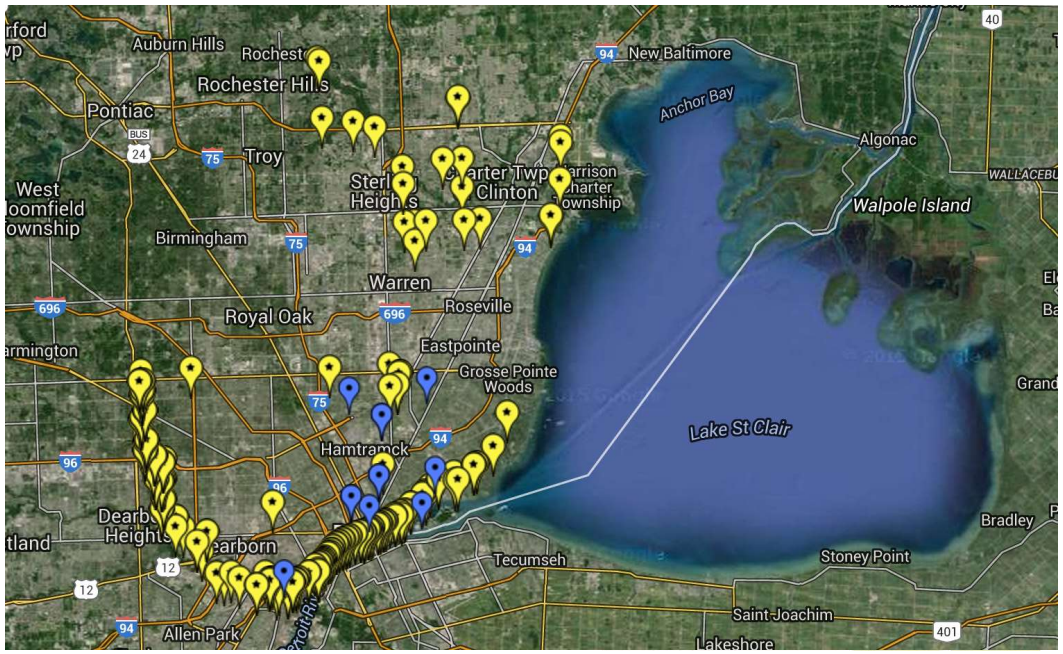
Build on existing informal relationship with universities to create formal, directed and long-term partnerships to conduct research that is mutually beneficial.

GLWA
Great Lakes Water Authority

The Problem


Image NOAA
Image Landsat / Copernicus
Google Earth

The Opportunity



100+ Sensors

20+ Control Points

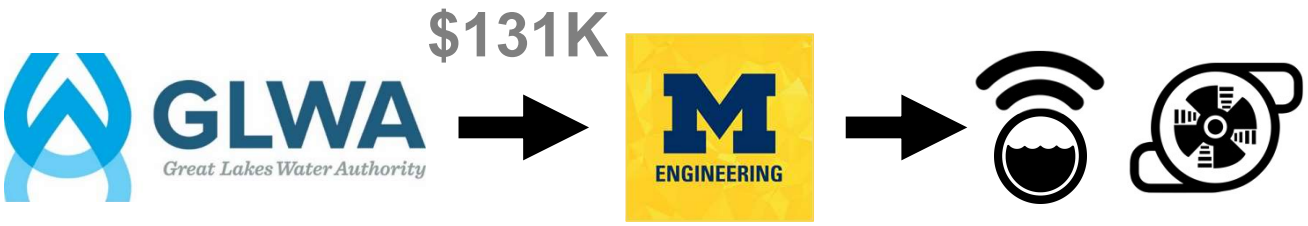
Project Principles

Nov 2017 – Nov 2018

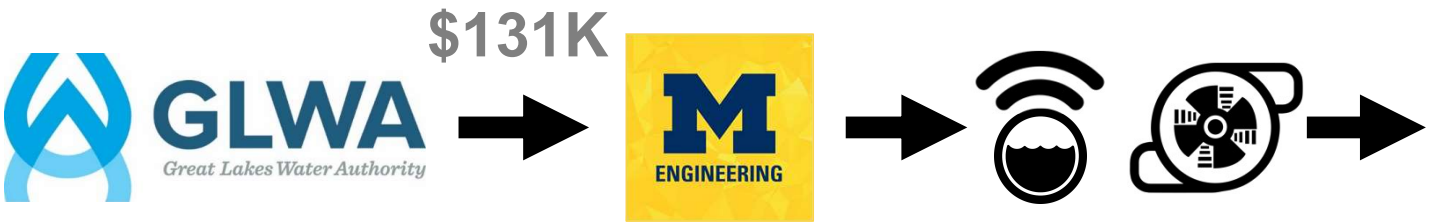
GLWA
Great Lakes Water Authority

Project Principles

Project Principles



Project Principles



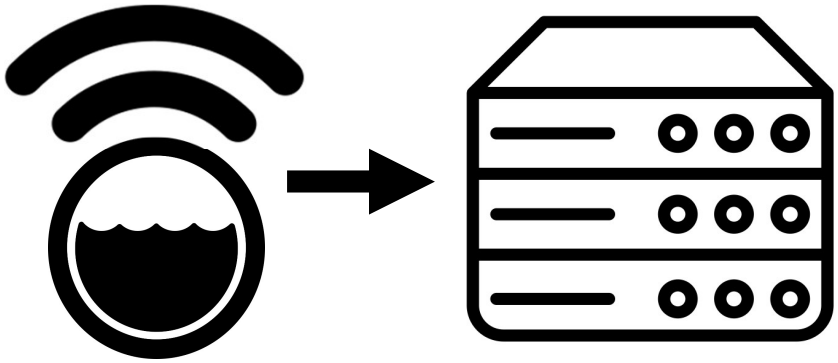
Outcomes & Considerations

1. No New Construction
2. Maximize Storage
3. Reduce CSOs
4. Equalize Flows

Existing SCADA Workflow

Sensors

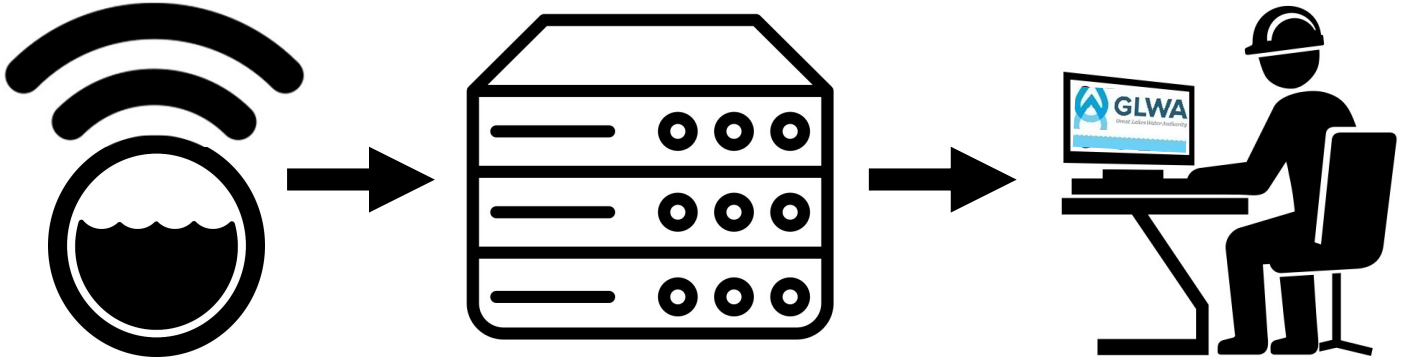
Existing SCADA Workflow



Sensors

Utility
Server

Existing SCADA Workflow

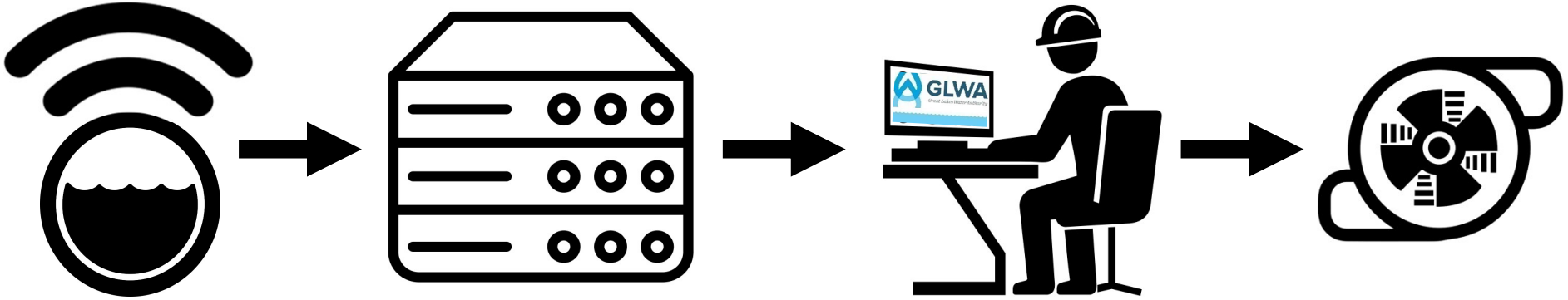


Sensors

Utility Server

Raw Data Feeds

Existing SCADA Workflow



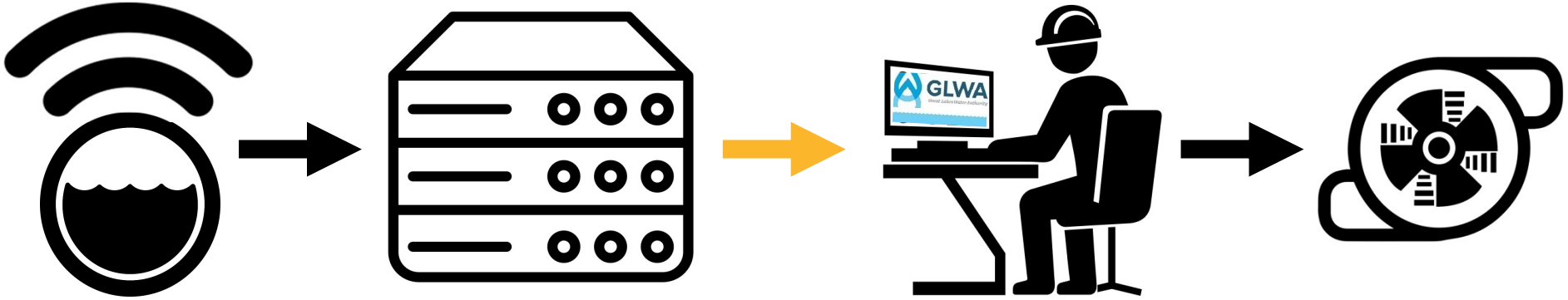
Sensors

Utility Server

Raw Data Feeds

Pumps Valves

Existing SCADA Workflow



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Utility Server

Raw Data Feeds

Pumps Valves

Analytics and Control Layer Opportunity

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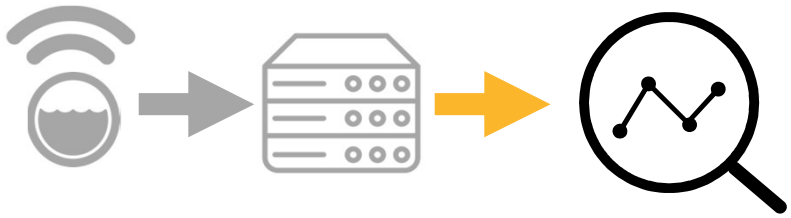
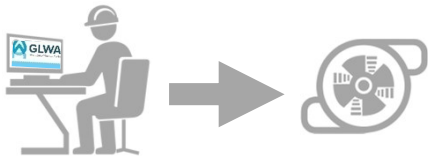
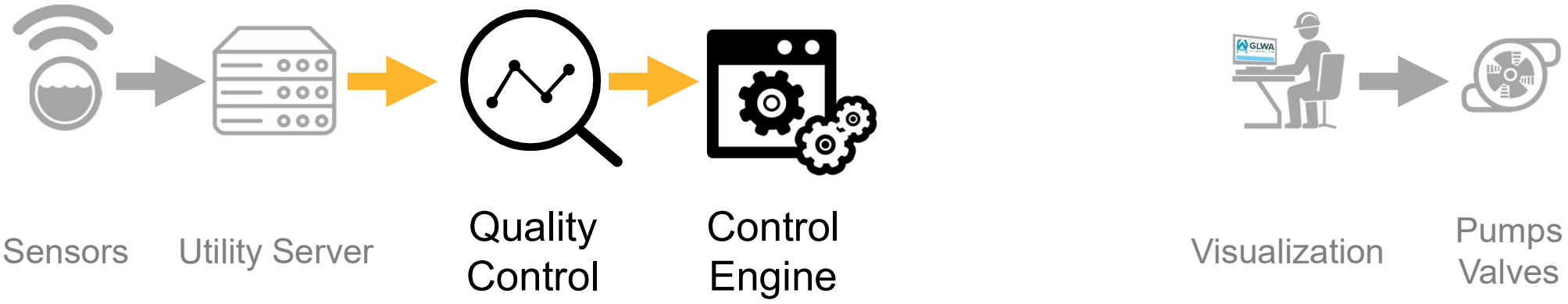


Sensors Utility Server Quality Control



Visualization Pumps Valves

Analytics and Control Layer Opportunity



Analytics and Control Layer Opportunity

Sensors

Utility Server

Quality Control

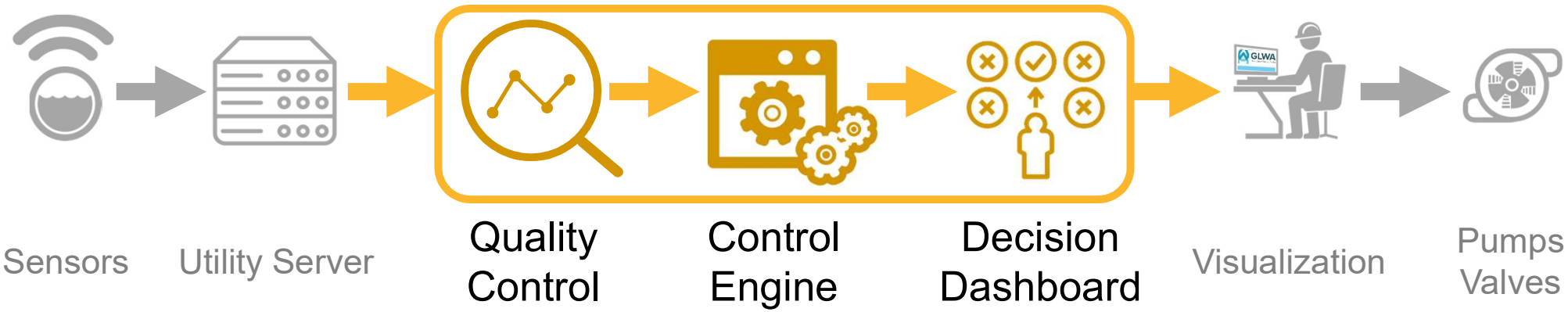
Control Engine

Decision Dashboard

Visualization

Pumps Valves

Analytics and Control Layer Opportunity



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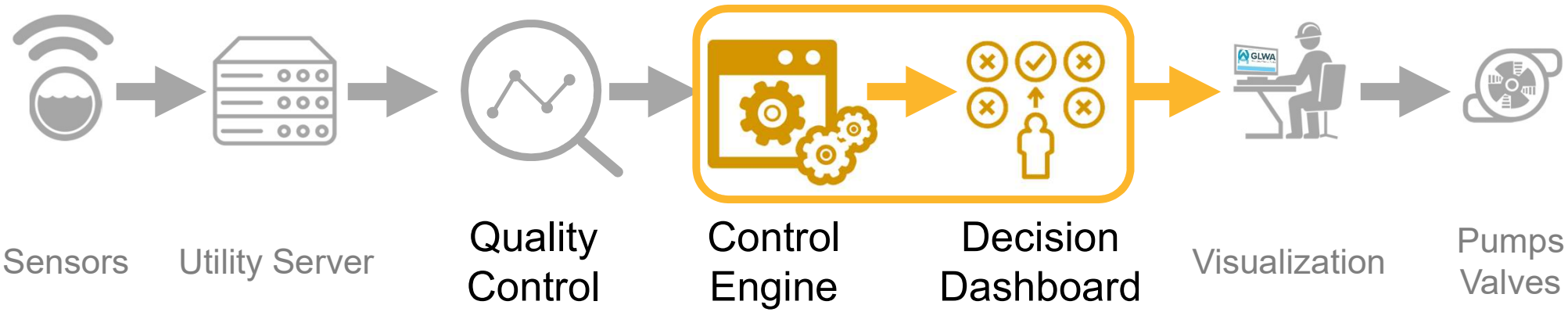

