Source: Healthy Water Ways 2013

tinyurl.com/bkerkez
Conceptual Example

Downstream point

Water level

Time

tinyurl.com/bkerkez
Conceptual Example

Downstream point

“Before” Max Flow

Water level

Time

tinyurl.com/bkerkez
Conceptual Example

Neighborhood 1

Downstream point

Water level

“Before” Max Flow

Time

tinyurl.com/bkerkez
Conceptual Example

Neighborhood 1

Neighborhood 2

Downstream point

Time

Water level

“Before” Max Flow
Conceptual Example

Water level vs Time

```
Neighborhood 1

Neighborhood 2

“Before” Max Flow
```

Downstream point

tinyurl.com/bkerkez
Rain, soil moisture and water quality sensors measure real-time conditions of green and gray infrastructure.

Smart covers measure underground flows and water quality.

Smart ponds adapt to changing weather by managing storage and detention time.

Multiple smart valves coordinate flows to achieve system-level benefits.

**Smarter Stormwater Systems**

Kerkez et al. (2016), Environmental Science and Technology

DOI: 10.1021/acs.est.5b05870
Nudged the system into a favorable state

Neighborhood 1
Neighborhood 2

Without Control

Downstream point

Time
Water level
Nudging the system into a favorable state

Controller

With Control

Without Control

Water level

Time

With Control

With Control

Downstream point

Neighborhood 1

Neighborhood 2

Rain, soil moisture and water quality sensors measure real-time conditions of green and gray infrastructure.

Smart covers measure underground flows and water quality.

Smart ponds adapt to changing weather by managing storage and detention time.

Multiple smart valves coordinate flows to achieve system-level benefits.
Measure

Node + Sensors =

[Graph showing depth measurements over time]

tinyurl.com/bkerkez
GI Sensing

Rain

Water Depth

Soil Moisture

10 cm
30 cm
60 cm
90 cm

10

tinyurl.com/bkerkez
Water Quality Measurements

Wong and Kerkez, “Toward the ubiquitous use of real-time environmental sensor data: an application to water quality” (Under Review)
Control
Pilot Sites

Milwaukee

Toledo

Ann Arbor
Rain barrels and soil sensors

tinyurl.com/bkerkez
A² Watershed

- 103 MG during design storm
- 6620 acres (22% impervious)
$A^2$ Watershed

- 103 MG during design storm
- 6620 acres (22% impervious)
Real-time Control

– Ann Arbor, MI
Real-time GI Monitoring

- Ann Arbor, MI
Basin

1. Retention Time increased by 48 hours
2. Five million gallons removed from storm window
1. Retention Time increased by 48 hours
2. Five million gallons removed from storm window
3. Additional five million gallons treated
4. Smaller flows mean lower erosion
Pilot Sites

Milwaukee

Ann Arbor

Toledo
Toledo, OH

tinyurl.com/bkerkez
Milwaukee, WI
Real Watershed

System Abstraction

b) System Abstraction

a) Physical Watershed

Controller
Sensor

Static Asset
Controller
Sensor

Real Watershed

System Abstraction

?
Toward a simulation framework for “smart” stormwater systems

\[
\frac{dc}{dt}V + \frac{dv}{dt}C = q_{in}C_{in} - q_{out}C - kCV
\]
Goals
Architecture
Initial modeling architecture
Initial modeling architecture

Diurnal
Initial modeling architecture

Diurnal + Hydrologic
Initial modeling architecture

Diurnal  +  Hydrologic  +  Statistical

tinyurl.com/bkerkez
- Real-time QA/QC
- Forecasting
- CSO control
- Treatment control

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Measured
Predicted