NEXT GENERATION OF SEWER MODELING - ISOLATING RDII SOURCES

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OWEA June 2017

Presenter

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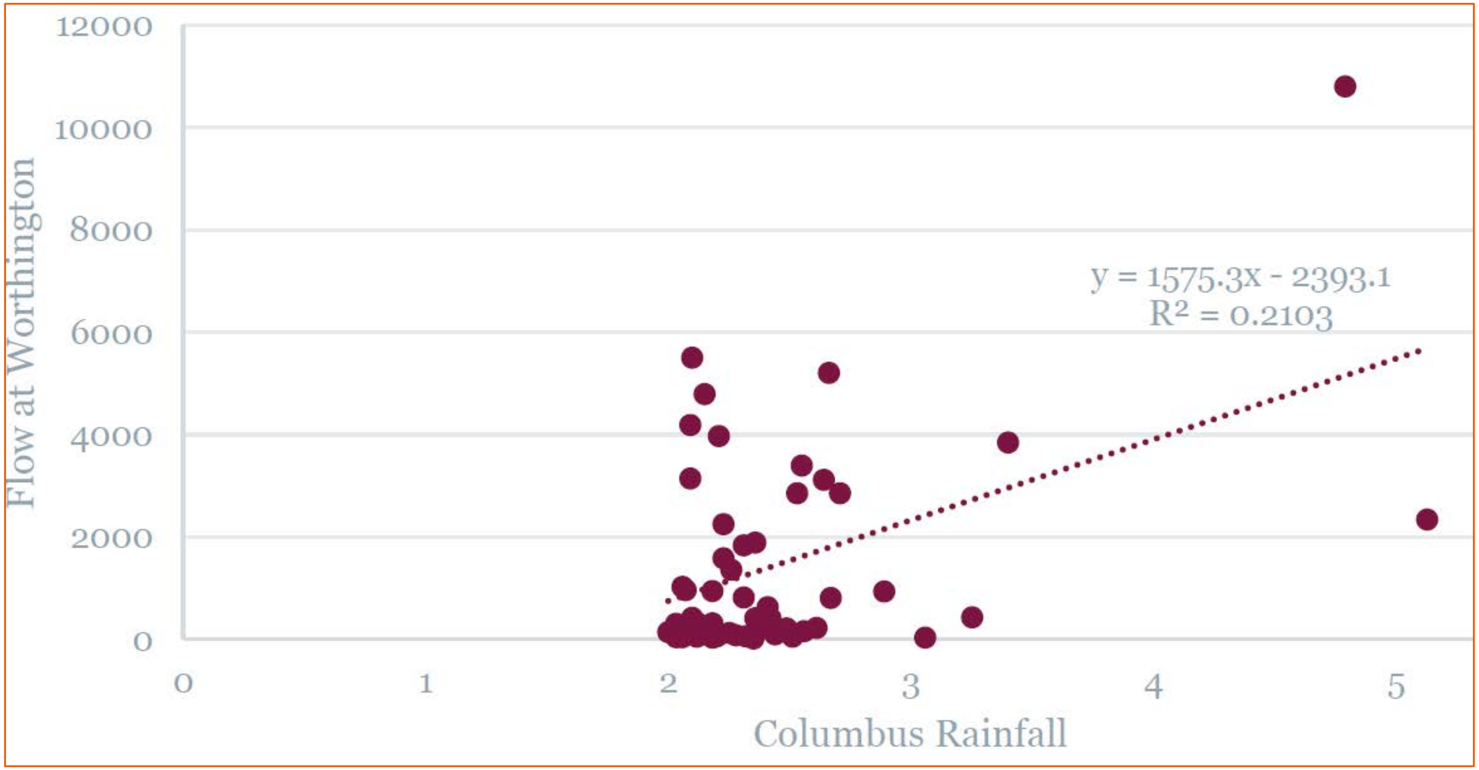
Urban Drainage Technical Leader

- 31 years of engineering experience
- Collection systems modeling and planning
- Stormwater management, green infrastructure programs
- New modeling approach to quantify flows at the source

Next generation of H/H Modeling

Answers the apparent randomness in Rain to RDII relationship



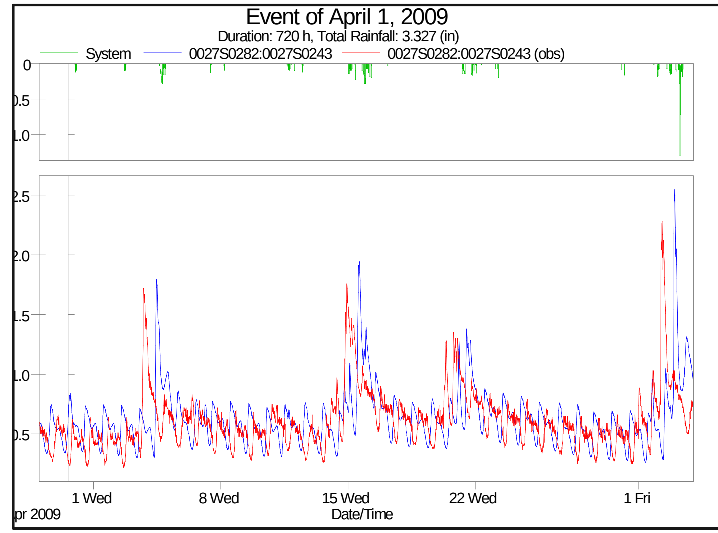
Next generation of Sewers Modeling Goals

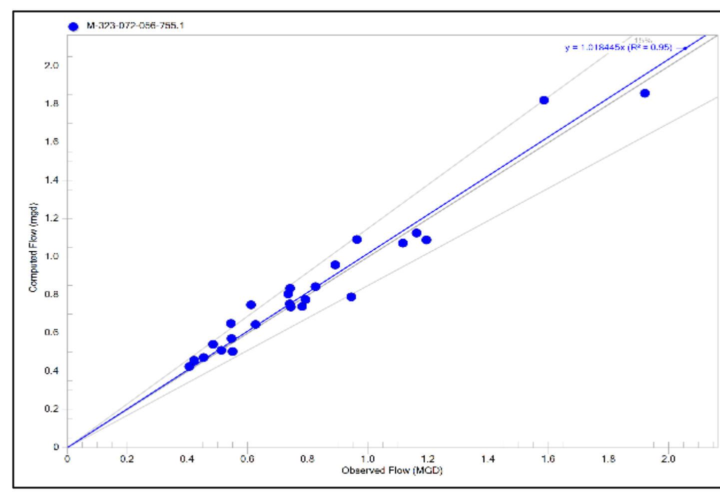
Goal:

- A planning tool (model) that matches all storms, across years of monitoring data
- A model platform that will include and isolate the various sources of RDII and runoff

Benefits:

- Reoccurrence of deficiencies is quantified using actual historical rainfall data – no more design storms
- Plan improvements that would include source control
- Reduce conservativeness or risk of under sizing improvements





Outline

- RDII Sources
- Physically Based Modeling Approach
- Continuous Calibration Results
- Planning RDII Mitigation Plans
- Example Case Study

