Continuous Calibration Promises Savings in Meeting Wet Weather Compliance Requirements

Date: June 20, 2012
Outline

• Introduction- City of Columbus, Ohio WWMP and Early Ditch Project
• Primary Goals of Early Ditch I/I Study
• Introduction to Model Development
• Initial recommendations based on the Design Storm Approach
• EPRP Goals and Objectives
• Continuous Calibration and Definitions
• Results of Continuous Calibration
• Cost Savings
• Conclusions
USEPA issued two sets of Federal Consent orders to the City of Columbus in 2002 and 2004.

Wet Weather Management Plan (WWMP) was developed in response to the Consent Order. The goal was to mitigate or eliminate overflows.

Several Priority Areas were developed and CIP 405.8 Early Ditch I/I Study Area was one such priority area.
Goals of Early Ditch I/I Study

Primary Goal of the project was to eliminate the following up to a 10-year level of service per the City of Columbus WWMP.

- Eliminate Sanitary Sewer Overflows (SSOs)
- Eliminate Designed Sanitary Relief (DSR) Activations
- Address Water-in-Basement (WIB) Occurrences based on hydraulic bottlenecks.
Project Background

• Project began in 2006
• Clean and CCTV 517,000 linear feet sanitary sewers
• Flow Monitoring
• Field Investigate Public and Private Sources
• Hydraulic Model Development
• Provide compliance with the City’s “SSO Consent Order” & Identify Improvements to Eliminate
  – DSR 250, 252, 254, and 256
  – SSOs
• Mitigate WIBs
**Project Area**

- Tributary Area = 2,831 acres
- Primarily Residential Development - ~11,200 homes
- Discharges to Early Ditch Trunk Sewer
ED I/I Study Modeling

Sanitary Only PCSWMM (EPA SWMM 5 engine)

- 2,656 nodes
- 2,723 conduits
- 2,831 acres
- Comprehensive flow monitoring and rain gauge program (46 Flowmeters, 4 Pairs of Rain Gauges) for more than 1 year).
Stepping back….Why do we model?

- Models serve as a predictive tool for simulating Inflow and Infiltration
- Modeling helps predict capacity constraints and useful tool for Level of Service Analysis and developing Mitigation Alternatives
- Calibration is an integral part of modeling
Components of Wet Weather Flow
RDII Modeling Methodology

- RTK Method is well established and widely used in the modeling industry.

- RTK Method assumes a unit hydrograph to represent a system’s response to a unit of rainfall.

(From Computer Tools for Sanitary Sewer System Capacity Analysis and Planning, EPA/600/R-07/111, October 2007)
RDII Analysis (Short Term, Medium Term and Long Term RTKs)

R is the fraction of rainfall volume entering the Sewer;
T is the time from the onset of rainfall to the peak of the RDII hydrograph
K is the ratio of time to recession of the RDII hydrograph to the time to peak.
Event Based Calibration

- Traditional Approach

- Calibration to selective storms usually a combination of big and small storms

- Effort to adjust several modeling parameters so as to simulate flow, depths etc. for a particular storm/s where flows and depths are actually measured

- Average RTKs selected for verification and design storm analysis
Event Based Hydrographs with Multi-Storm RTKs
# Existing System Capacity Analysis

<table>
<thead>
<tr>
<th>Existing System</th>
<th>10-Year LOS (Event Based)</th>
<th>Meets Level of Service Objective?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential WIB Occurrences</td>
<td>5,960</td>
<td>No</td>
</tr>
<tr>
<td>Potential SSO Occurrences</td>
<td>200</td>
<td>No</td>
</tr>
<tr>
<td>Predicted SSO Flooding Volume (MG)</td>
<td>4.30</td>
<td>No</td>
</tr>
<tr>
<td>Potential DSR Activations</td>
<td>4</td>
<td>No</td>
</tr>
<tr>
<td>Predicted DSR Flooding Volume (MG)</td>
<td>2.38</td>
<td>No</td>
</tr>
</tbody>
</table>
Alternatives Analysis 2010 (10yr Design Storm and Event based RTKs)
City of Columbus EPRP and Goals

- Expert Peer Review Panel (EPRP) SWMM Modeling Guidelines, November 2010

- City of Columbus Objectives
  - Increase confidence in project sizing
  - Move beyond design storm approaches to include statistically robust continuous simulation-based approaches
  - Promote consistency in modeling of existing and proposed wet-weather facilities amongst consultants and across projects
Calibration Approach-
- Use of long term good quality flow monitoring data to calibrate models
- Properly represents inter-event hydrology and soil storage fill/drain behavior to characterize system performance.

Simulation Approach-
- Use of long term rainfall record
- Modified Continuous Simulation approach for I/I Basin Studies
Hydrologic Cycle
Definitions

• Antecedent Moisture Conditions
  - Plays a major role on RDII peak and volume
  - More RDII will be captured by the collection system when the soil around is in a more saturated condition and vice versa.

• Initial Abstraction (in)
  - The amount of rainfall that will be intercepted before RDII enters the collection system.