Approach has three stages

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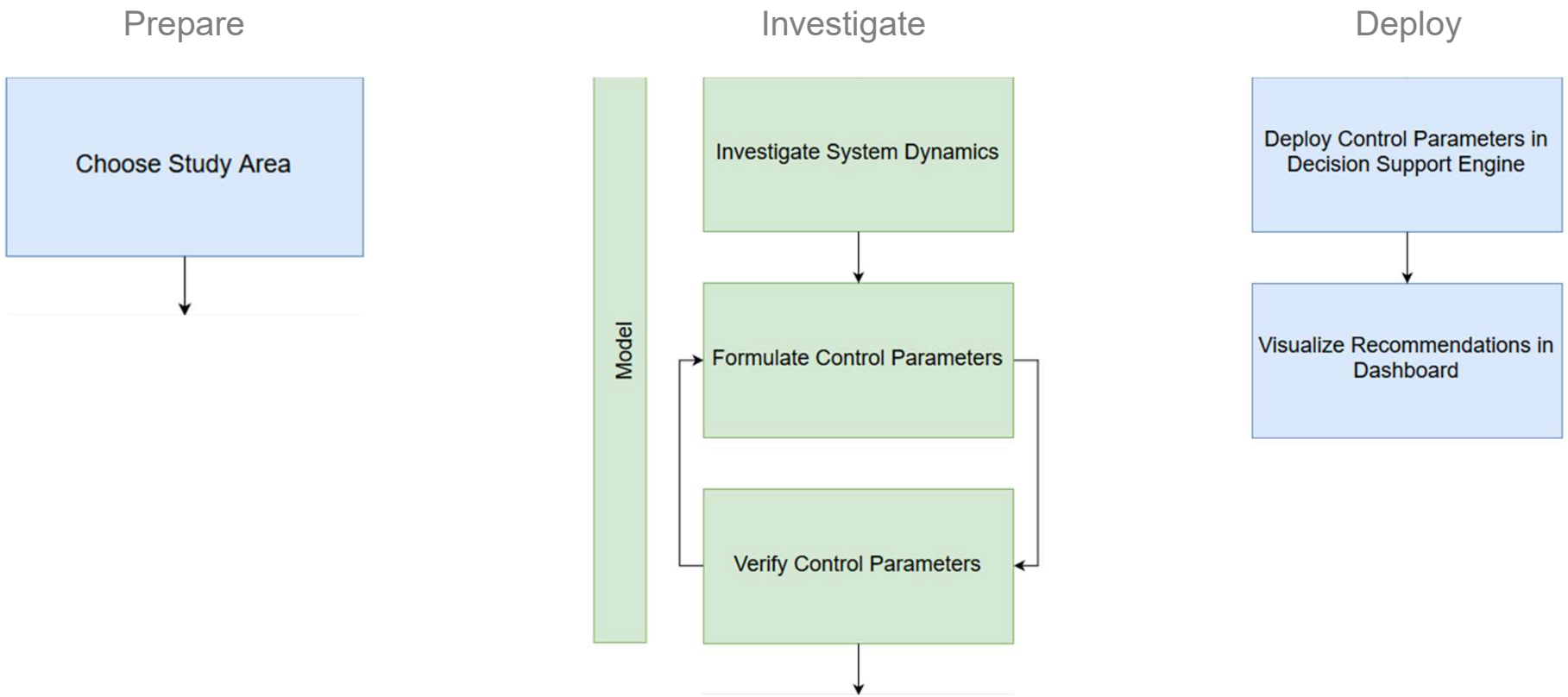
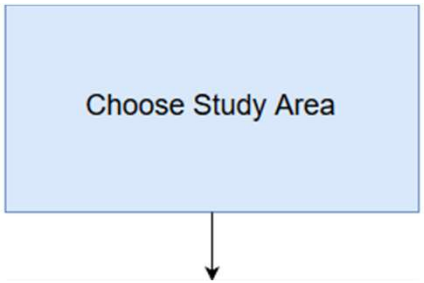


Prepare: Choose Study Area

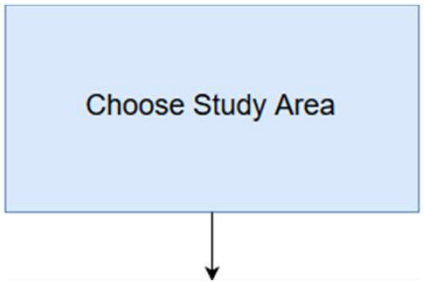


Consider:

- Storage assessment
- Network topology
- Sensor Locations
- History of CSO
- Model (SWMM)
- Control capabilities

Relied on GLWA operations team

Prepare: Choose Study Area



Consider:

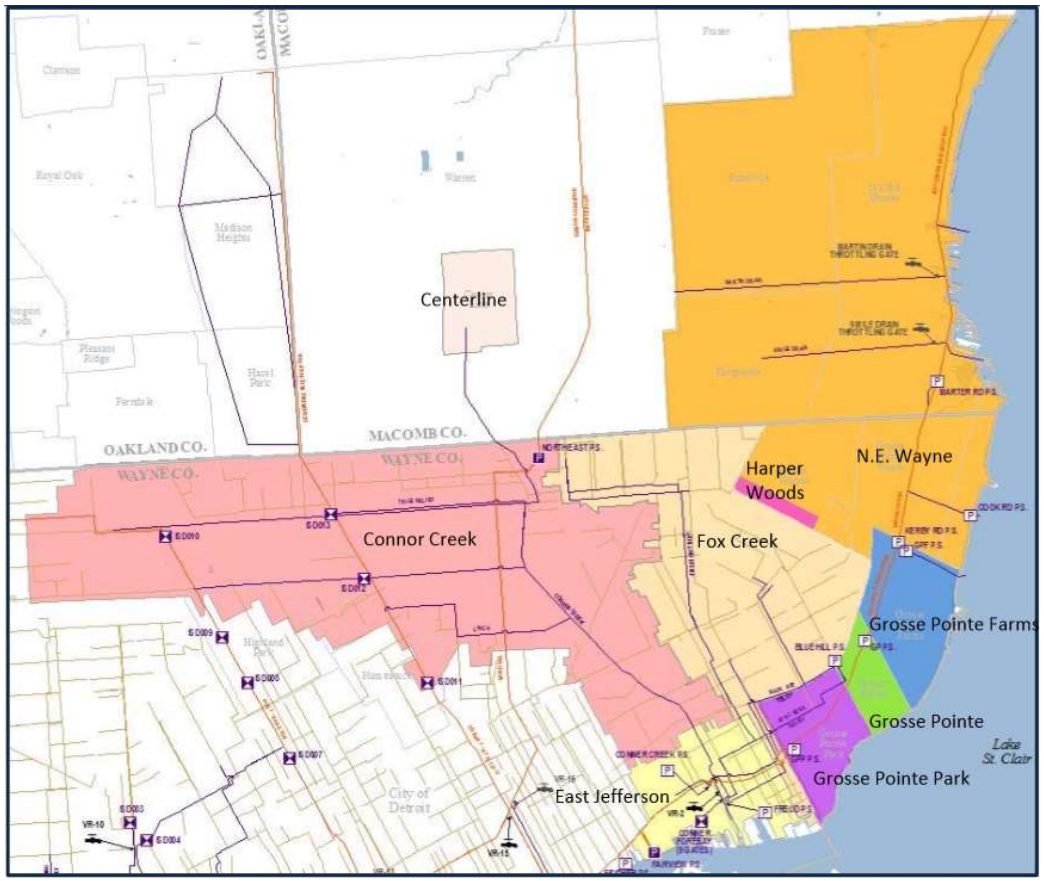
- Storage assessment
- Network topology
- Sensor Locations
- History of CSO
- Model (SWMM)
- Control capabilities

Relied on GLWA operations team

Result: Eastside of System

- Multiple Storage Elements
- Identifiable Subnetwork
- Numerous sensored assets
- Discharges common
- SWMM available
- Centralized Control

Prepare: Choose Study Area



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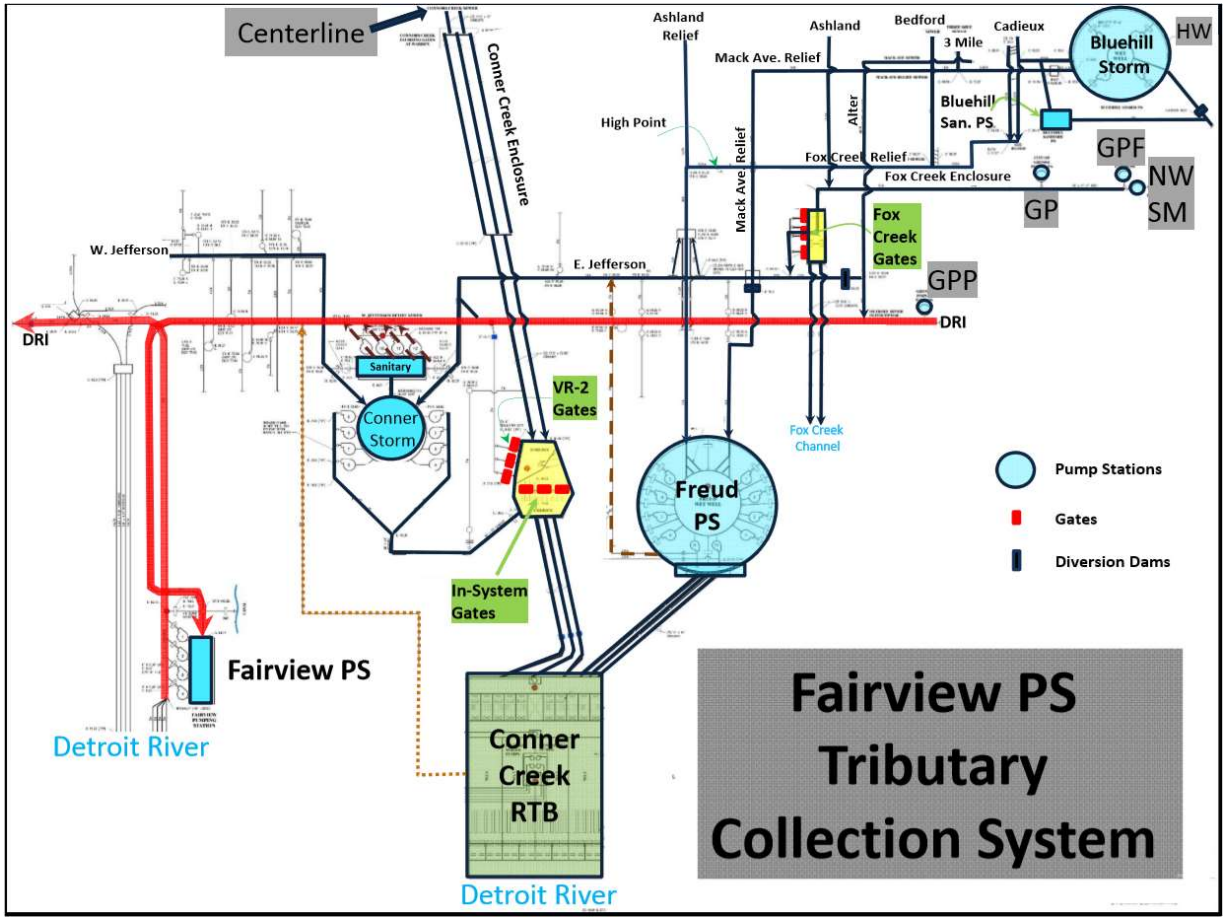

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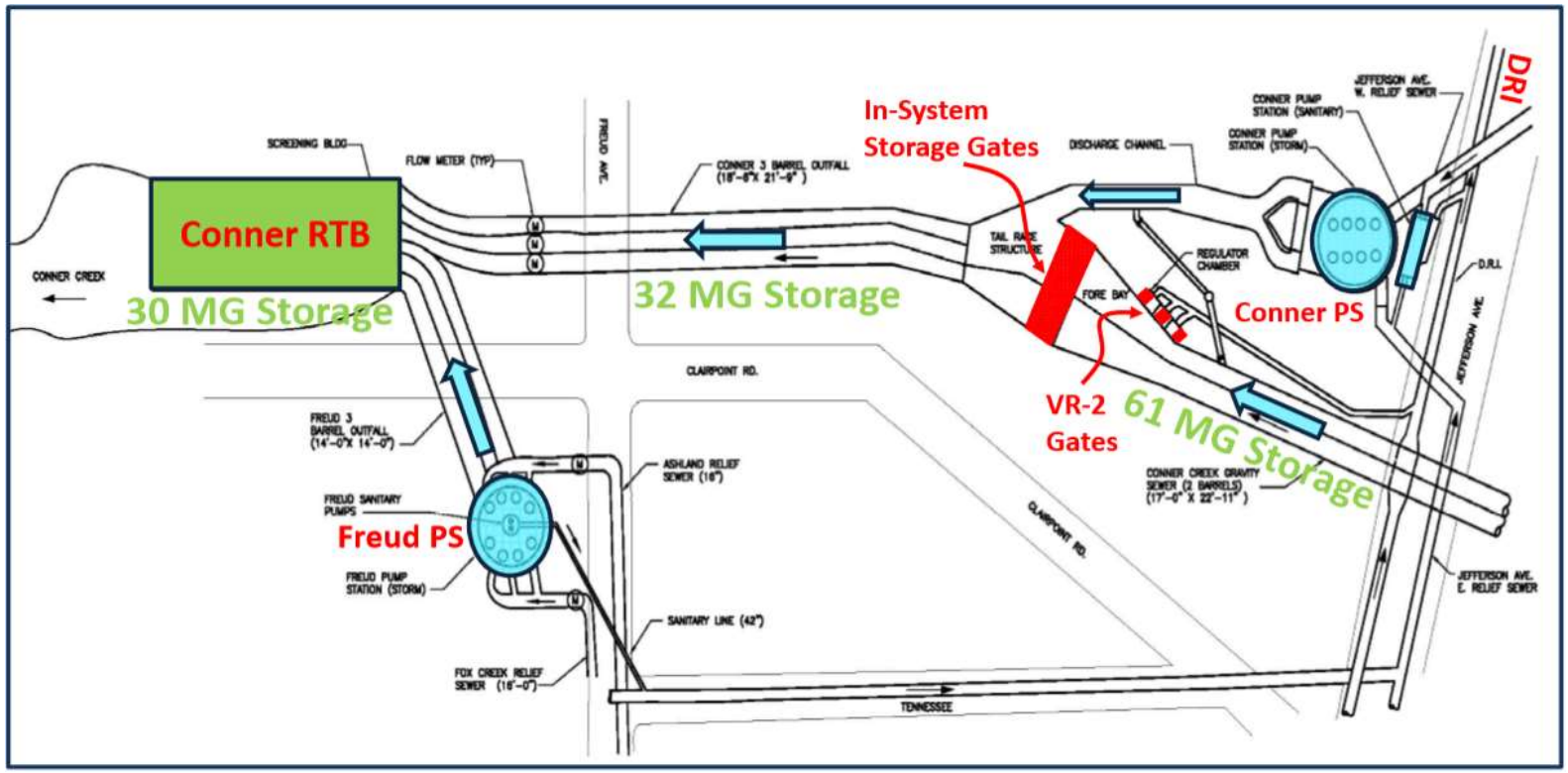