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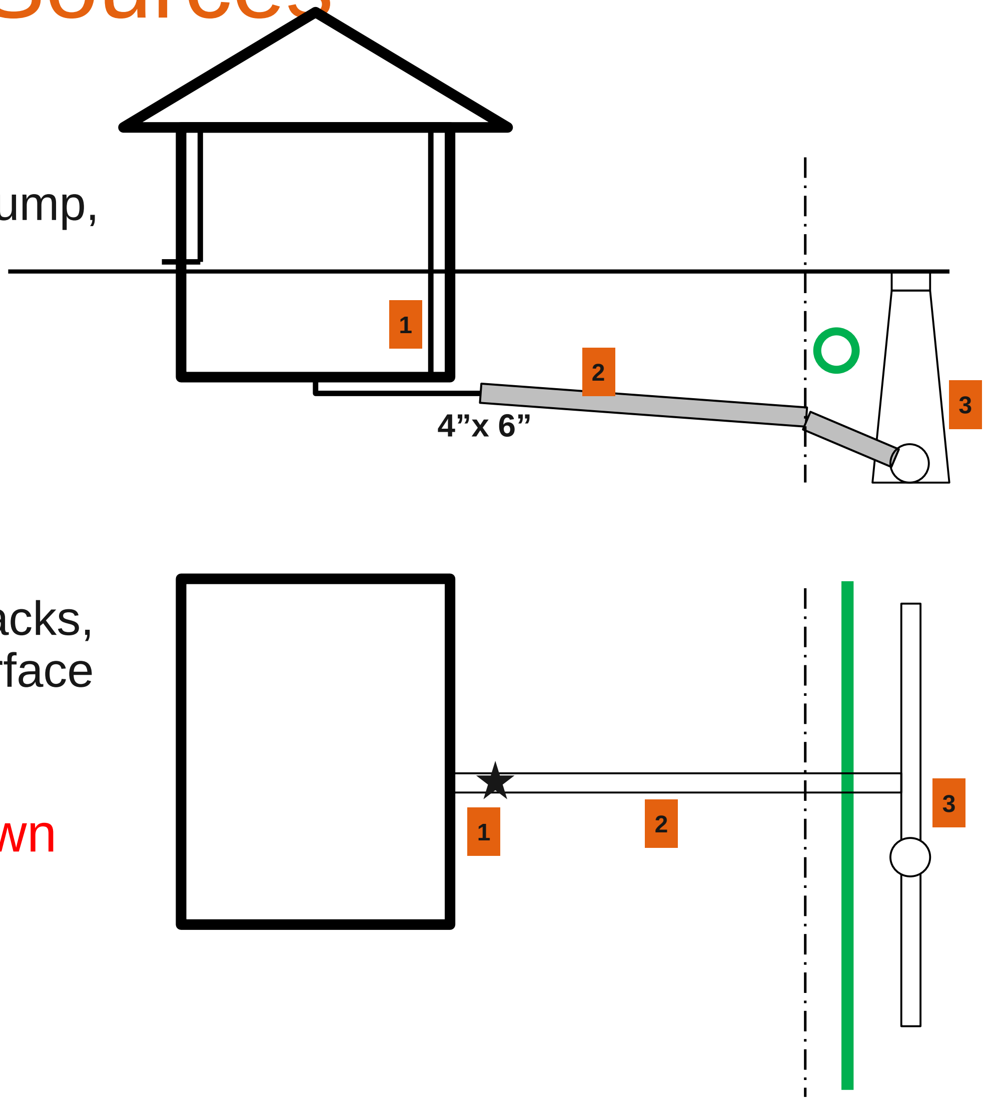
RDII Subsurface Sources

1. Foundation
   - ✓ Drains, 4”x 6”, illegal sump pump, etc.
2. Lateral Service Lines
   - ✓ Joints, cracks, roots intrusion
3. Sewer Mains
   - ✓ Lateral connection, joints, cracks, manholes under pervious surface

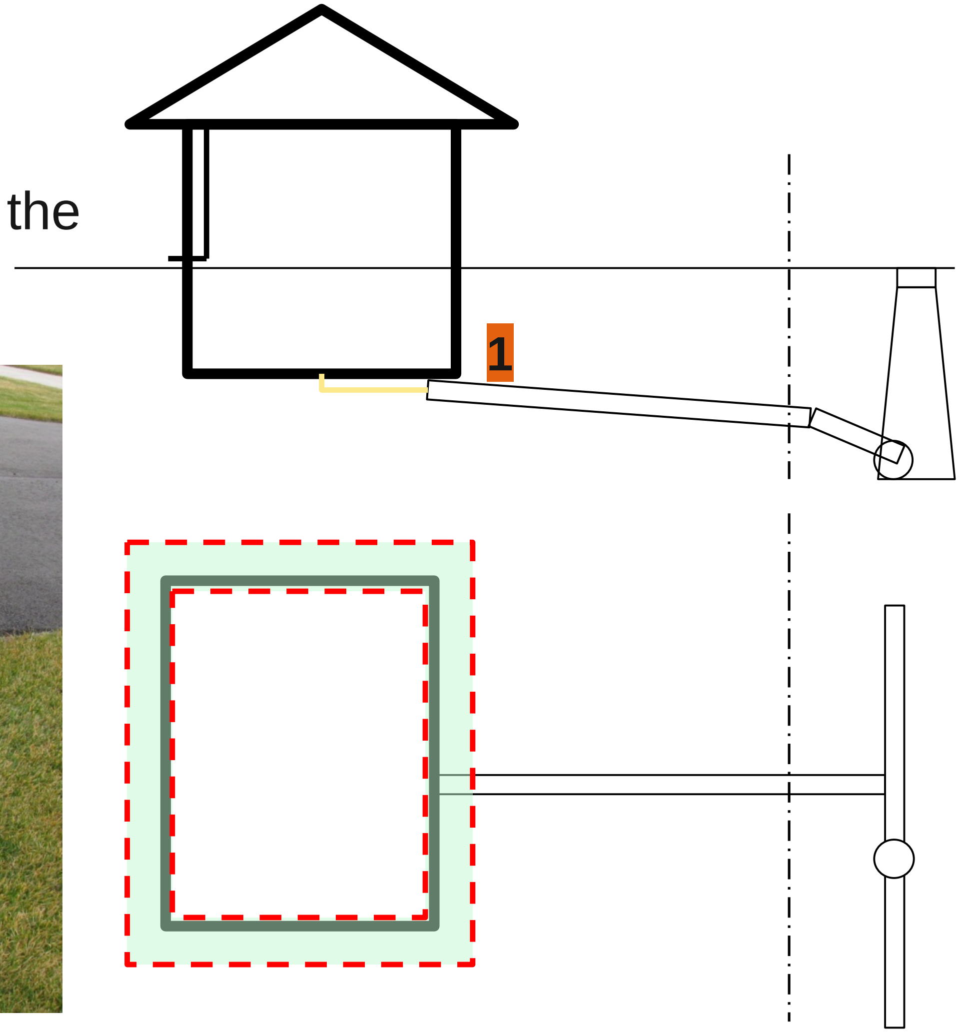
Each RDII point source receives flow from a known contributing runoff area



