Green Infrastructure Modeling Strategies

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American Water Resources Association – National Capital Region Section
November 12, 2015
Agenda

- Green Infrastructure Modeling Overview
- DC Water Green Infrastructure
- Timeline of DC Water GI Models
- Next Steps
Green Infrastructure Model Basics

- Why do we need a computer model?
  - Models are used as tools to help us predict CSO overflows caused by different management scenarios.

- Why can we trust models?
  - The models used here are calibrated to actual sewer flow measurements specifically selected to quantify CSO overflow volume and frequency.

- How is GI modeled?
Combined vs. Separated Areas

- Different goals in combined vs separated areas

- Separate area flows directly to receiving waters
  - Reduce runoff volume
  - Reduce pollutant load
  - Capture first flush

- Combined area flows to Blue Plains AWTP
  - Reduce peak flows
  - Reduce volume during large storm events
The Task

Quantify reduction in volume and frequency of CSO overflows caused by:

- Increased Green Infrastructure
- Variations in pumping
- Variations in tunnel volume
- Grey infrastructure improvements
What is Green Infrastructure?
What is Green Infrastructure?
What is Green Infrastructure?
GI Modeling Methods

- Runoff/pollutant reduction
  - Volume reduction percentage
  - Treatment percentage
  - Peak flow reduction

- Drain time/volume simulation
  - Assume treatment volume and drain time
  - Link with runoff model, or use as separate model

- Complex GI representation
  - Model internal processes of GI practice: soil permeability, infiltration, underdrain, vertical conductivity

Must have on-the-ground data to support level of detail
Lumped Parameter Model
Lumped Parameter Model

Example data – for demonstration
Lumped Parameter Model

Represent all GI within a catchment as one GI practice per catchment
Hydrologic Modeling Tools

- MIKE URBAN by DHI Software
  - Fully dynamic hydraulic and hydrologic model
  - Developed for urban runoff and collection systems
- EPA SWMM5
  - Also fully dynamic hydraulic and hydrologic model
  - Recent built-in support for LID Controls
  - Used throughout the industry
- Other tools
  - InfoWorks, InfoSWMM, PCSWMM, xpswmm, HSPF, and other H&H modeling packages
- EPA Stormwater Calculator, GIS, Excel, R, Python...
Project and Model Progression

1998 CSO Long-term Control Planning Begins

2007 Green Buildout Model

2013 Proposed Modified Consent Decree

2015 GI Design Standards

Closer to Green Infrastructure Construction

More detailed modeling and monitoring
Model Development

- 1998-2006 MIKE MOUSE/MIKE URBAN collection system model
  - Calibrated model of combined sewer area
  - Pumps and inflatable dams operated with real-time controls
  - Quantify volume and frequency of CSO overflows
  - Tunnels (and other grey improvements) to reach LTCP goals

- 2007-2009 Green Build-out Model (GBOM) – MIKE URBAN
  - What runoff volume can we capture with GI in DC?
  - Green Infrastructure as depression storage with evaporation
Green Buildout Model

IMPERVIOUS SURFACE

GREEN INFRASTRUCTURE

Roofs to Rain Barrels
Roofs to Rain Gardens
Green Roofs
Streetside Bioretention Planters
Curb Bumpout Bioretention
Tree Cover
Permeable Pavement

- Building Roofs (9 sq mi)
- Sidewalks (3 sq mi)
- Streets (8 sq mi)
- Parking Lots (3 sq mi)
- Alleys (1 sq mi)
GBOM Green Infrastructure Representation

Evapotranspiration

Rainfall

Runoff to surface

Depression Storage = GI Storage Volume
Green Buildout Model

- Identified the potential benefits of GI implementation
- Quantified District-wide runoff reductions
- Formed basis for moving forward with Green Infrastructure
Project and Model Progression

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Closer to Green Infrastructure Construction

More detailed modeling and monitoring
Model Development

- 2010-2013 SWMM5/MIKE URBAN coupled model
  - We know that GI is feasible in certain areas. How much do we need?
  - Shift to SWMM5 to leverage LID Controls
  - GI represented as mix of bioretention, pervious pavement, cisterns, and rain barrels
  - Higher resolution drainage areas
  - Link *runoff reduction* to *combined sewer overflow reduction*
  - Can we use GI to offset tunnels?
SWMM5 and MIKE URBAN Linkage

SWMM GI/Runoff Model

- Precipitation
- Land Characteristics
- Green Infrastructure

Runoff to collection system

MIKE URBAN Hydraulic Model

- Tidal Boundary Conditions
- External Flow Boundary Conditions
- System Operations
- Dry-weather Flow

CSO Overflow and Volume
SWMM5 Runoff Framework
SWMM5 LID Controls

- Environmental Variables
  - Infiltration
  - Evapotranspiration (ET)

- Design Variables
  - Volume capture
  - Time to empty
## Results

- Indicated performance comparable to Long Term Control Plan using mix of green infrastructure and grey infrastructure

### EXAMPLE RESULTS FROM GROUP OF SCENARIOS

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>% GI</th>
<th>TUNNEL VOL (ML)</th>
<th>STRUCTURE 70 WEIR HEIGHTS</th>
<th>CSO PREDICTIONS (AVE YR)</th>
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Model Scenario Progression

- General approach:
  - Increase GI within reasonable limits
  - Is increase in GI enough to offset tunnel?
  - Make small but detailed changes in grey infrastructure controls necessary to meet reduction goal

- Over 60 scenarios evaluated and modeled for CSO overflow frequency and volume
Results

- Optimized Green/Gray approach
  - Remove and/or “right-size” tunnels
    - Potomac River Tunnel reduced from 58 MG to 30 MG
    - Piney Branch Tunnel eliminated
  - Determined % GI implementation
    - Range 30% to 60% across select sewersheds
  - Refined control structure modifications
Project and Model Progression

- **1998**: CSO Long-term Control Planning Begins
- **2007**: Green Buildout Model
- **2013**: Proposed Modified Consent Decree
- **2015**: GI Design Standards

The timeline highlights key milestones in project progression.
Develop GI Design Standards

- What if we let low flows bypass GI?
- What if GI is not uniformly distributed?
- What if we make our GI larger/smaller?
First Flush Bypass Modeling

- Bypass small amount of flow to save storage volume for the “peak” of the storm
- Used 3-year “average” period to test concept
- Results were mixed. In general, bypass only beneficial if full treatment depth cannot be obtained.

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<td>1.13</td>
<td>1.05</td>
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**50% Impervious**

FFB Flow Rate per 10 acres (cfs)
Location Sensitivity

- Determine if effect exists from applying GI in upstream vs. downstream locations (sewershed wide)
- Catchments grouped into near, mid and far travel times
- 1.2 inches runoff routed into idealized GI practices, which drain in 48 hours
Volume of GI practices used in model were varied to capture full range of runoff depths over contributing area.

As treatment depth increases, the number of events exceeding GI capacity decreases.

At treatment depth greater than 1.2” diminishing to no returns on investment.
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Next Steps

- Monitor green infrastructure sites before and after GI implementation
- Incorporate detailed GI practices into models based on site-specific monitoring
- Incorporate GI model results in receiving water quality modeling of rivers – link runoff reduction and water quality improvement
- Use modeling to inform the GI implementation process as the DC Clean Rivers Project moves forward
Special thanks to:
John Cassidy, Volker Janssen, Brad Udvardy, Seth Charde, Caitlin Feehan
Brian Busiek, Mike Sullivan, Justin Carl, Ed Shea, Carlton Ray

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