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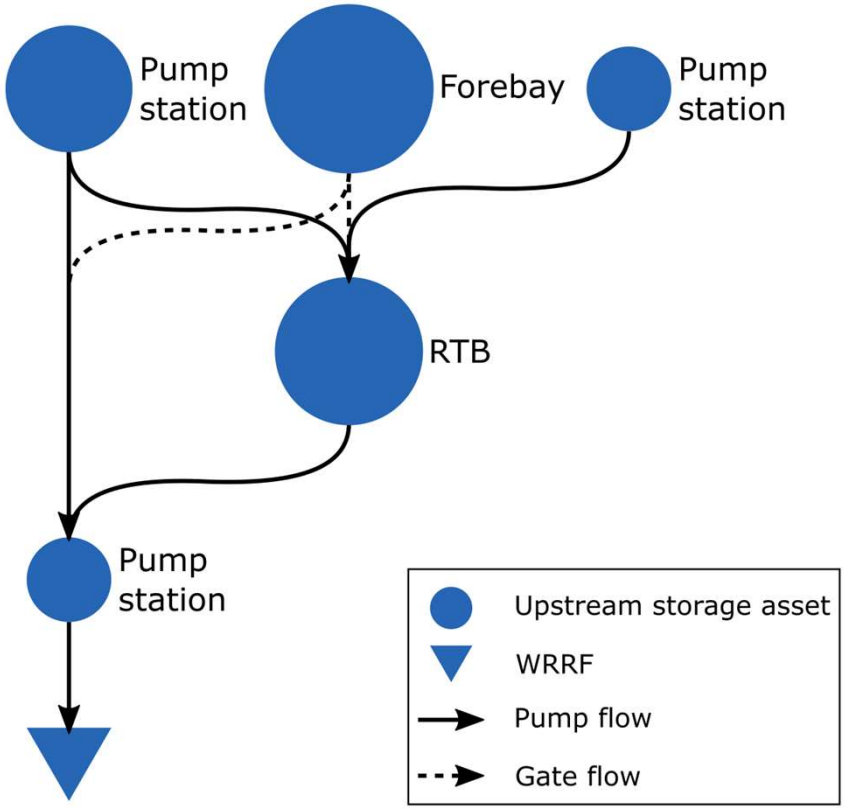

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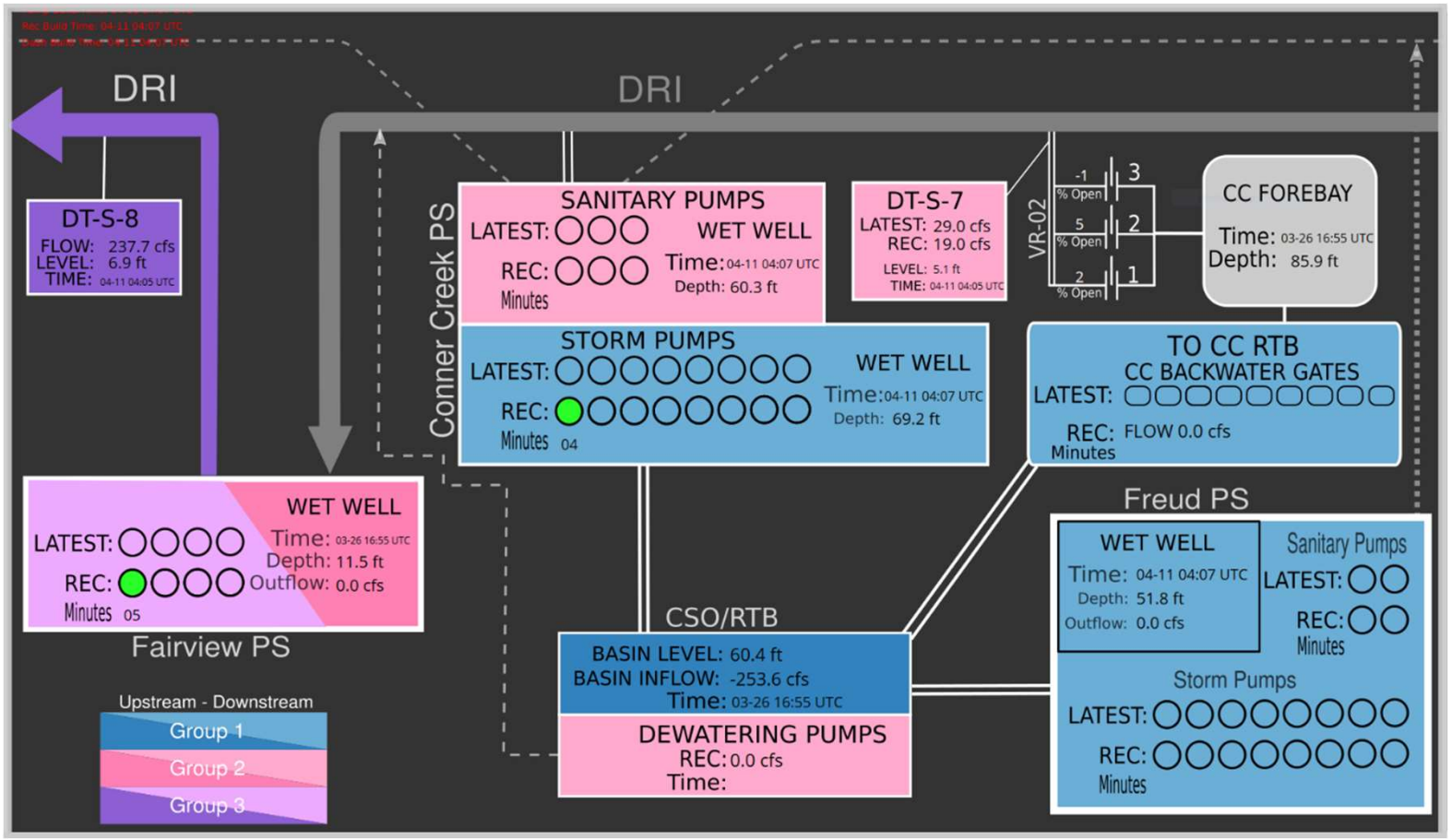

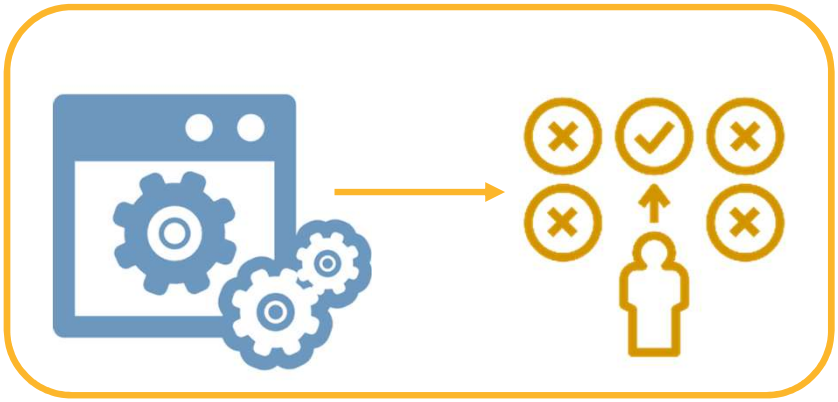

Investigate study area in model space

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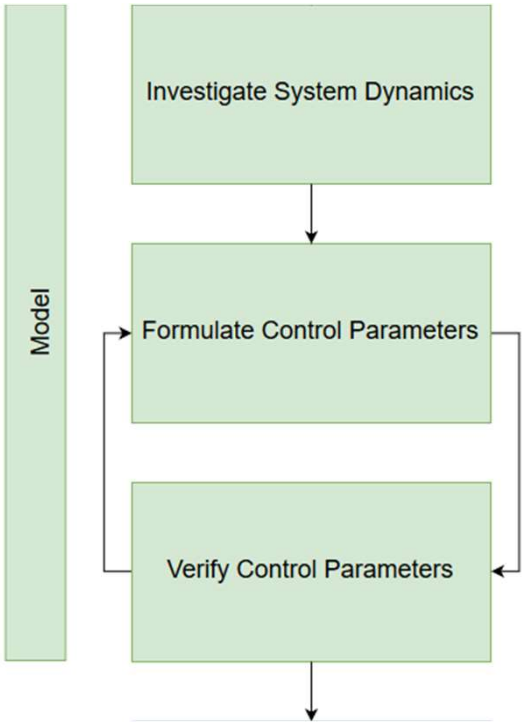

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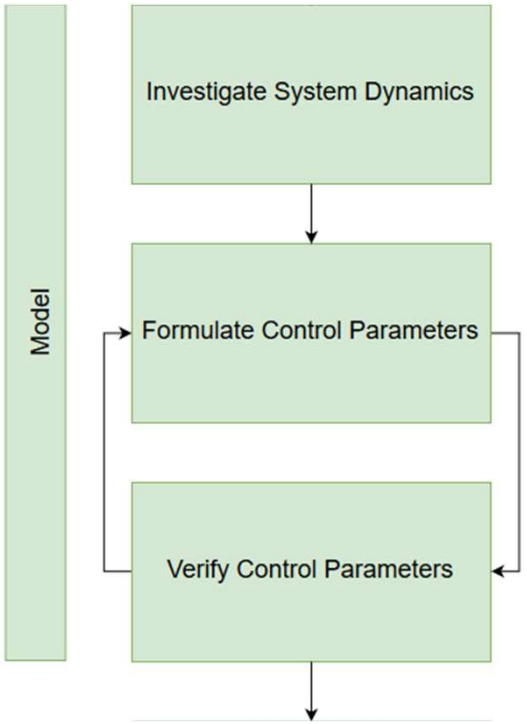


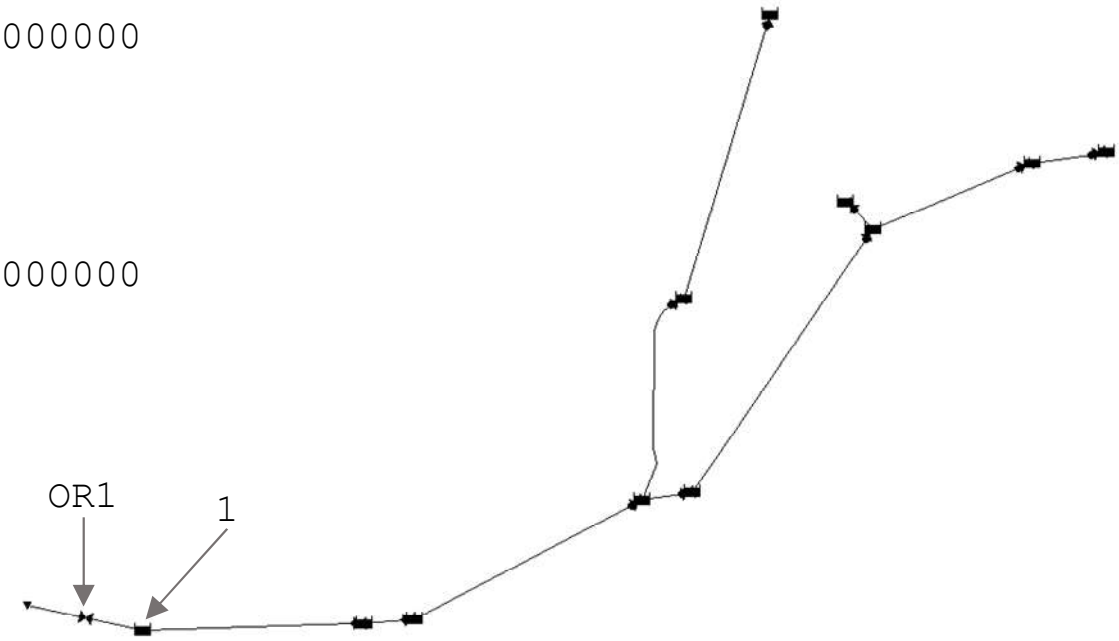
Means and Methods

- EPA SWMM & PySWMM
- Load Balancing Algorithm
- Genetic Algorithm for optimization

SWMM controls are not dynamic

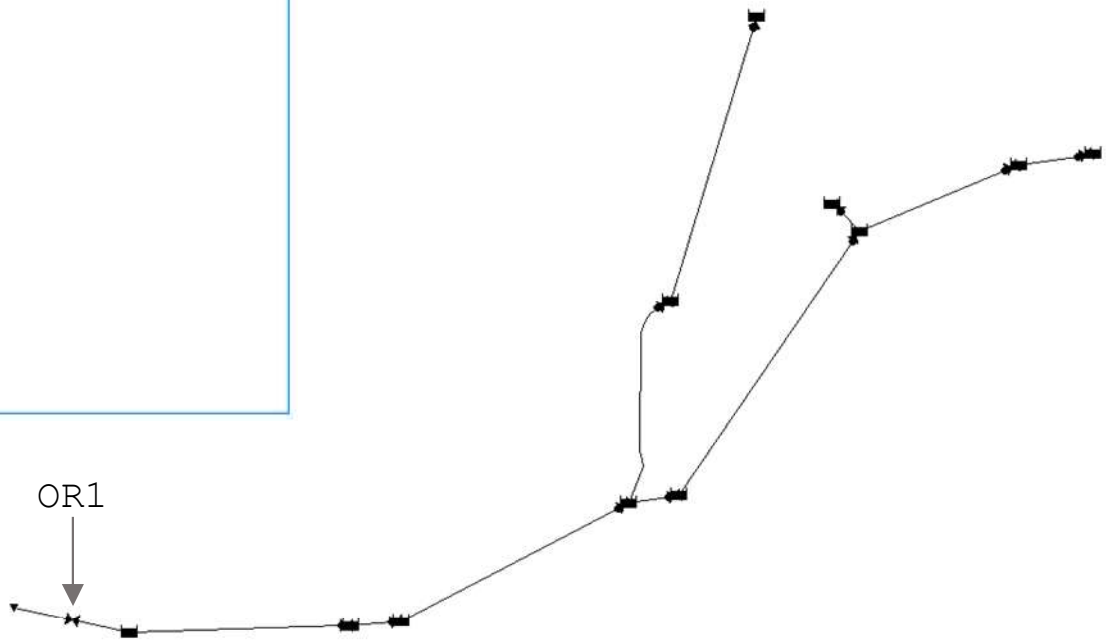
Traditional SWMM Controls

```
RULE OR1A
IF NODE 1 DEPTH > 16.700000
THEN ORIFICE OR1 SETTING = 0.000000
PRIORITY 1.000000

RULE OR1B
IF NODE 1 DEPTH <= 16.200000
THEN ORIFICE OR1 SETTING = 1.000000
PRIORITY 2.000000
```