1. Foundation

Runoff area:

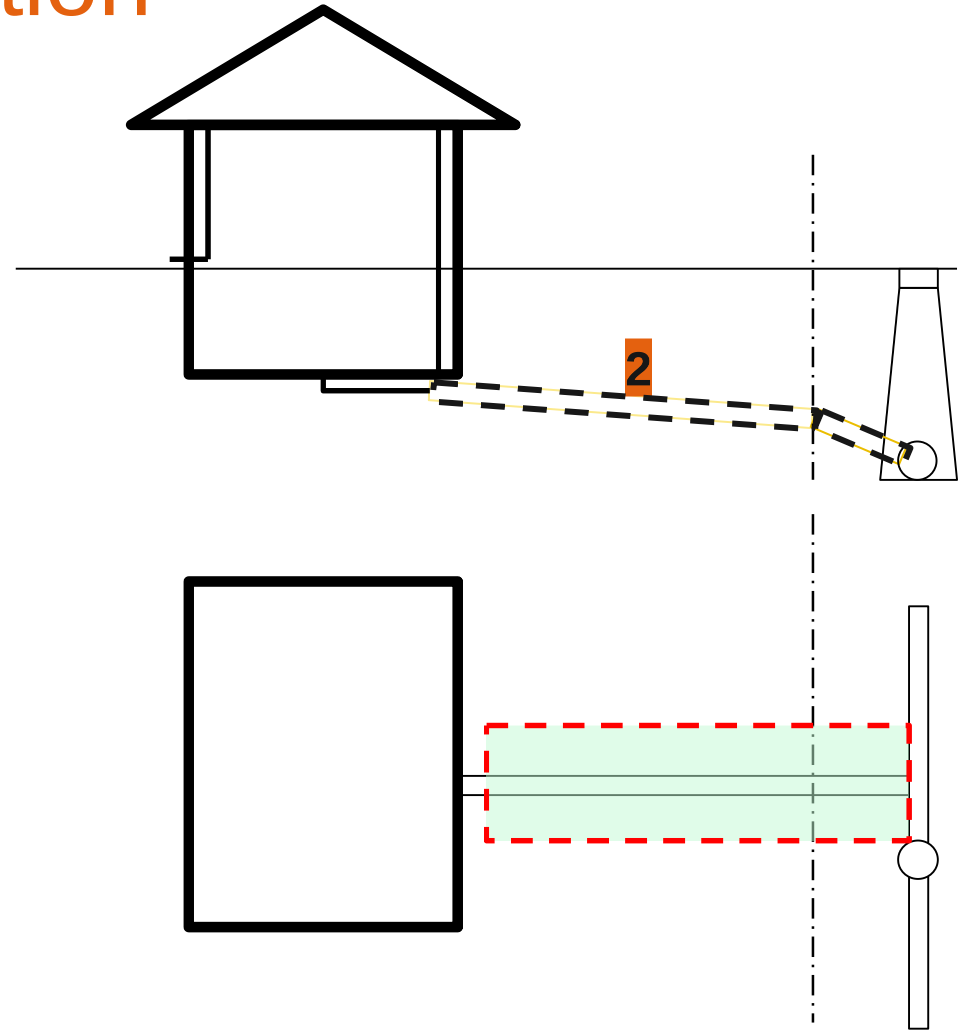
Roof top and splash area around the house (buffer ~ 6 ft or less)



2. Lateral Connection

Runoff area:

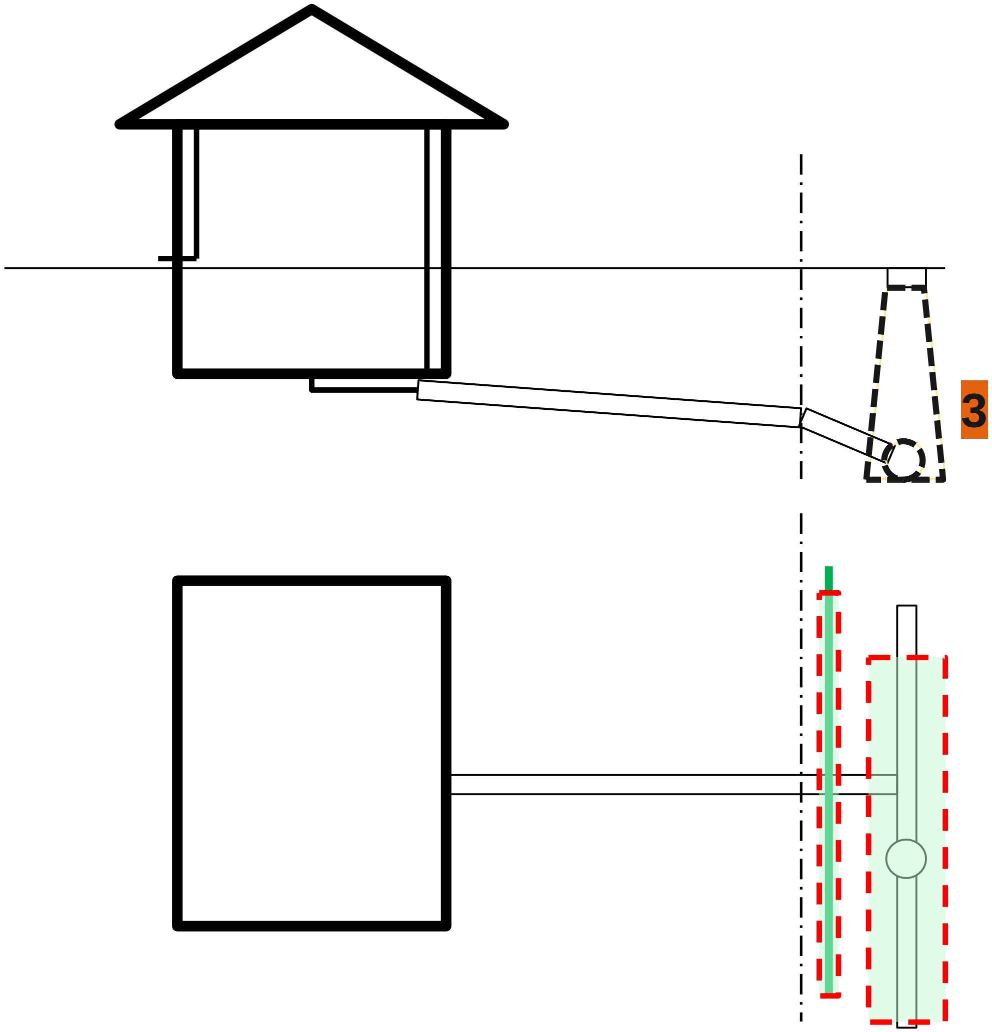
Buffer (~ 12 ft) area above the lateral pipe