• Recovery (in/day)
  - Recovery is the process of regenerating the initial abstraction, or draining the effective storage between rainfall events.
SWMM 5 Functionality

Unit Hydrograph Editor

- Name of UH Group
- Rain Gage

Month
- All Months
- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

Hydrograph Parameters

<table>
<thead>
<tr>
<th>Response Type</th>
<th>R</th>
<th>T</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-Term</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-Term</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Long-Term</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R = fraction of rainfall that becomes I&I
T = time to hydrograph peak (hours)
K = falling limb duration / rising limb duration

Initial Abstraction Parameters:

| Maximum Depth, in
| Recovery Rate, in/day
| Initial Depth, in |
|-------------------|-------------------|-------------------|

OK Cancel Help
Applications to Early Ditch Model

• Data from October 2006 to September 2007

• Early Ditch model
  – Monthly Ground Water Infiltration (GWI) Patterns
  – 2 sets RTKs (Fast, Medium, Slow)
    • October to March (Dormant Season)
    • April to September (Growth Season)
  – Monthly Initial Abstraction and Recovery Rates
Continuously Calibrated Basin

Graph showing rainfall in inches per hour, depth in feet, and total inflow in cfs over time from Mar 2007.
Initial Abstraction vs Evaporation Rate
Recovery vs Evaporation Rate
Continuous Simulation

- A Continuously Calibrated Model is ideally suited for continuous simulations

- Availability of long term rainfall record (60-years of record from Port Columbus International Airport)

- Extremely long run times

- Computer processors
Modified Continuous Simulation - Basis

- We wanted to find the biggest flow producing storms that occurred in the last 60 years
- Top storms of each duration – 1 hour through 72 hours
- Time series generated using 71 unique storms

Table 1: Distribution of Selected 71 Storms
Modified Continuous Simulation - Basis

Table 1: Distribution of Selected 71 Storms

<table>
<thead>
<tr>
<th>Month</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>6</td>
</tr>
<tr>
<td>February</td>
<td>0</td>
</tr>
<tr>
<td>March</td>
<td>3</td>
</tr>
<tr>
<td>April</td>
<td>0</td>
</tr>
<tr>
<td>May</td>
<td>3</td>
</tr>
<tr>
<td>June</td>
<td>16</td>
</tr>
<tr>
<td>July</td>
<td>22</td>
</tr>
<tr>
<td>August</td>
<td>15</td>
</tr>
<tr>
<td>September</td>
<td>3</td>
</tr>
<tr>
<td>October</td>
<td>1</td>
</tr>
<tr>
<td>November</td>
<td>1</td>
</tr>
<tr>
<td>December</td>
<td>1</td>
</tr>
</tbody>
</table>
Tropical Storm Season in US

Average Number of Hurricanes per Month  Atlantic 1950-2001

Number of Hurricanes

Month
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Comparison of GWI to Average Treatment Plant Flow

![Comparison of GWI to Average Treatment Plant Flow](image_url)
Modified Continuous Simulation – Created Time Series

• 15 month time series using the 71 historical storms

• Storm placed in month of occurrence (exact date not used)

• Ranked top 10 storms
Compare 10yr Design Storms to Top 10

10 year Design Storm Exceeds 50 Year Continuous Calibration

Flow Rankings

- No. 1
- 10yr 6hr SCS (Jan.)
- 12hr SCS (Jan.)

Model Peak Flow (cfs)

<table>
<thead>
<tr>
<th>Storms</th>
<th>Modeled Peak Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>200</td>
</tr>
<tr>
<td>No. 2</td>
<td>150</td>
</tr>
<tr>
<td>No. 3</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>75</td>
</tr>
<tr>
<td>No. 5</td>
<td>50</td>
</tr>
<tr>
<td>No. 6</td>
<td>30</td>
</tr>
<tr>
<td>No. 7</td>
<td>20</td>
</tr>
<tr>
<td>No. 8</td>
<td>15</td>
</tr>
<tr>
<td>No. 9</td>
<td>10</td>
</tr>
<tr>
<td>No. 10</td>
<td>5</td>
</tr>
</tbody>
</table>

Rainfall Intensity (in/hr)

- No. 1 (Total 5.24in)
- 10yr 6hr SCS (Total 2.79in)
- 10yr 6hr Huff (Total 2.89in)

- No. 2 (Total 5.42in)
- No. 3 (Total 3.25in)
- No. 4 (Total 2.56in)
- No. 5 (Total 2.4in)
- No. 6 (Total 3.12in)
- No. 7 (Total 3.56in)
- No. 8 (Total 3.02in)
- No. 9 (Total 4.29in)
- No. 10 (Total 4.11in)

Time (hr)
Compare Peak Flow – Historical Rainfalls & Design Storms

Flow Rankings

Dormant Season

Growth Season

Recommended Storm for ED----10yr 6hr Huff with October AMC Conditions
## Cost Comparison between EB and CC Alternatives

<table>
<thead>
<tr>
<th></th>
<th>Event Based Model (Preferred Alternative)</th>
<th>Continuously Calibrated Model (Preferred Alternative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyance</td>
<td>7 miles</td>
<td>4.7 miles</td>
</tr>
<tr>
<td>Storage</td>
<td>12 MG</td>
<td>No Storage</td>
</tr>
</tbody>
</table>

Significant Savings based on differences
Conclusions

• Continuous Calibration has profound effects on R values and peak flows.

• Reliance on typical design storms with low winter abstraction/recoveries or without inter-event hydrology will over predict flow in the sanitary sewer system.

• In this day and age of reduced funding and heightened compliance, this is a practical approach to addressing wet weather compliance needs that other communities can implement.
Thank you!

Questions?