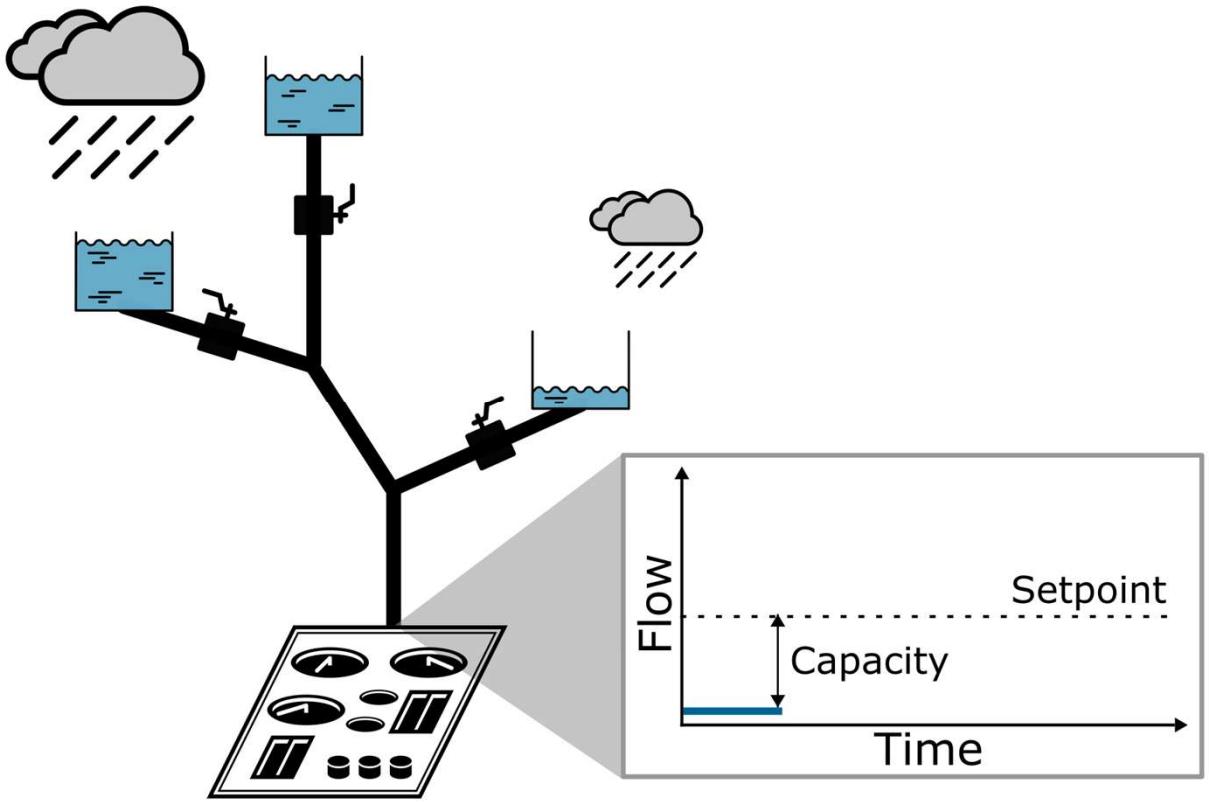
PySWMM offers dynamic capabilities

```python
from pyswmm import Simulation, Links, Nodes

with Simulation('my_model.inp', outputfile='my_results.out') as sim:
    nodes = Nodes(sim)
    links = Links(sim)

    # outlet orifice
    OR1 = links['OR1']
    max_flow = 1000

    # upstream orifices
    OR2 = links['OR2']
    OR3 = links['OR3']
    OR4 = links['OR4']

    # run model
    for step in sim:
        flow_ave = (OR2.flow + OR3.flow + OR4.flow) / 3

        OR1.target_setting = flow_ave / max_flow
```



More here: https://pyswmm.readthedocs.io/en/stable/index.html

Multiple control points create challenges for coordination



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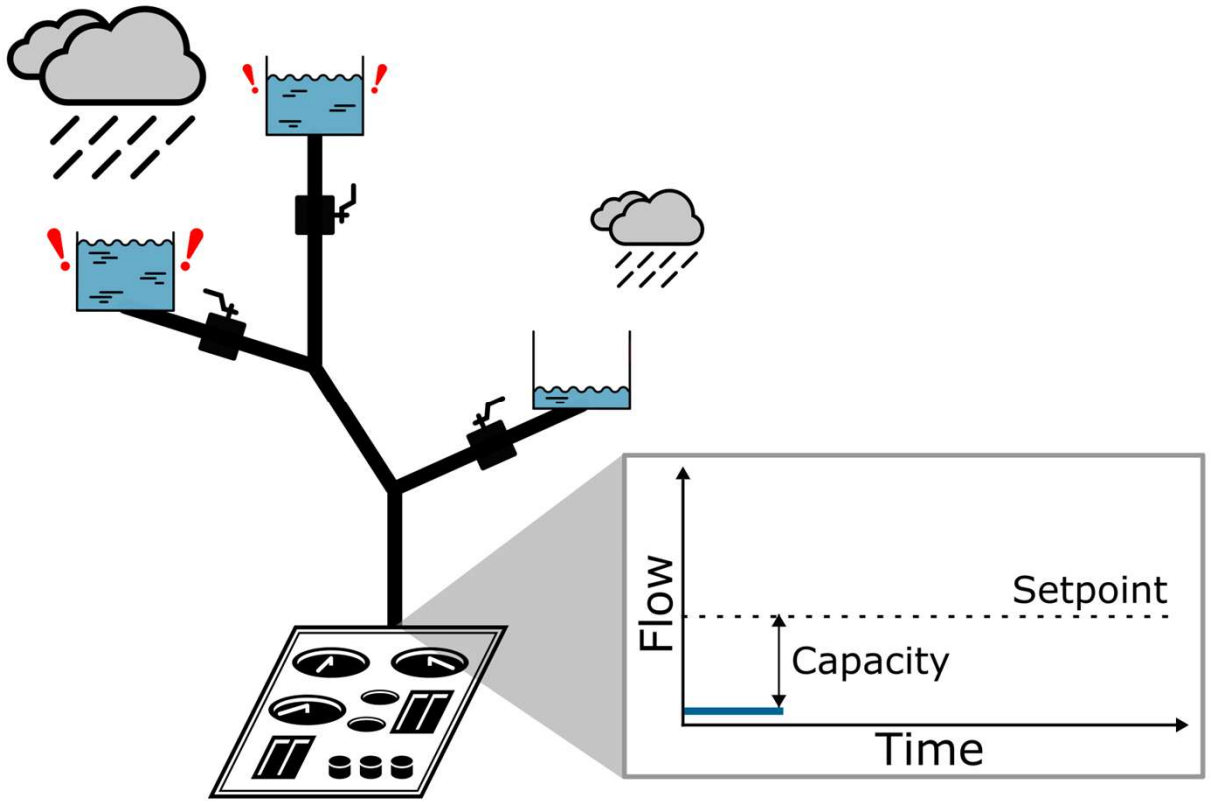

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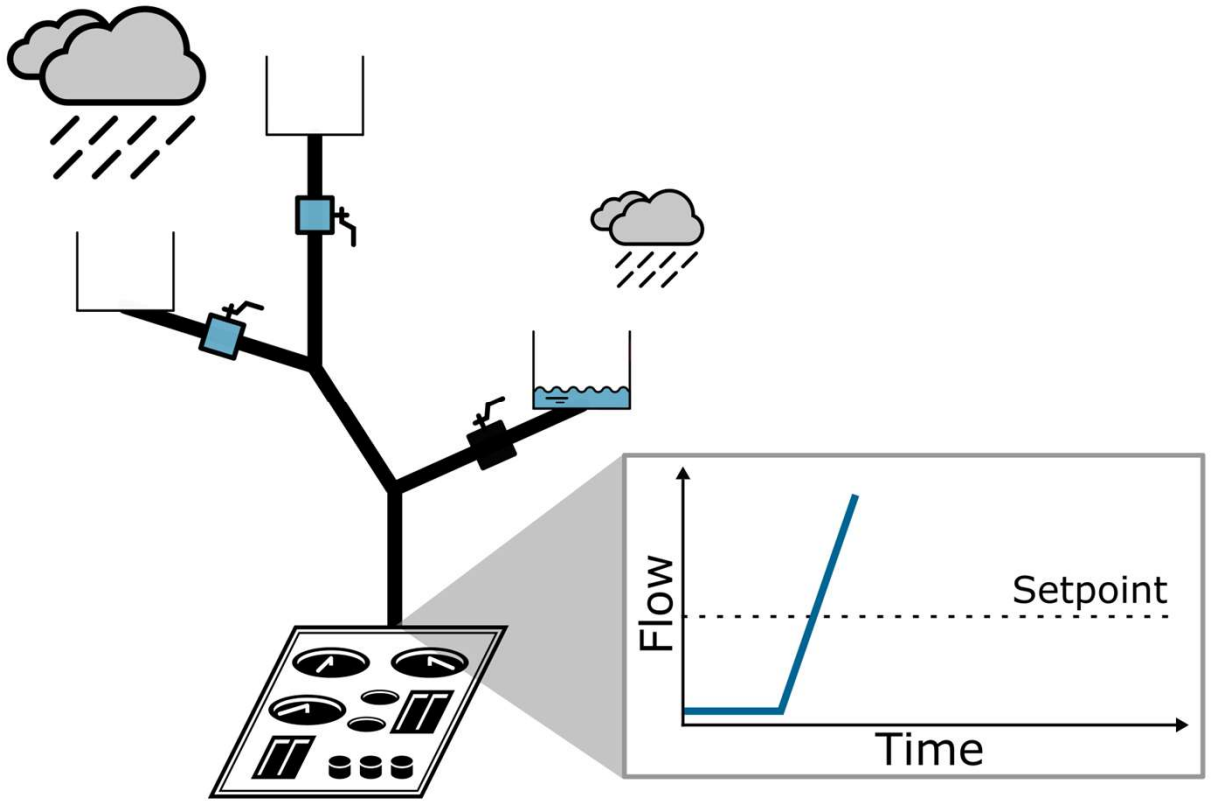

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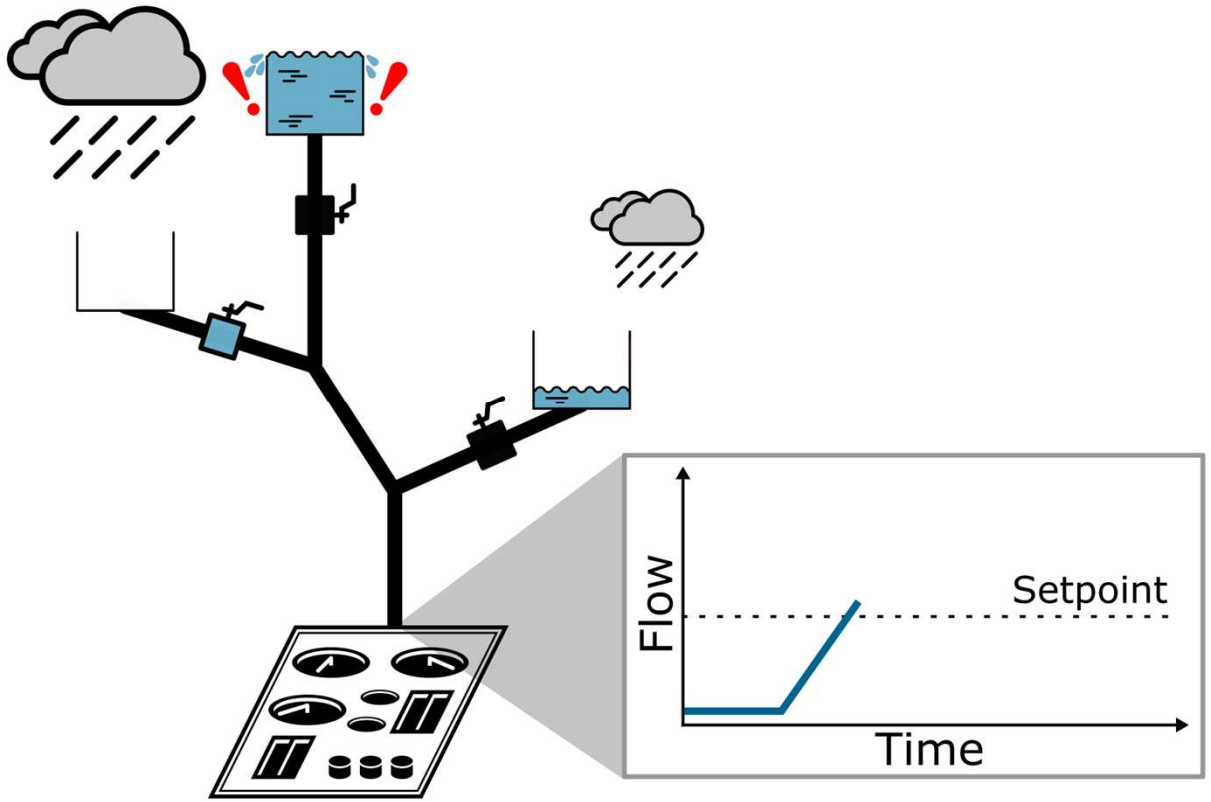
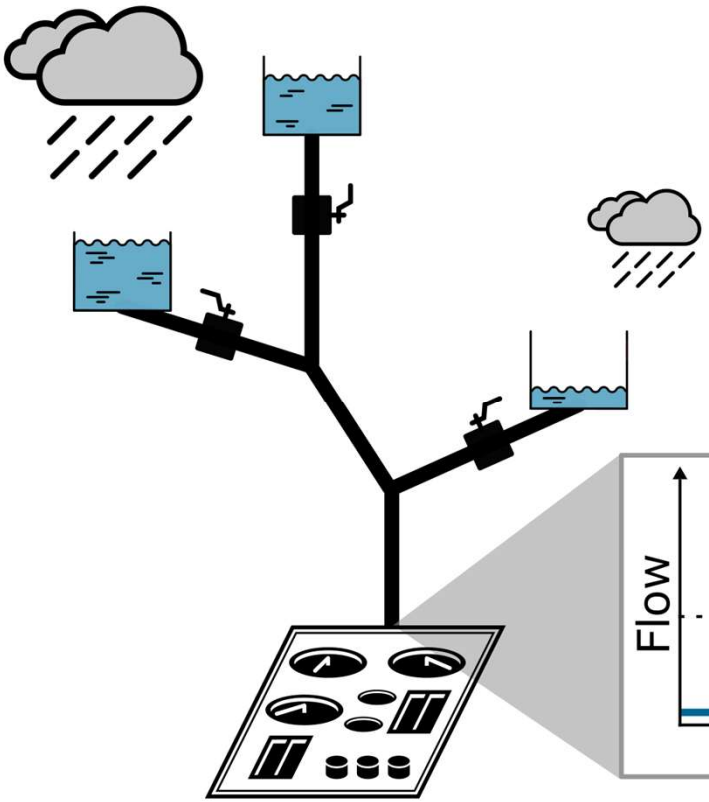
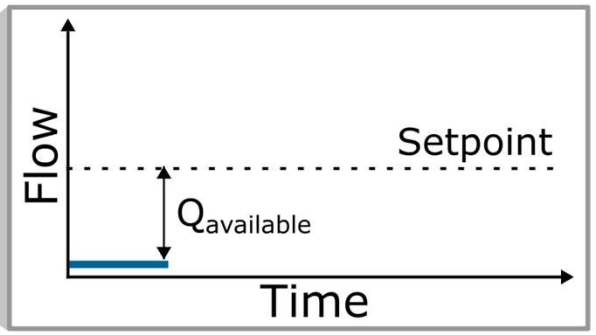