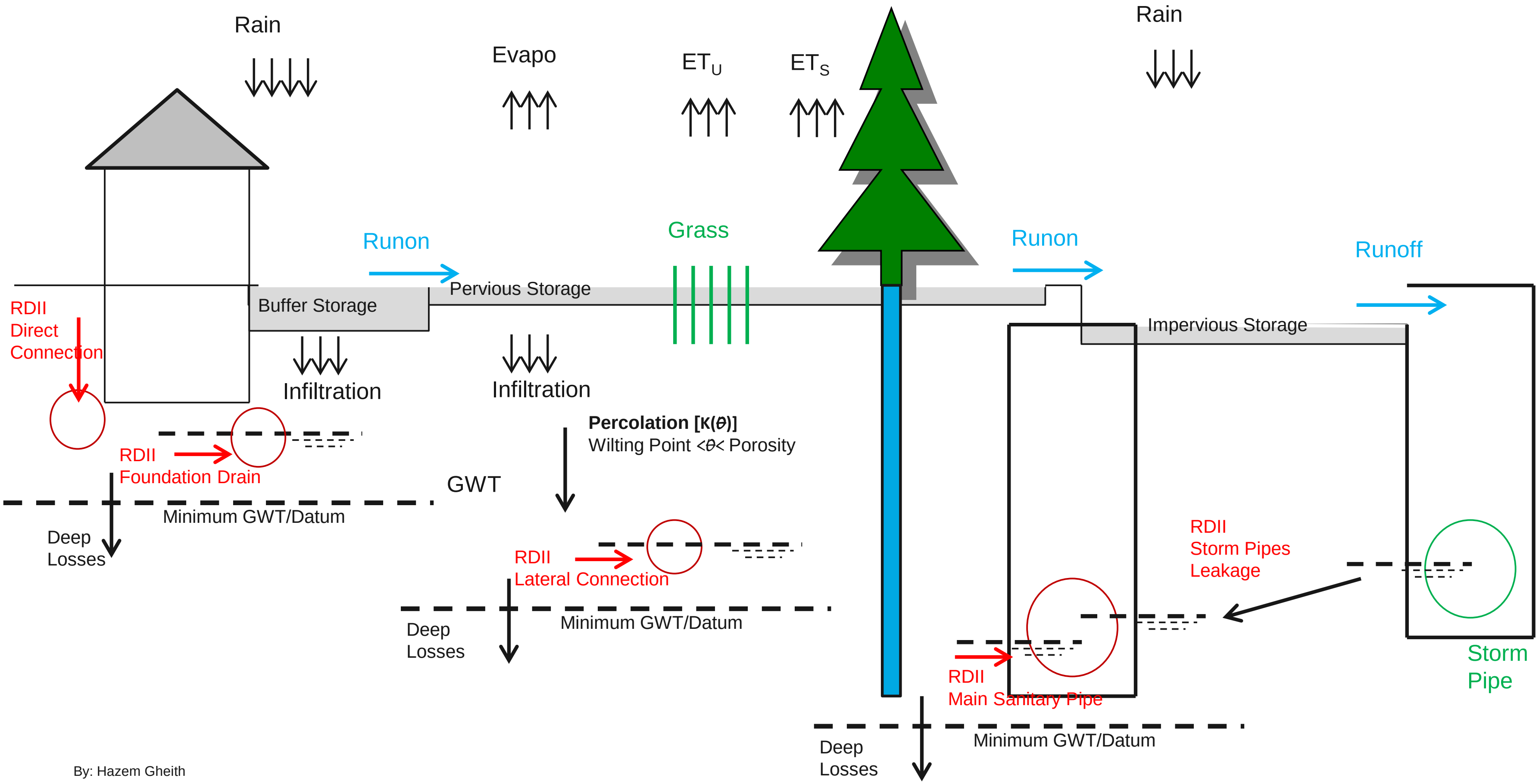
3. Sewer Main

Runoff area:

- Buffer area if sewer is under pervious surface
- Co-located with storm trench



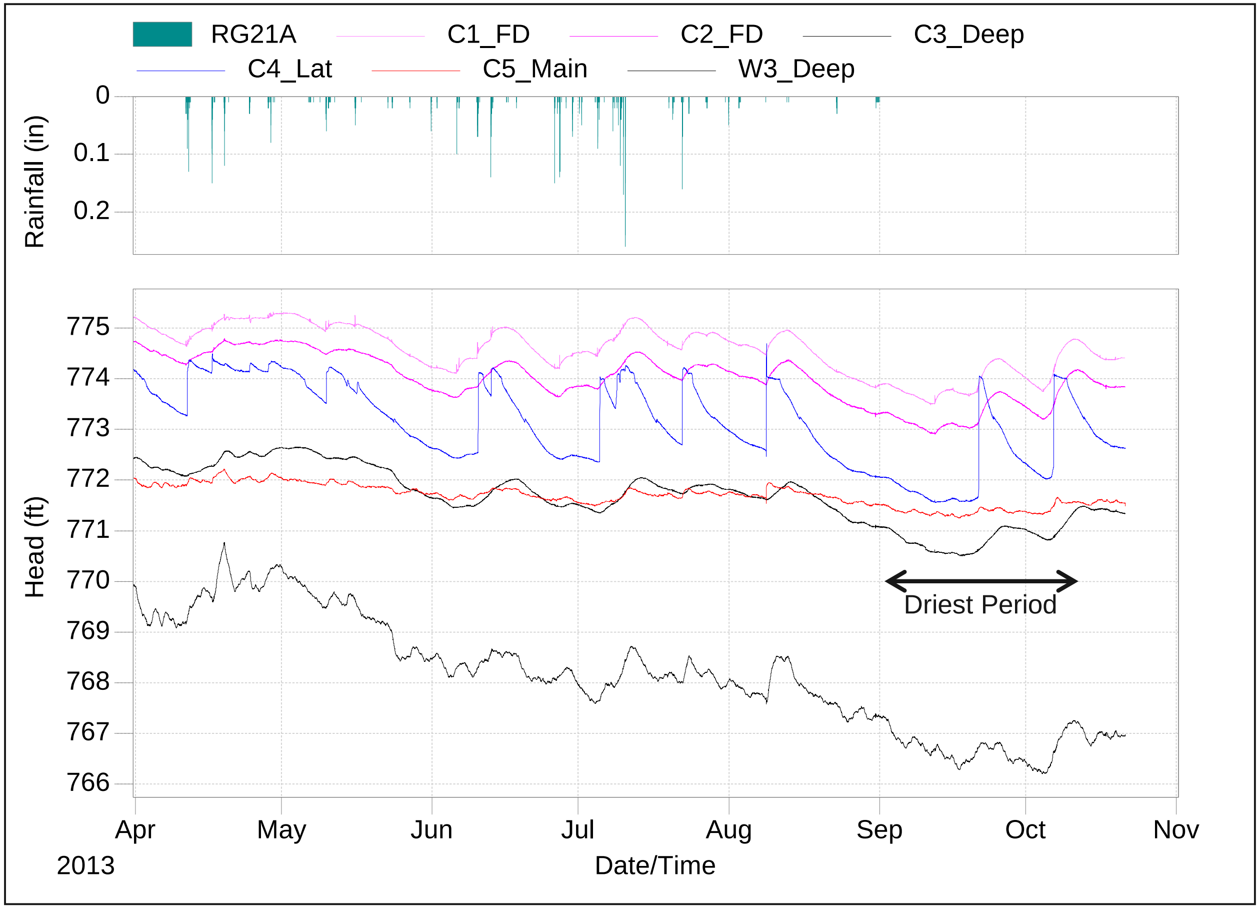
GWI in Relation to RDII



By: Hazem Gheith

GWT Monitoring

- Aquifers are independent due to clay soil



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Subarea Delineation

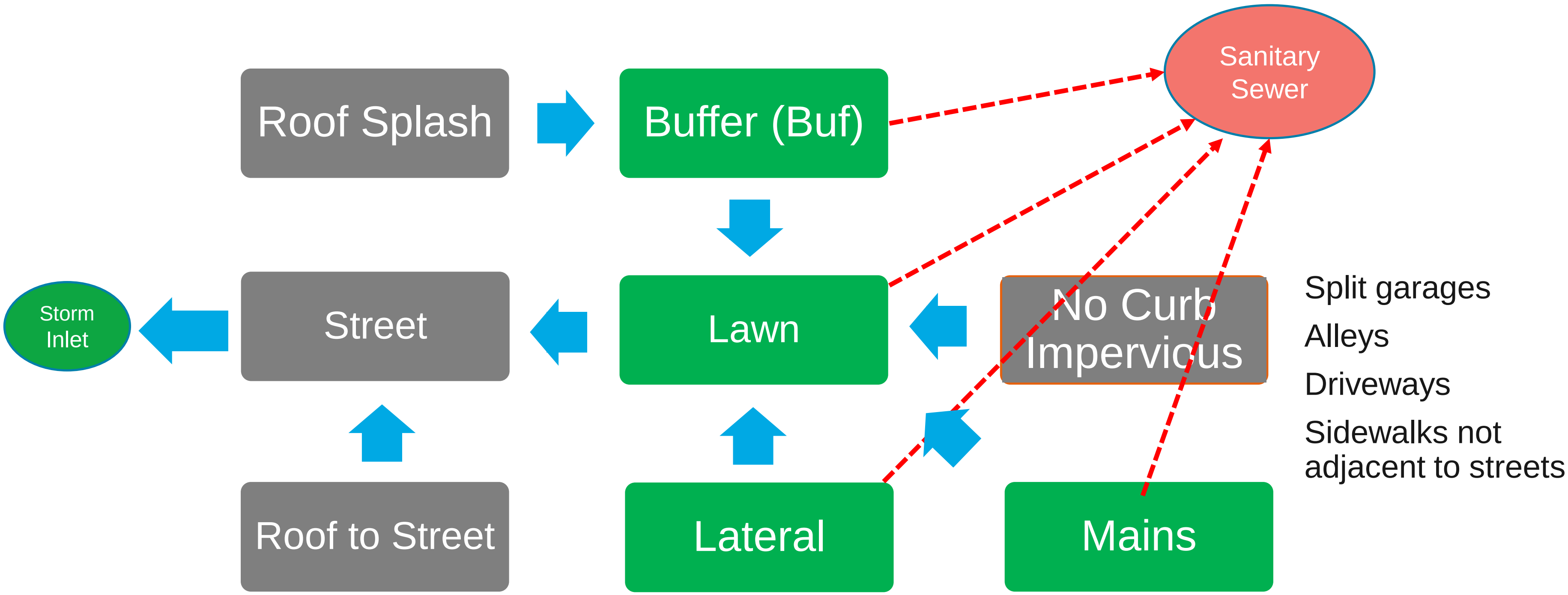
- Use the available wealth of GIS data
- Split the independent hydrology features (subareas) in each catchment

Model Visualization

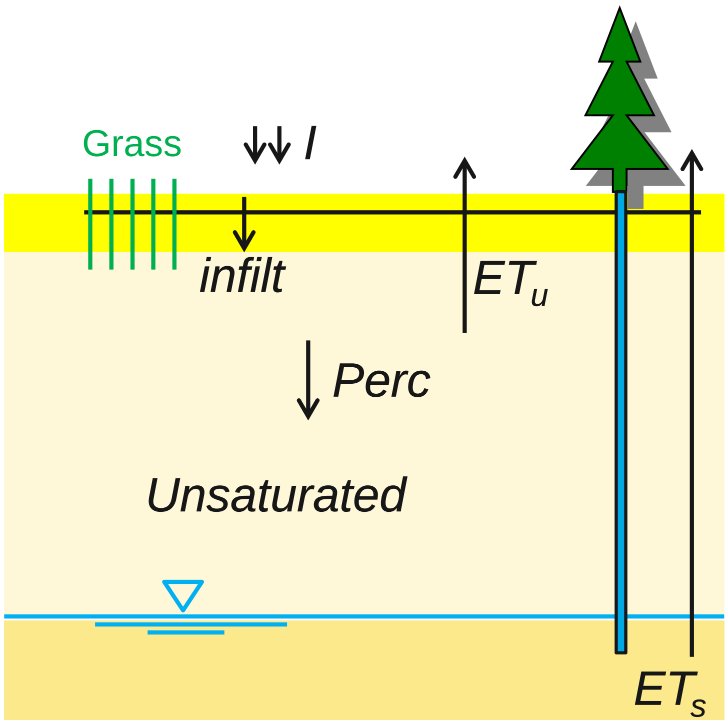
Subareas can be visualized “as is” in the model, preserving their spatial location.

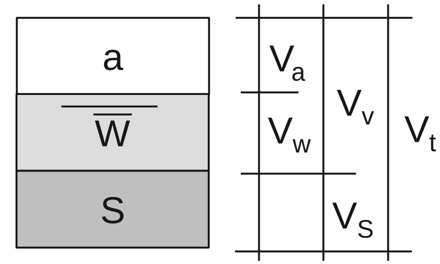
Sewershed Subareas

Each sewershed consists of individual hydrologic subareas

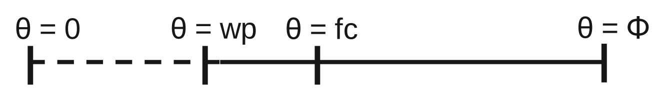


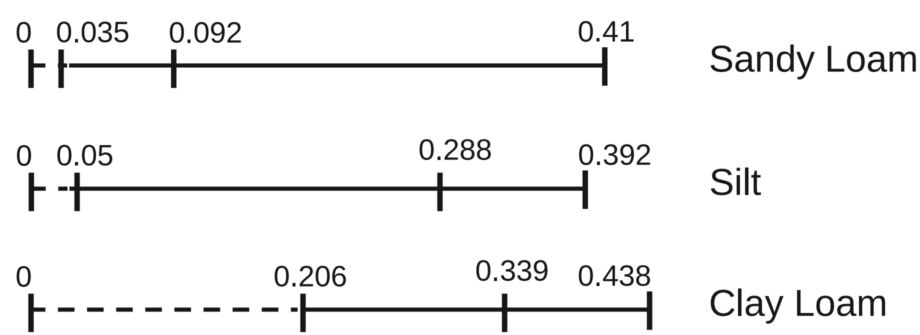
Physics of the Unsaturated Zone





Moisture Content $\theta = \frac{V_w}{V_t}$ Porosity $\Phi = \frac{V_v}{V_t}$





GWI Governing Equations (SWMM)