Implementation





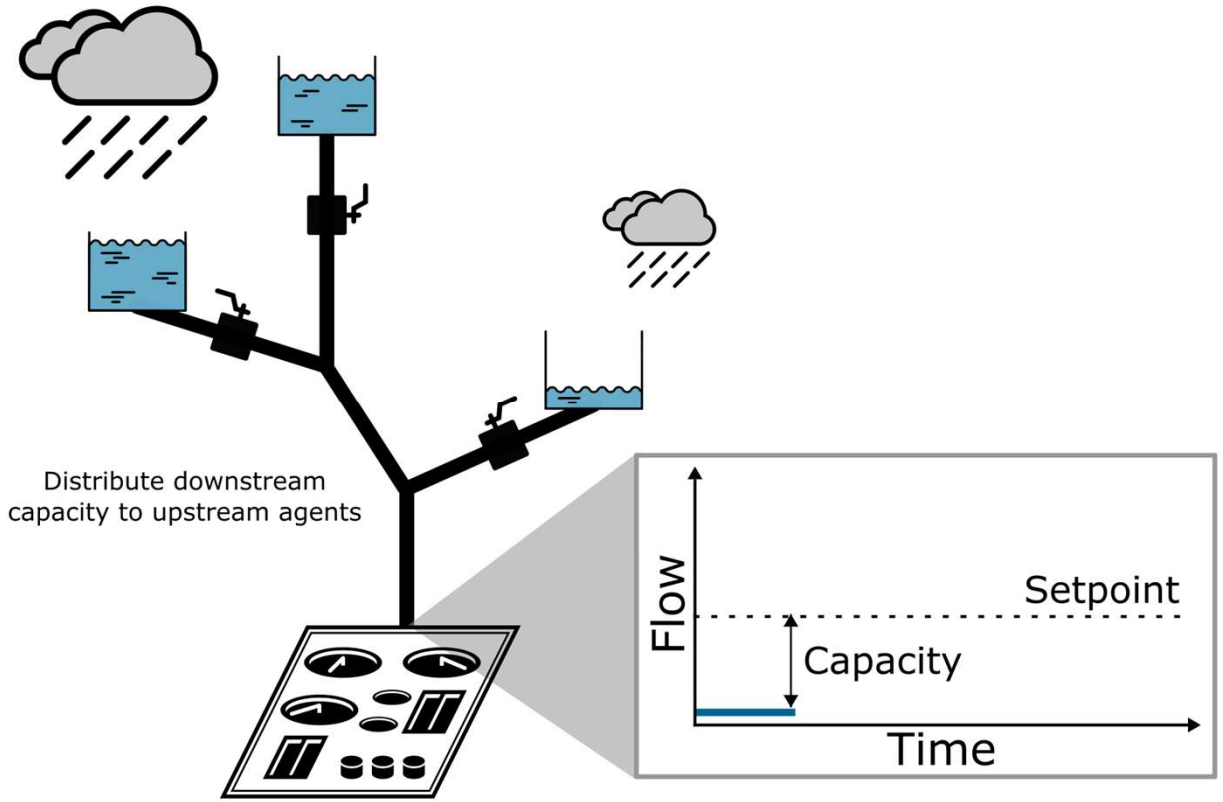
$$P_i = \beta_i \cdot V_{up,i}$$

$$D = (V_{down} - setpoint) \cdot \varepsilon$$

$$p = \frac{1}{n+1}\left[\sum_i P_i + D\right]$$

$$Q_{goal,i} = Q_{available} \cdot (P_i - p)$$

Balance load from upstream discharges to meet downstream objectives



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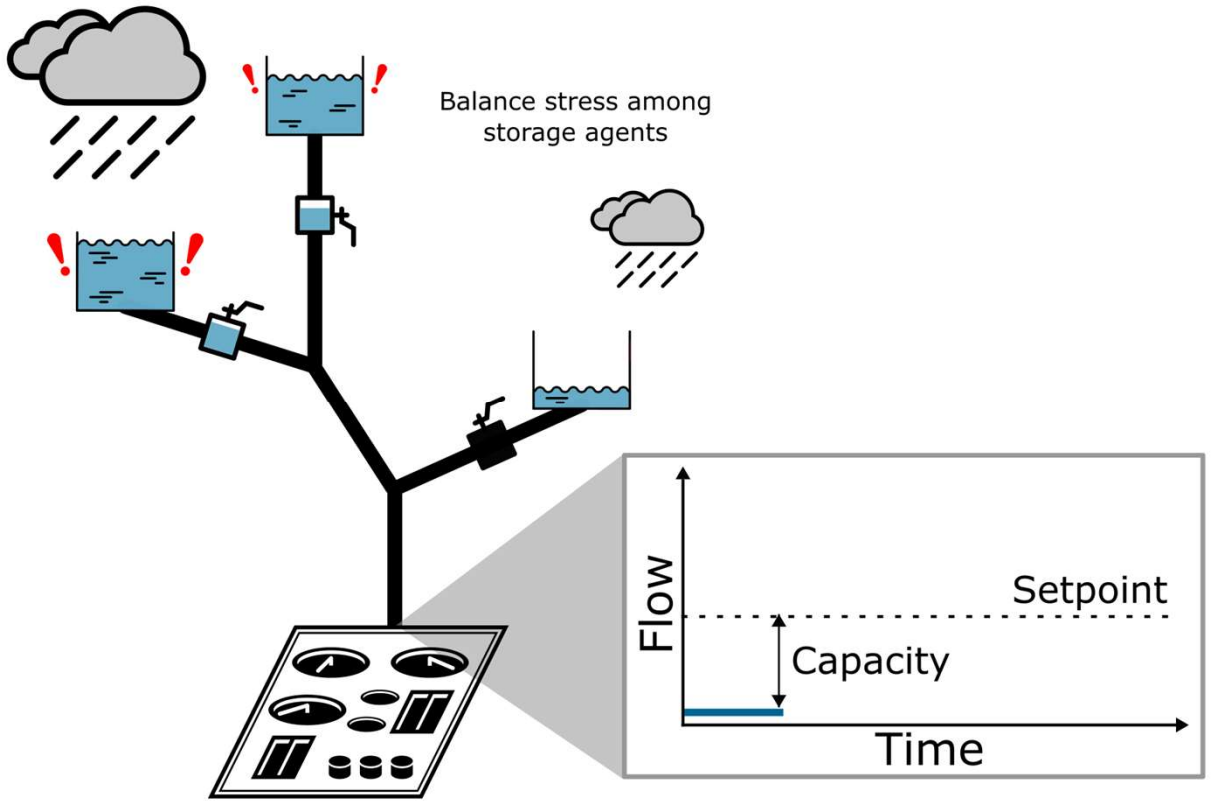

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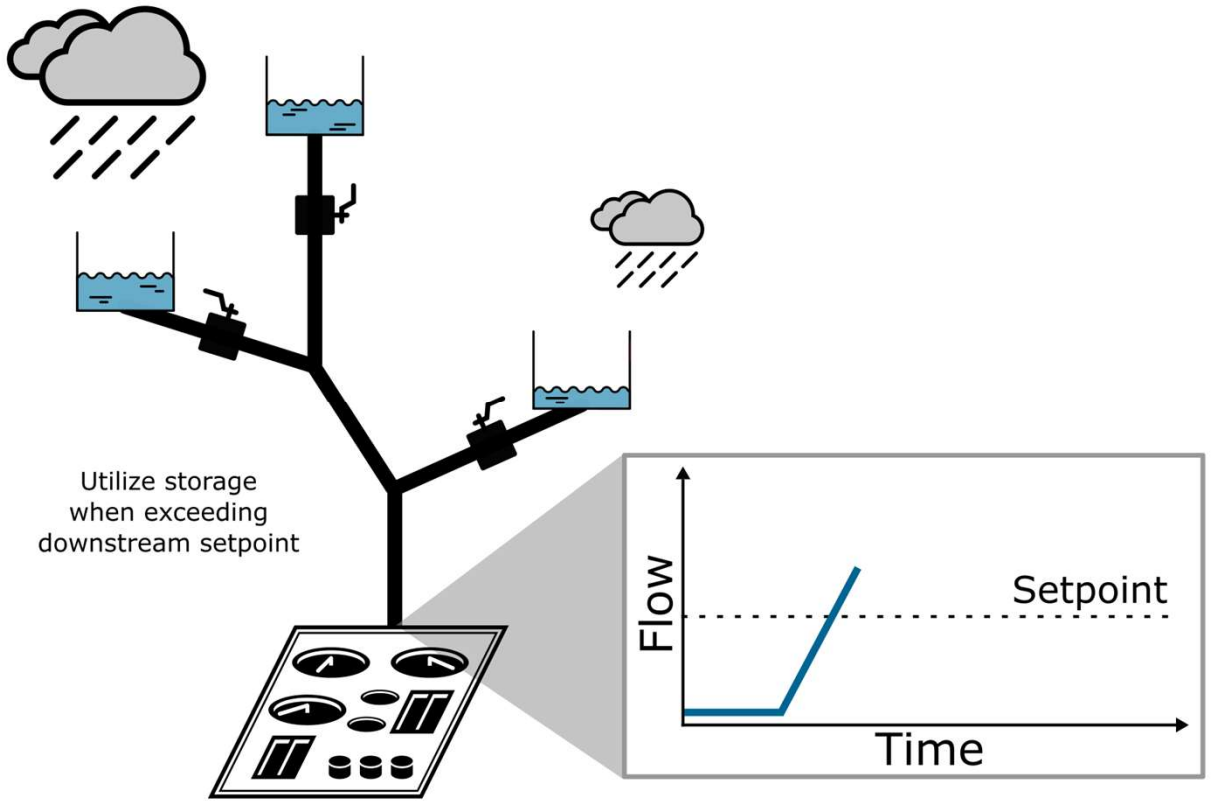

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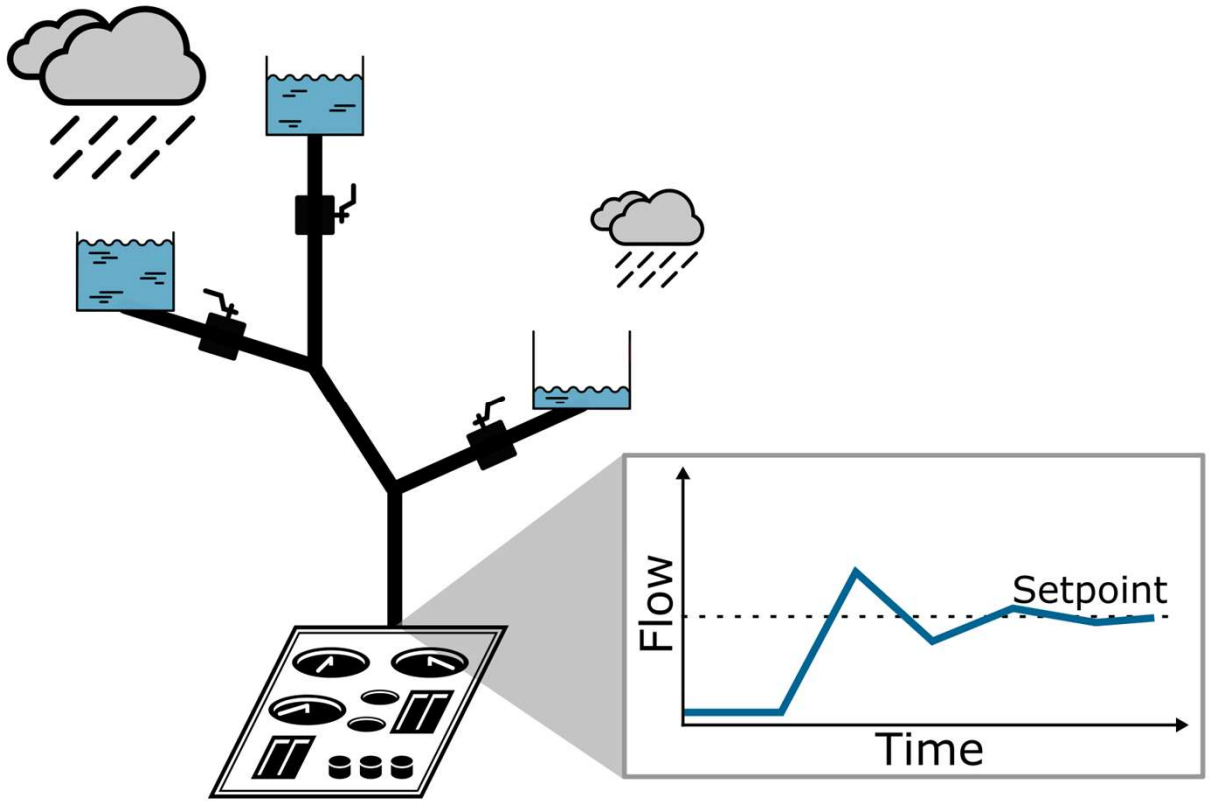


Load Balancing Algorithm approach applied

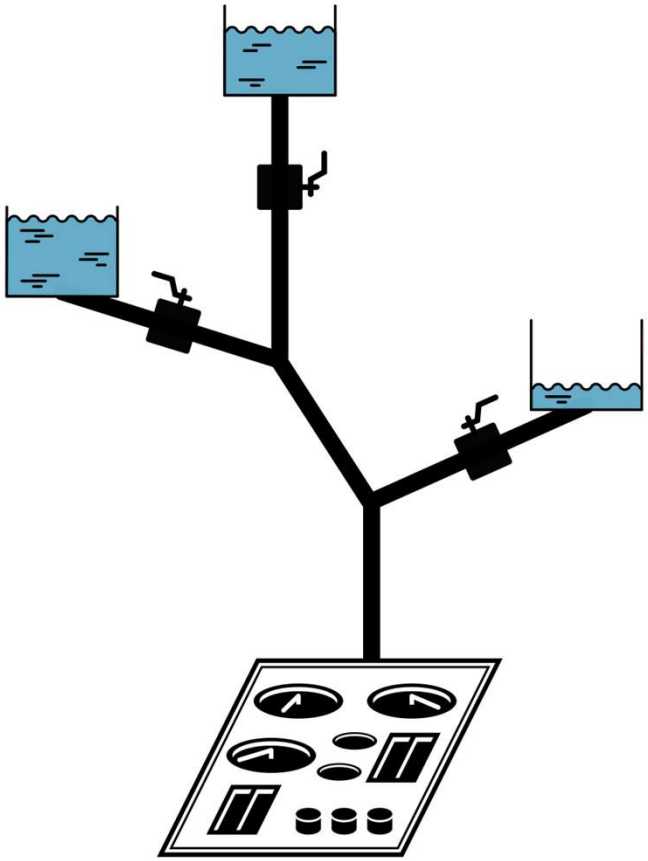
<u>To Determine Control Actions</u>

1. Calculate Importances
   - Upstream: normalize storage depth, multiply by a weighting factor
   - Downstream: take the difference between the normalized depth and the setpoint, multiply by a weight factor

2. Take [weighted] average of these importances

3. If asset's calculated importance is greater than the average, they can release

4. Calculate release quantity



Note: See forthcoming paper on updated Load Balancing Algorithm method (Troutman, Love, Kerkez)

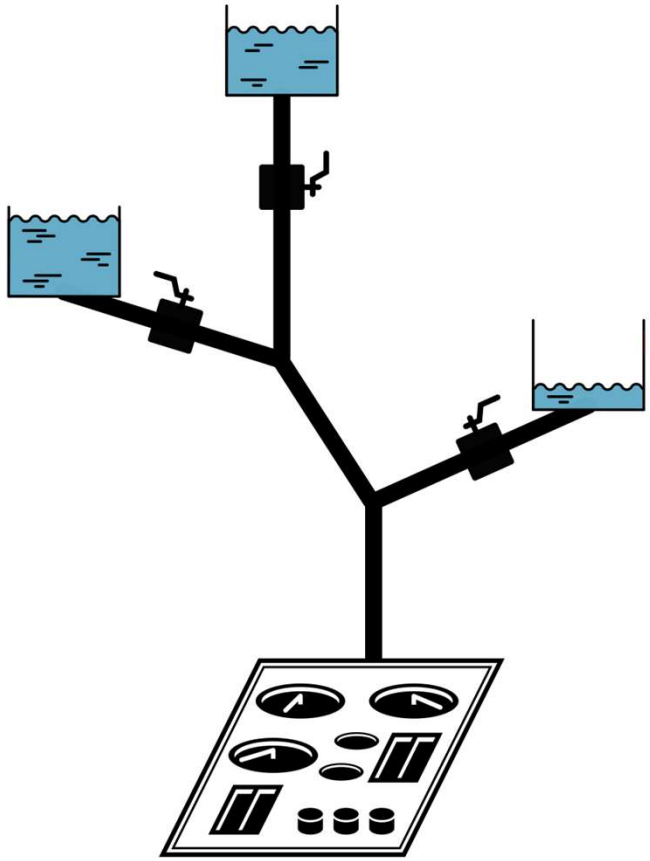
Load Balancing Algorithm approach applied

$$I_{i,up} = d_{up,i} \cdot \beta_i$$

$$I_{down} = (d_{down} - setpoint) \cdot \varepsilon$$

$$I_{ave} = \frac{1}{n+1}\left[\sum_i I_{i,up} + I_{down}\right]$$

$$Q_{goal,i} = Q_{available} \cdot \left(I_{i,up} - I_{ave}\right)$$



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Algorithm includes user-defined parameters

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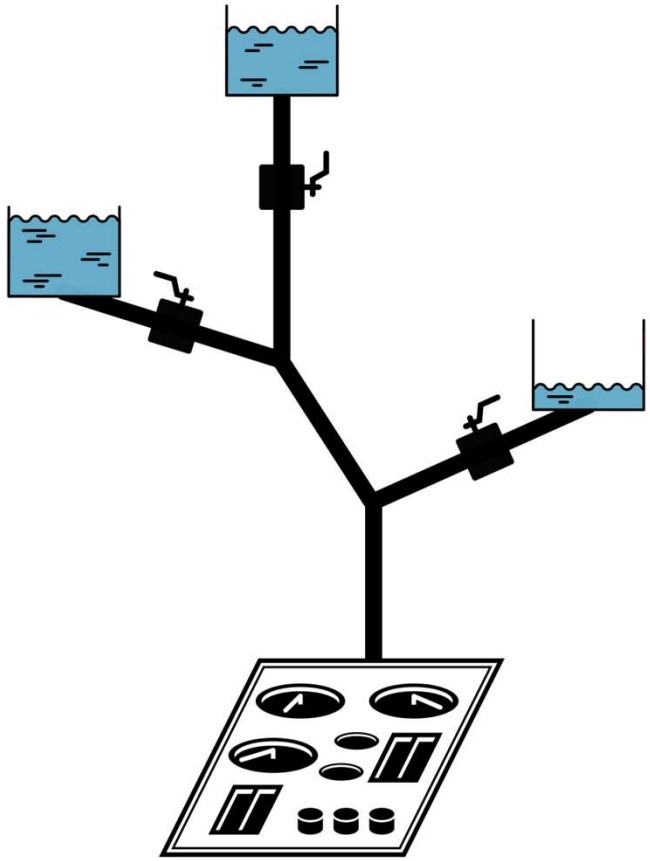