- Infiltration Process (Green-Ampt):

$$f = \begin{cases} I \; before \; ponding \\ K_s \left[1 + \dfrac{\Psi(\phi - \vartheta)}{F_{total}}\right] \end{cases}$$

- Percolation Process:

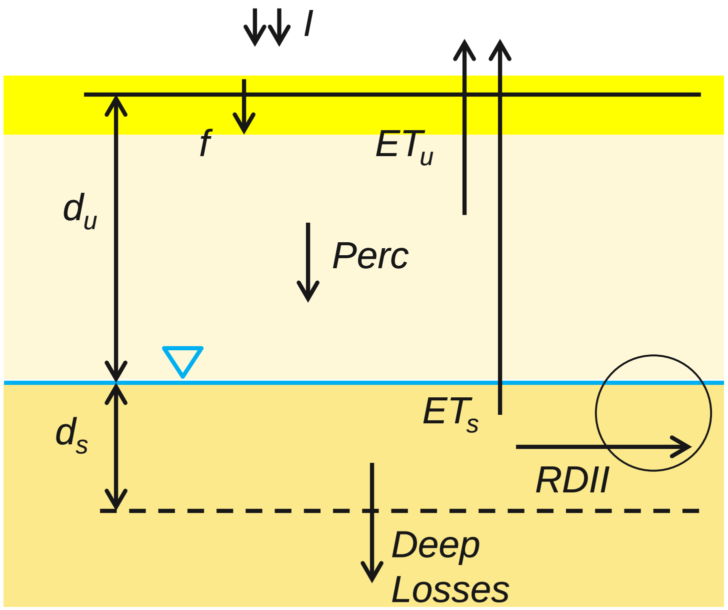
$$\begin{cases} \Delta\vartheta d_u = f A'_p - ET_u A'_p - Perc \\ ET_u = C_{ET} \, Evapo \\ Perc = \dfrac{K_s}{e^{(\phi-\vartheta)HCO}} \left[1 + \dfrac{\Psi'(\vartheta - \vartheta_{FC})}{d_u/2}\right] \end{cases}$$

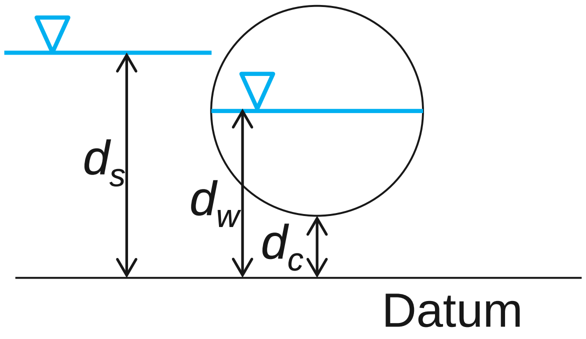
- RDII Process

$$(\phi - \vartheta)\Delta d_s = Perc - ET_s A'_p - D_L \frac{d_s}{d_{total}} - RDII$$

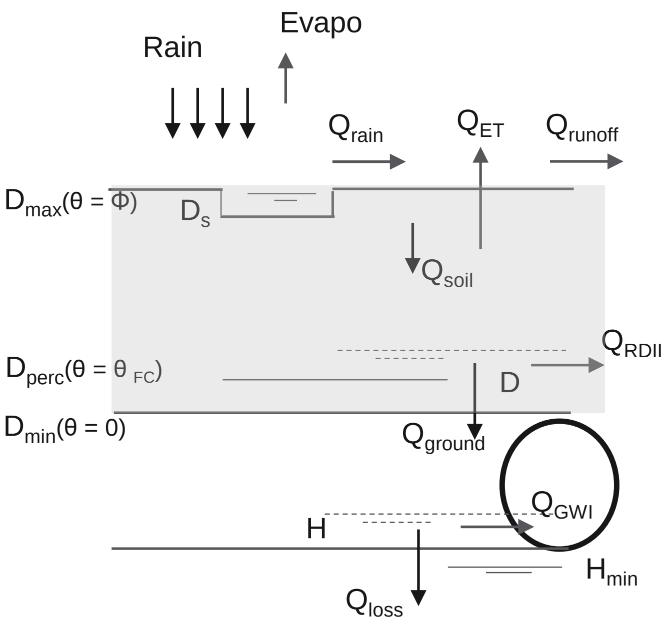
$$ET_s = (1 - C_{ET}) \, Evapo \frac{d_{tree} - d_u}{d_{tree}}$$

$$RDII = a_1 (d_s - d_c)^{b_1} - a_2 (d_w - d_c)^{b_2}$$





ICM Aquifers Approach



$$Q_{soil} = K_h \left[1 + \frac{\psi(\Phi - \theta_{wp})}{F}\right] * A$$

$$\Phi Q_{perc} = \alpha Q_{RDII} + (1 - \alpha) Q_{ground}$$

$$\frac{D_{perc}}{D_{max}} = \frac{\theta_{FC}}{\Phi}$$

$$ET = \frac{D}{D_{max}} Evapo \quad * \, monthly\ factor$$

Month	ET Coefficient
January	0.10
February	0.10
March	0.20
April	0.40
May	0.40
June	0.70
July	0.80
August	0.80
September	0.75
October	0.65
November	0.65
December	0.50