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$$Q_{goal,i} \rightarrow Recommendation$$

Note: See forthcoming paper on updated Load Balancing Algorithm method (Troutman, Love, Kerkez)

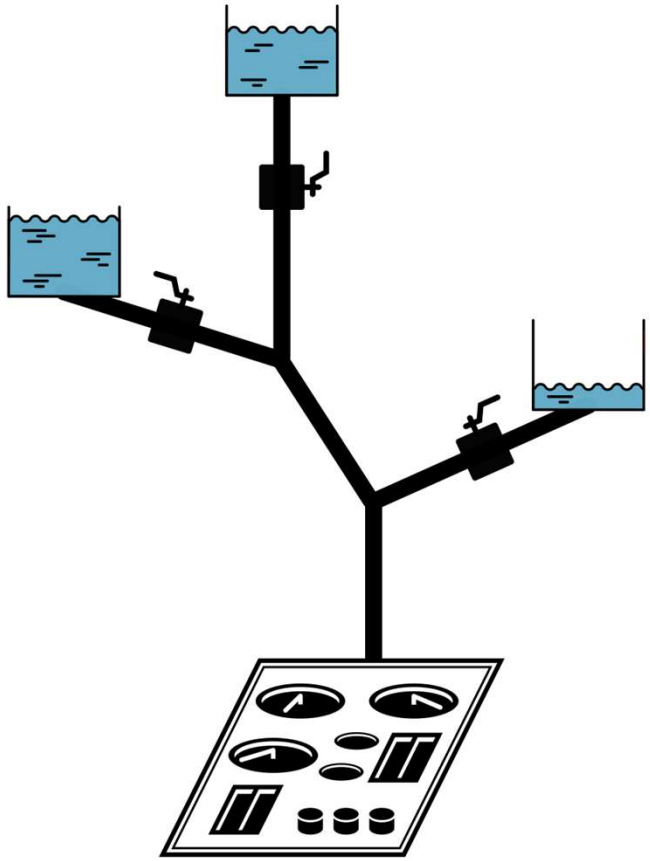
Load Balancing Algorithm (LBA) provides benefits over other control schemes

Straightforward

Computationally Cheap

Instantaneous values only

Extendible beyond flow control



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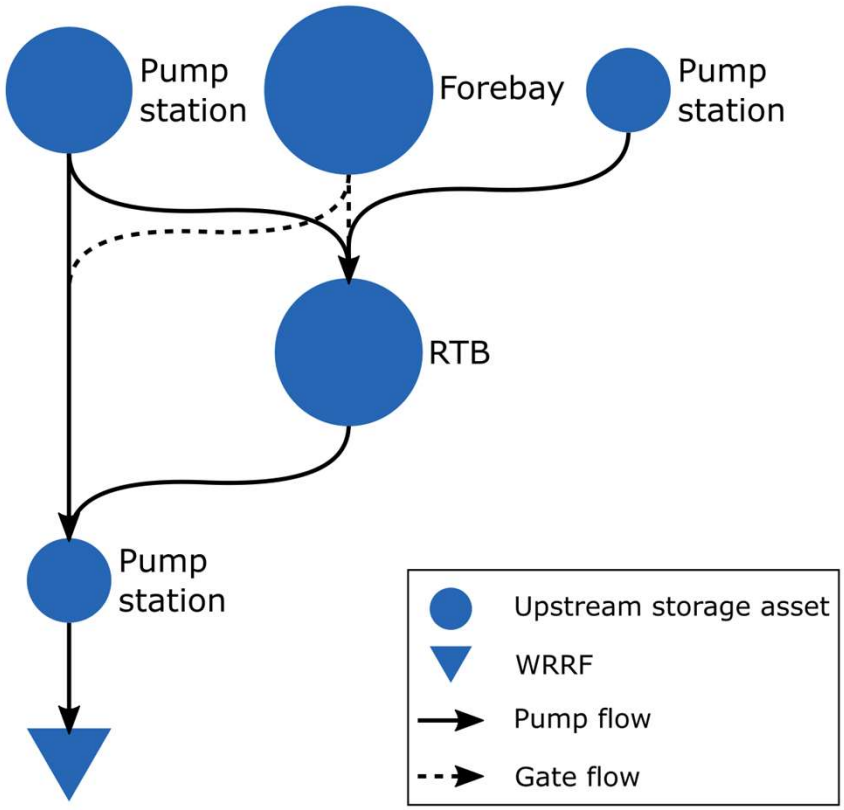
Subdivide study area for LBA application



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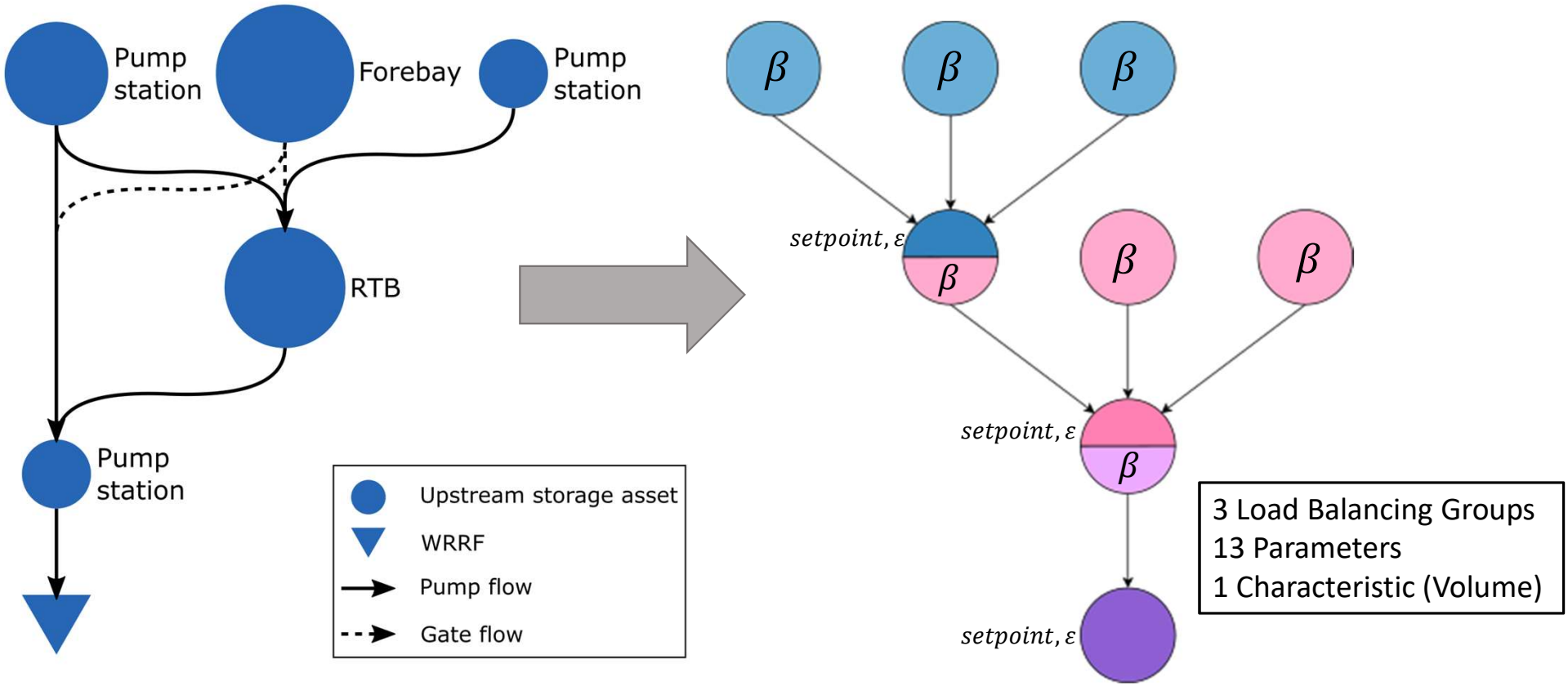

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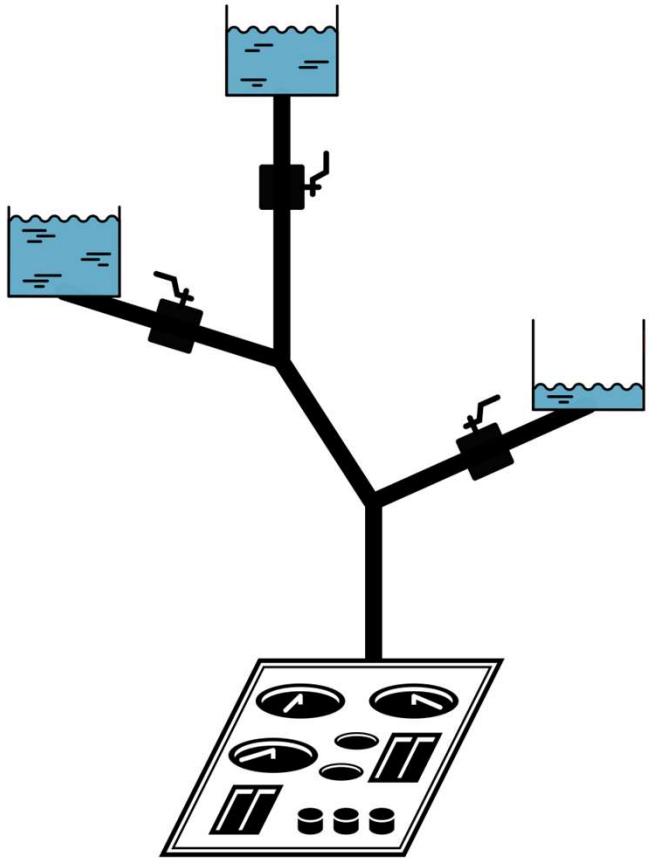
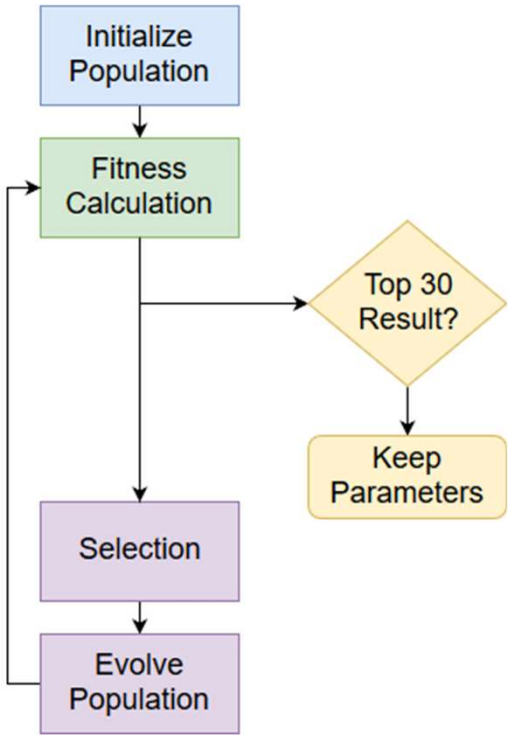


Note: See forthcoming paper on updated Load Balancing Algorithm method (Troutman, Love, Kerkez)

Parameter optimization could require advanced techniques, such as genetic algorithms



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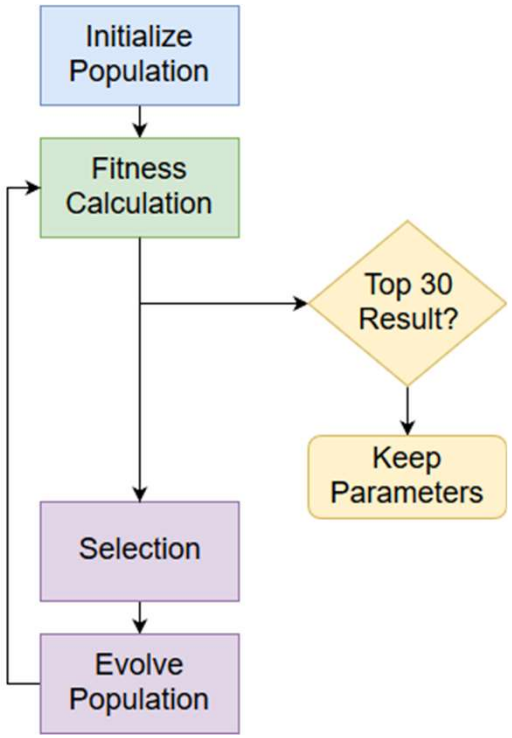

Fitness Calculation:
Simulate wet weather event with LBA control and unique parameter set

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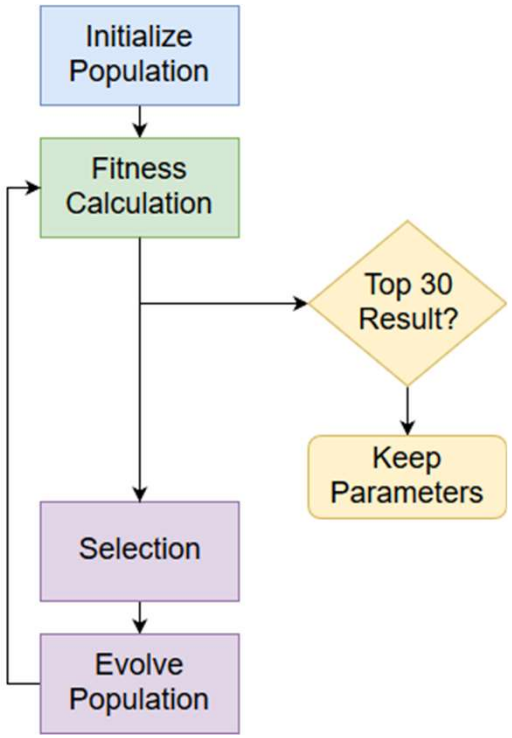

Fitness Calculation:
Simulate wet weather event with LBA control and unique parameter set

Best Parameters:
Analyze control performance with best parameters and different wet weather events

Results show this method and algorithm can reduce discharge for a variety of storm types

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Event Date	Event Type	Event Duration (hours)	Precipitation Depth (inches)
4-May-17	Calibration	16	1.0

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Event Date	Event Type	Event Duration (hours)	Precipitation Depth (inches)
4-May-17	Calibration	16	1.0
11-May-18	Evaluation	96	2.8
2-Jun-18	Evaluation	1	0.7
31-Jul-18	Evaluation	8	1.3
31-May-15	Evaluation	28	2.0

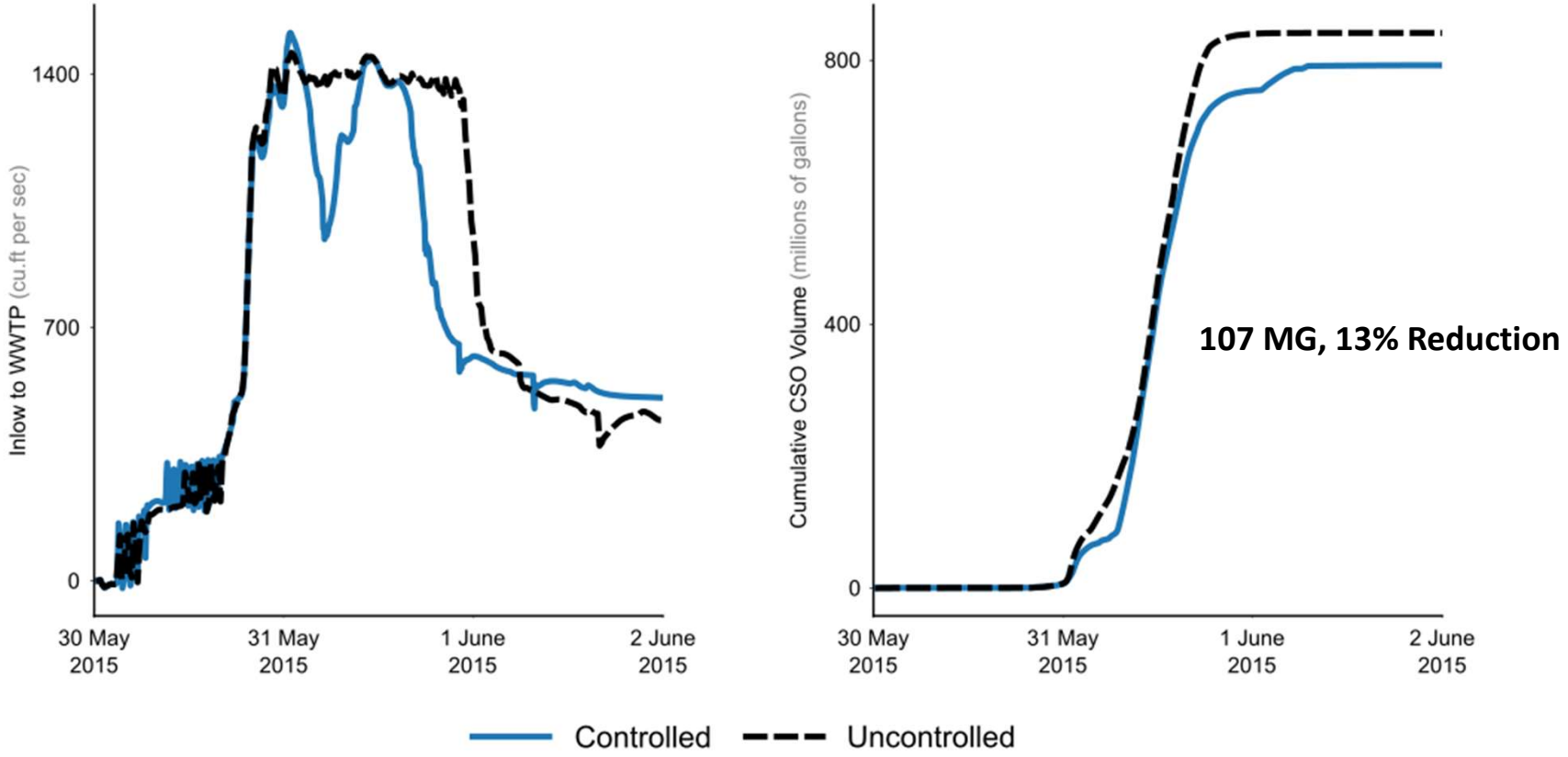
Results show this method and algorithm can reduce discharge for a variety of storm types

Event Date	Event Type	Event Duration (hours)	Precipitation Depth (inches)	Baseline
4-May-17	Calibration	16	1.0	130
11-May-18	Evaluation	96	2.8	1666
2-Jun-18	Evaluation	1	0.7	47
31-Jul-18	Evaluation	8	1.3	1318
31-May-15	Evaluation	28	2.0	842

Results show this method and algorithm can reduce discharge for a variety of storm types

Event Date	Event Type	Event Duration (hours)	Precipitation Depth (inches)	Total CSO Volume (millions of gal)			
				Baseline	With real-time control	Volume Reduction	Percent Reduction
4-May-17	Calibration	16	1.0	130	30	100	77%
11-May-18	Evaluation	96	2.8	1666	1906	-240	-14%
2-Jun-18	Evaluation	1	0.7	47	46	1	2%
31-Jul-18	Evaluation	8	1.3	1318	1274	44	3%
31-May-15	Evaluation	28	2.0	842	735	107	13%

Real-time control algorithm study demonstrates potential to reduce CSOs



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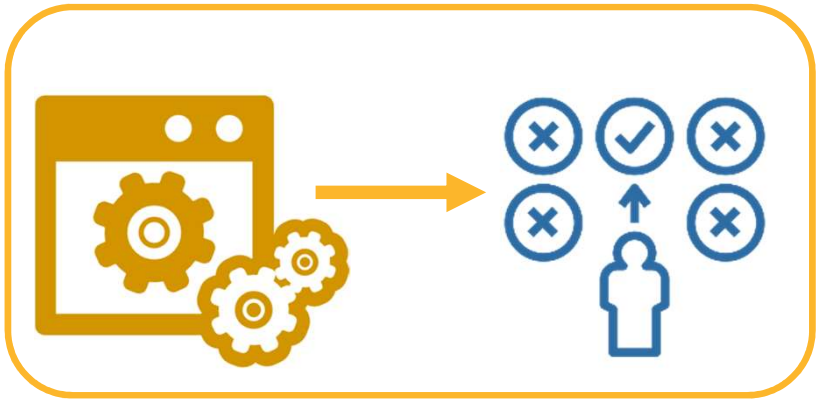
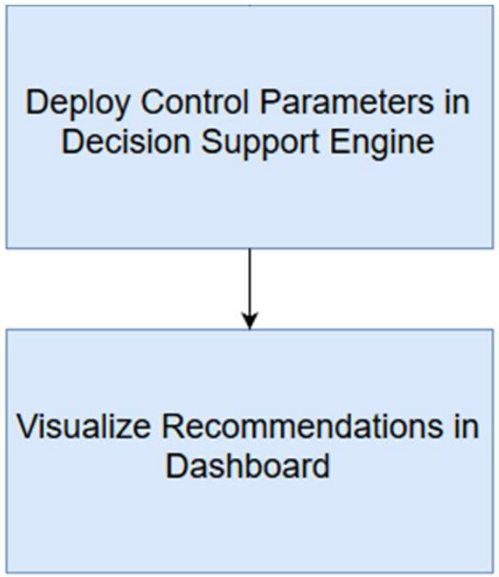


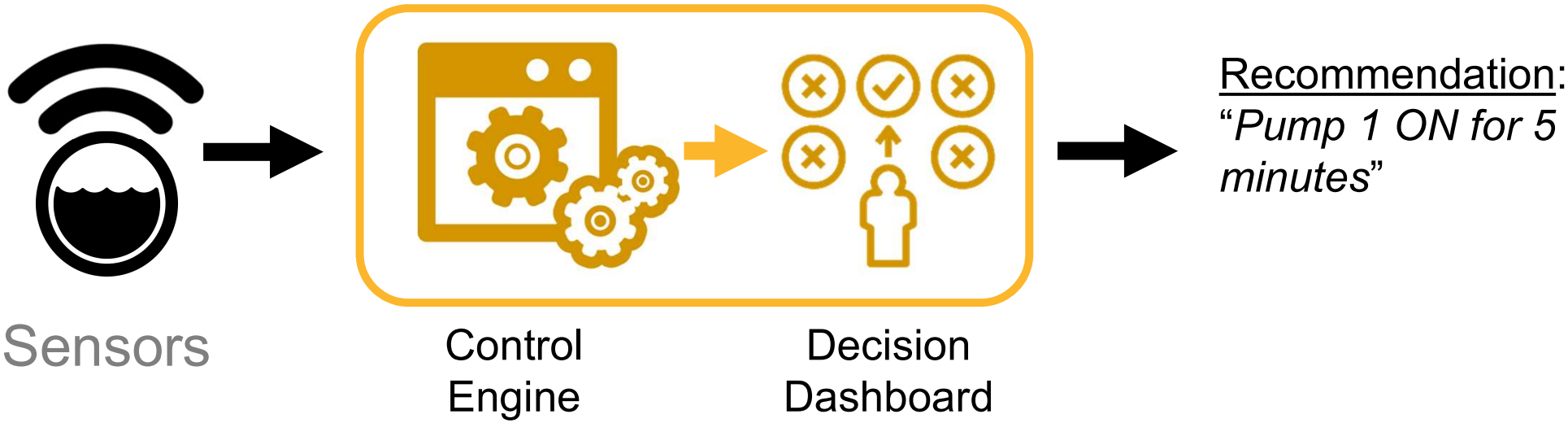
Deploy LBA in real-time recommendation engine



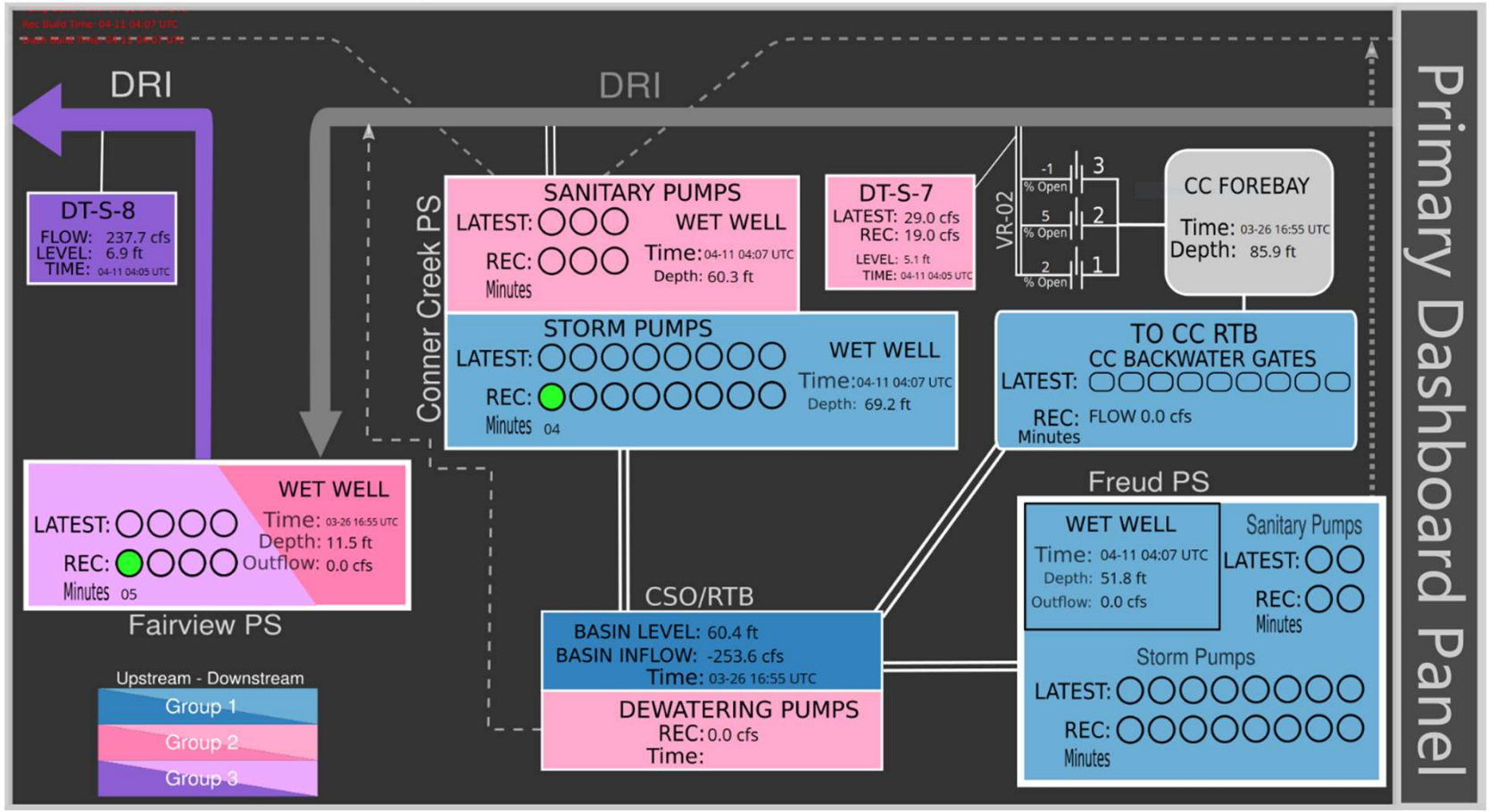
Consider:

- Account for model to physical differences
- Making actionable recommendations
- Application Architecture

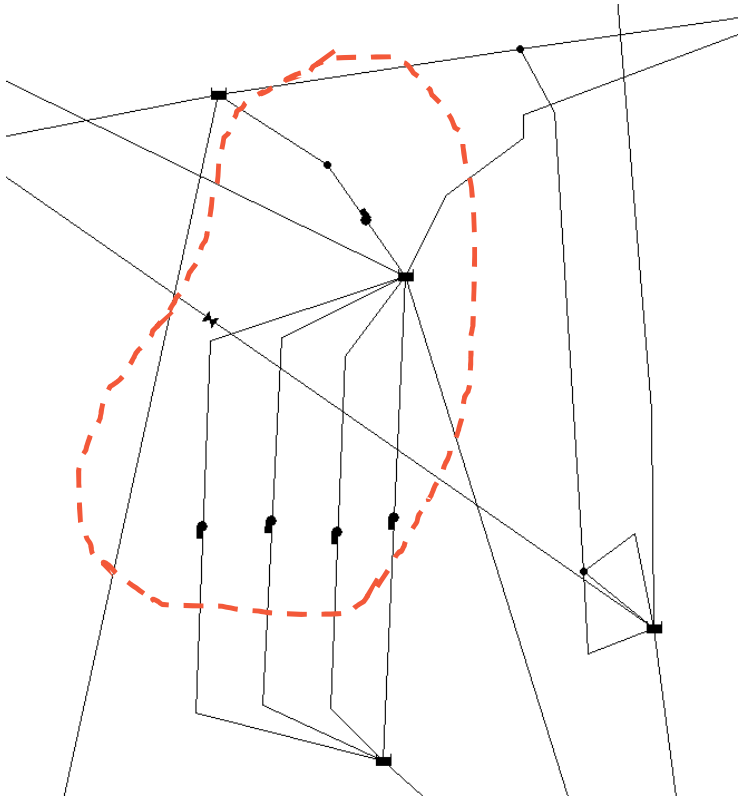
Objective is to provide actionable information



From Results, Recommendation Dashboard



Converting to real-time application requires system knowledge and engineering judgement



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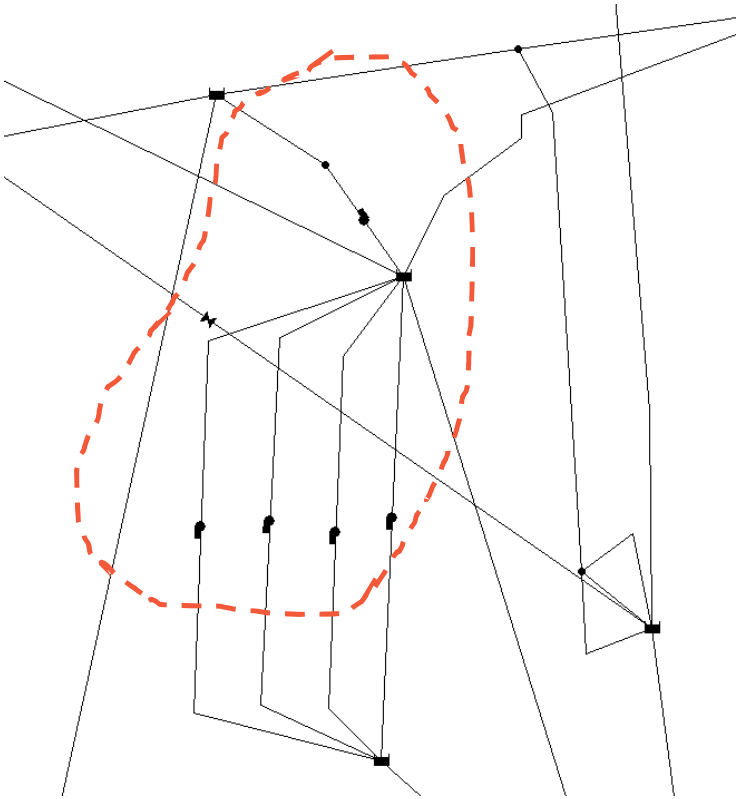