$$Q_{ground} = \frac{(D - D_{perc})\Phi A}{K_1}$$

$$Q_{loss} = \frac{(H - H_{min})A}{K_2}$$

$$Q_{GWI} = \frac{H^{1/2}}{K_3}$$

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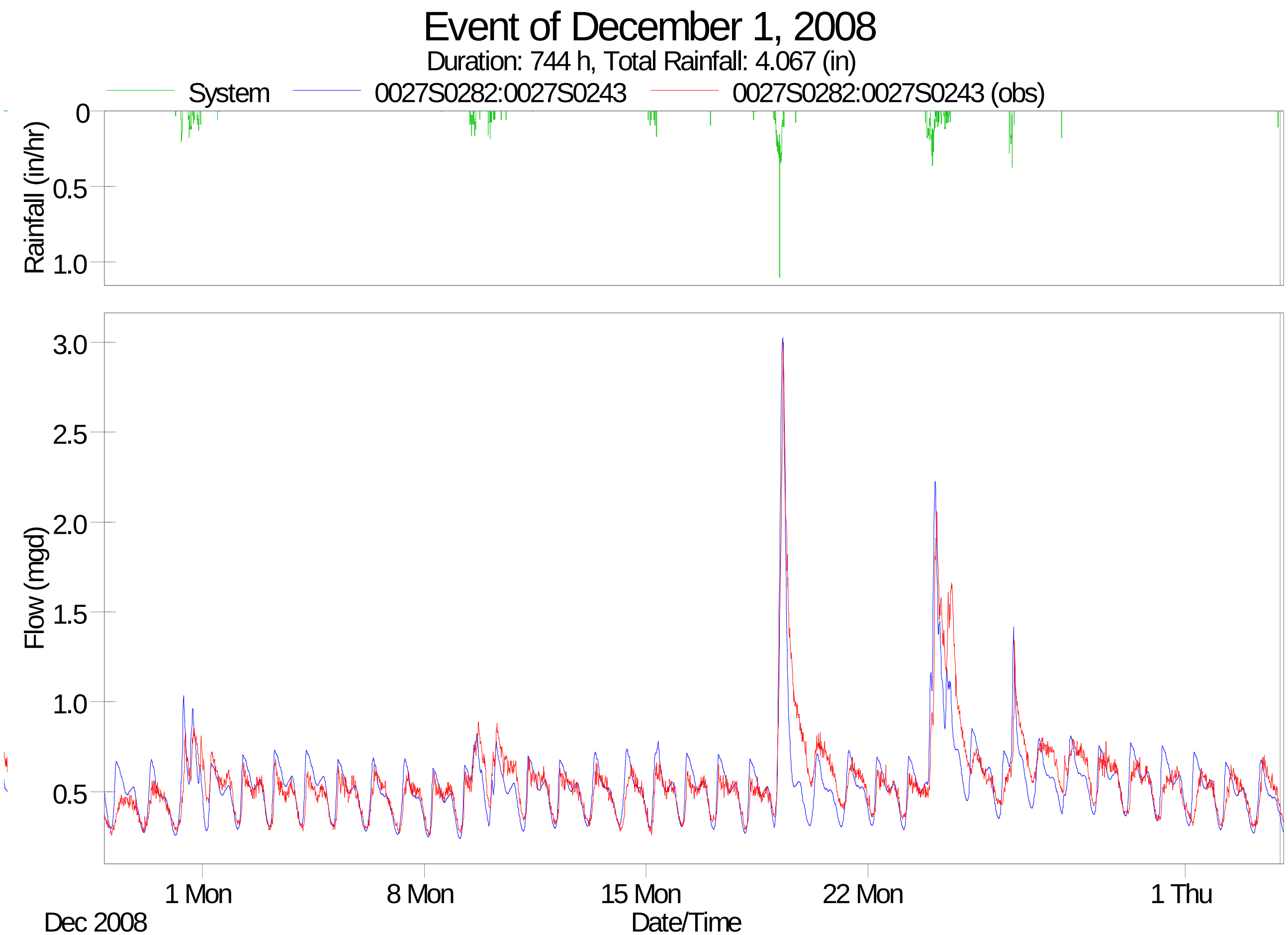
Continuous Calibration Examples – Columbus



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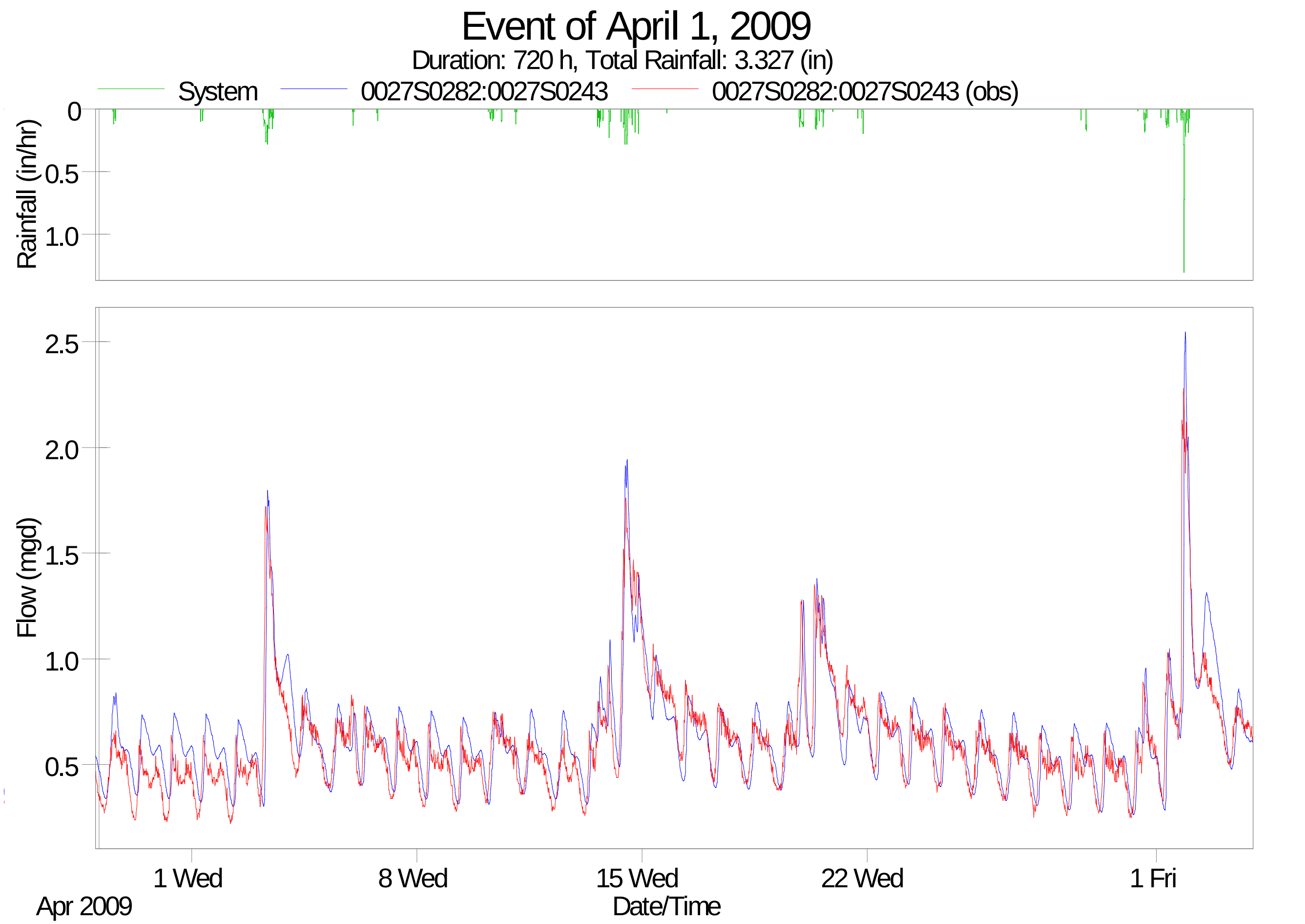