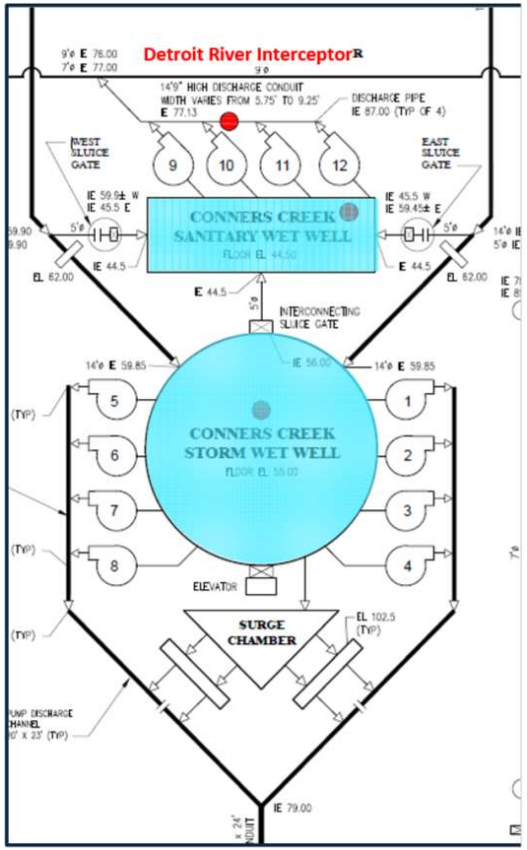

User-defined parameters are critical in data-to-information transformation

Considerations

$Q_{goal,i} \rightarrow Recommendation$

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- Setpoint Determination: Available Flow/Volume Downstream

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- Curves: Pump, Gate, Valves, and Storage

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- Measurement Type, Upstream & Downstream
- Curves: Pump, Gate, Valves, and Storage

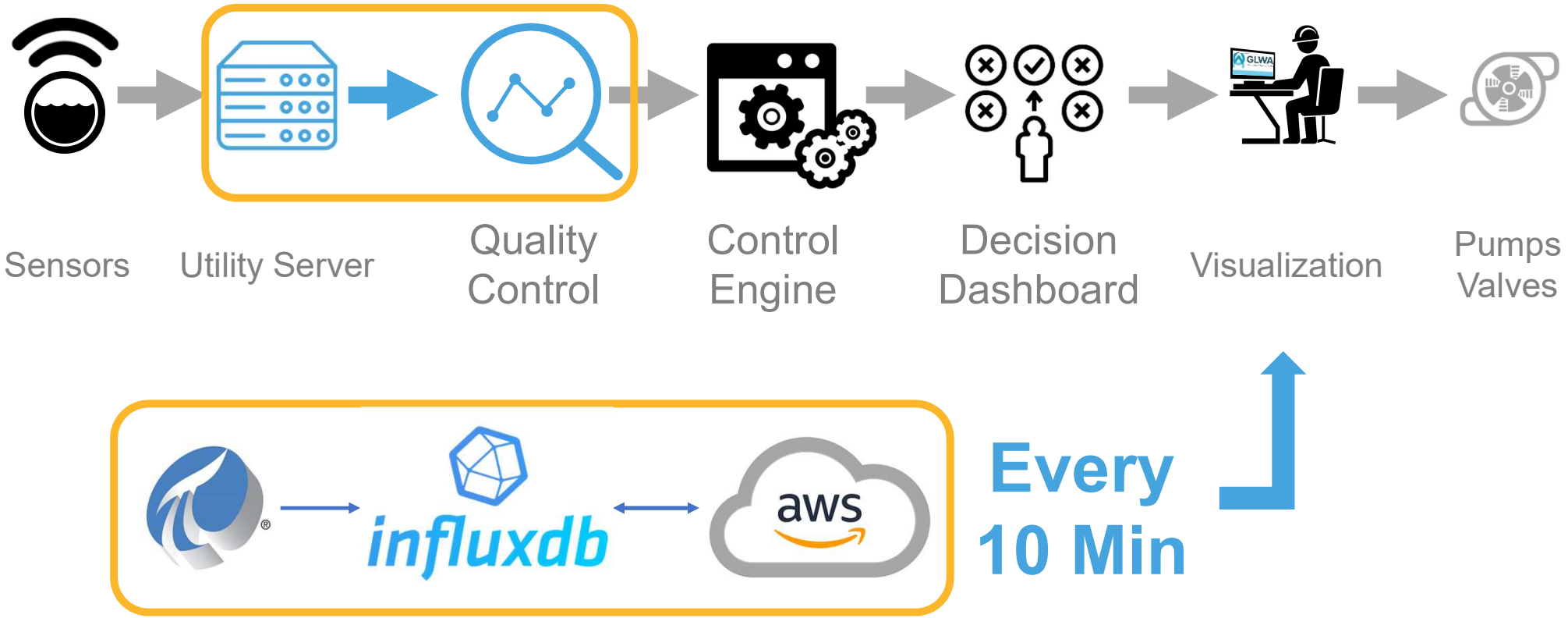
Recommendation Types:

- Station Flowrate
- Pump On/Off Status
- Gate/Valve State

Leverage cloud infrastructure to provide real-time application

Sensors
Utility Server
Quality Control
Control Engine
Decision Dashboard
Visualization
Pumps Valves

Leverage cloud infrastructure to provide real-time application



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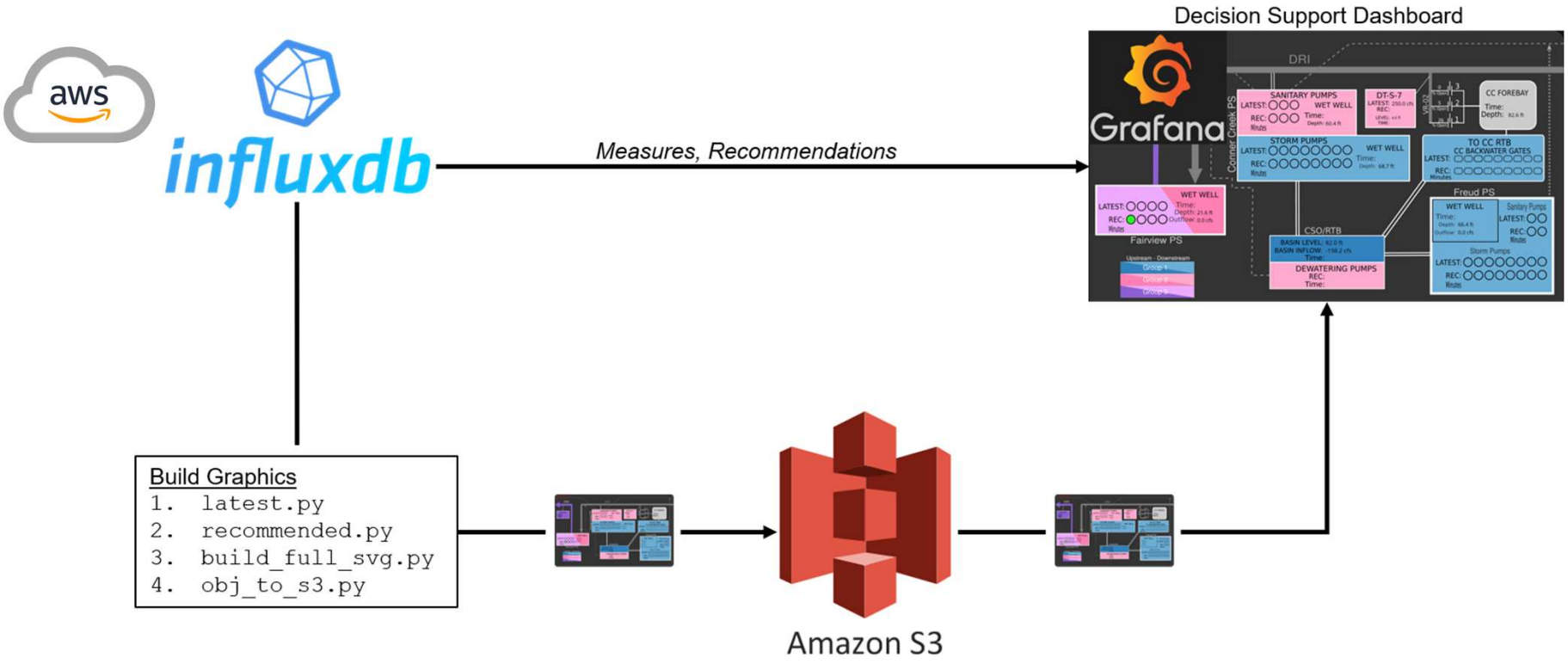

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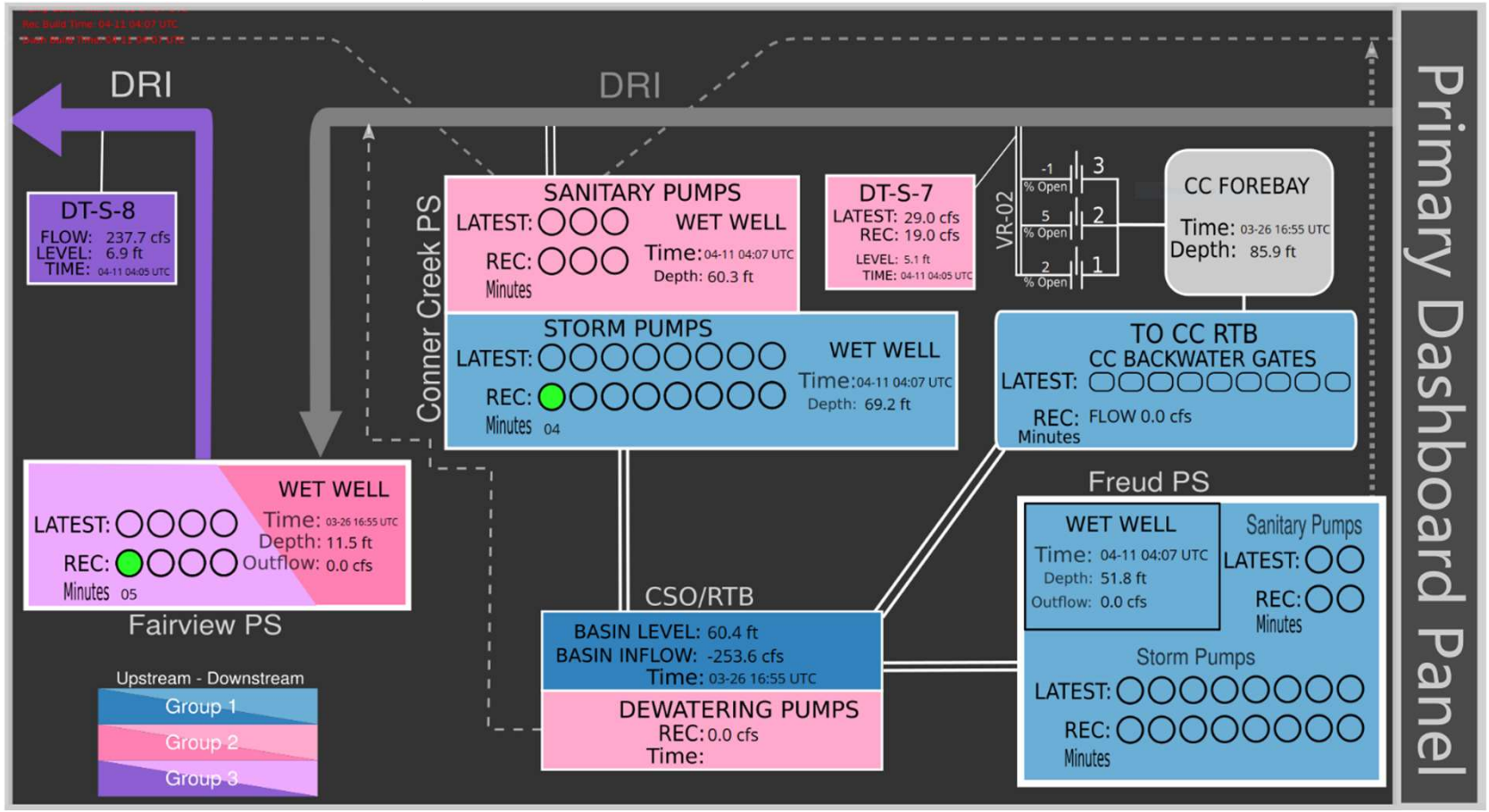

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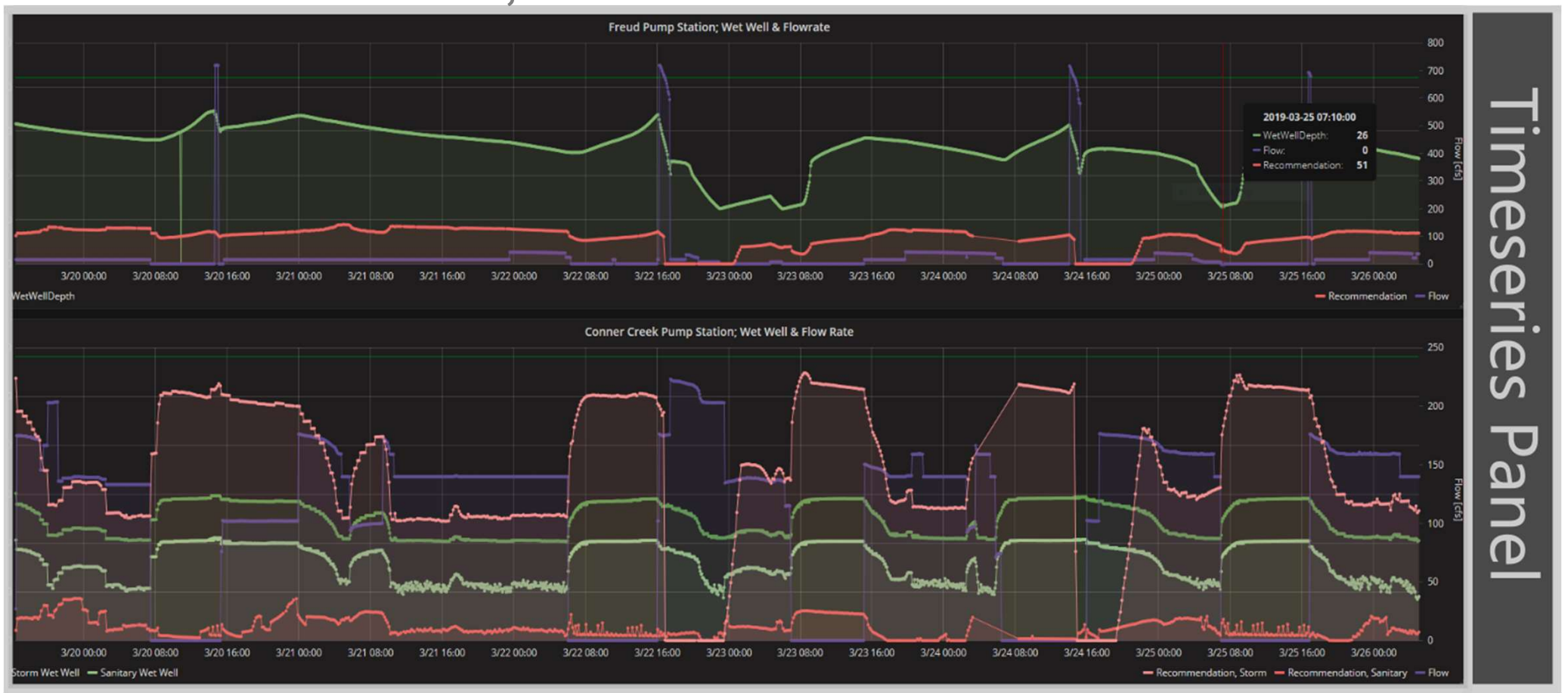

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Lessons learned and advice

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Utility staff may have the needed skills already

Algorithms require inspection and iteration

Next Steps

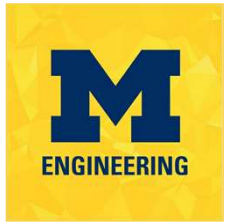
Model studies (optimization)

Prototype monitoring

Refine communication of recs

Value added analysis

Scaling studies



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Funding Sources, Thank You

Questions?

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