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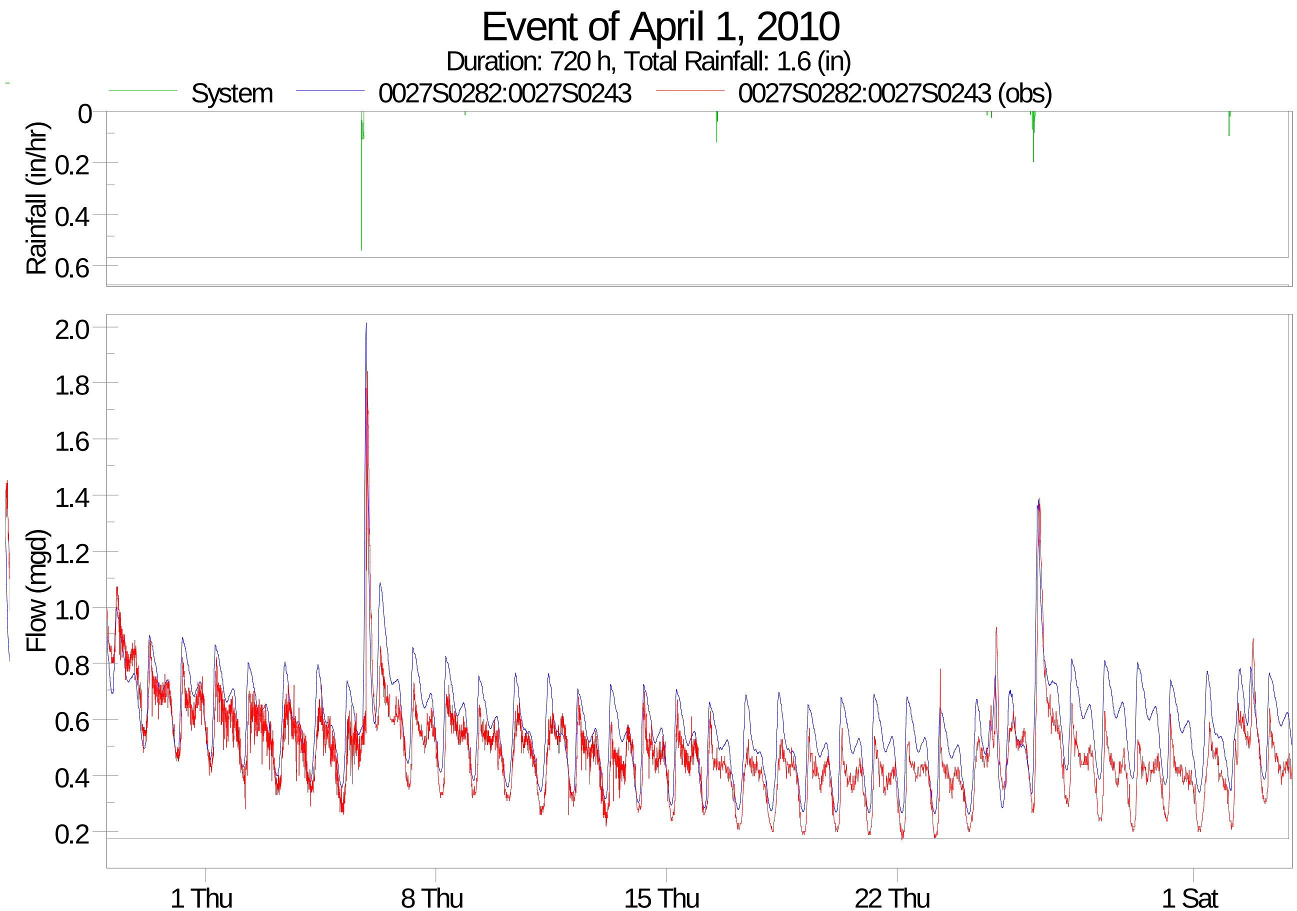

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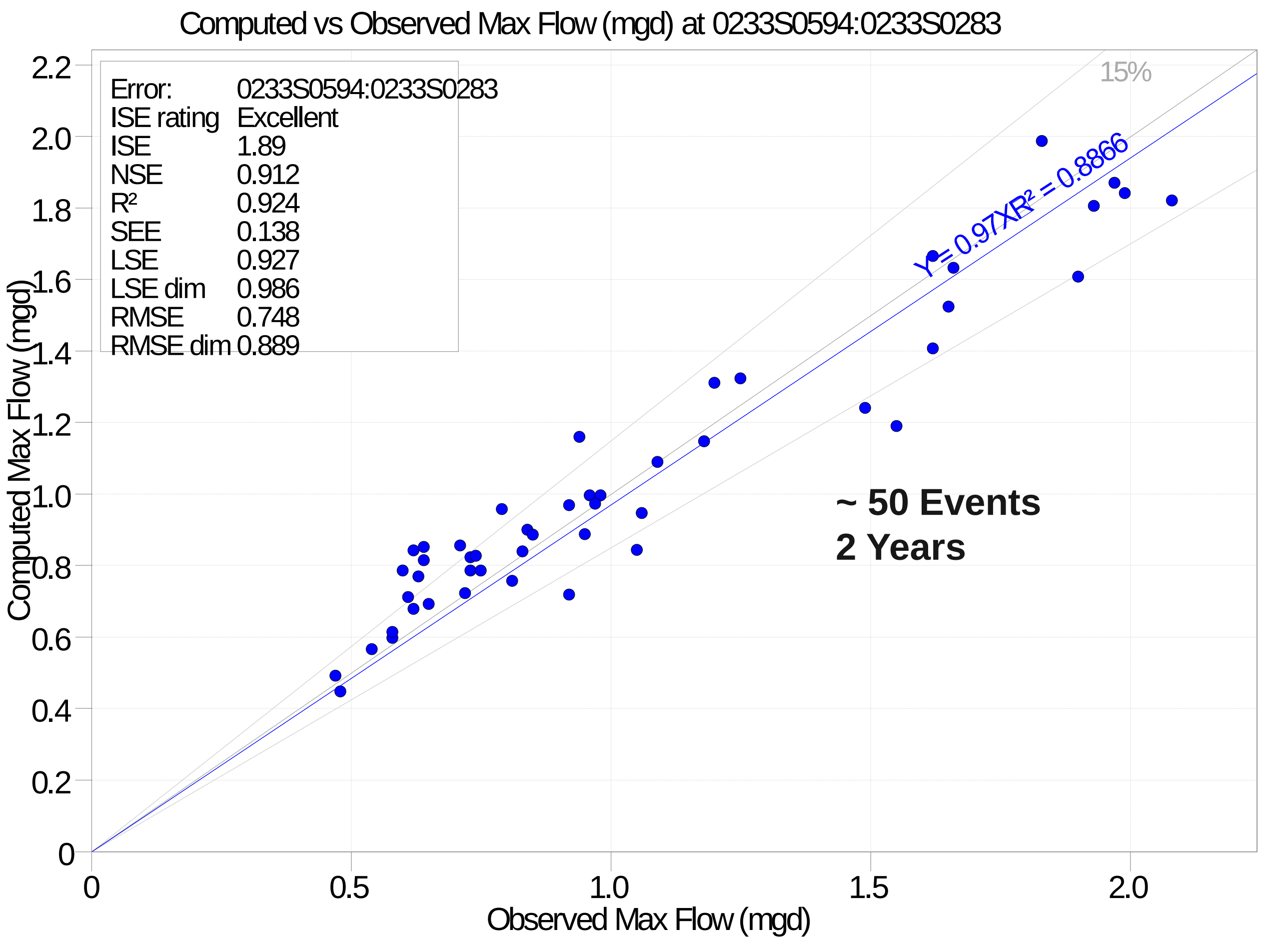

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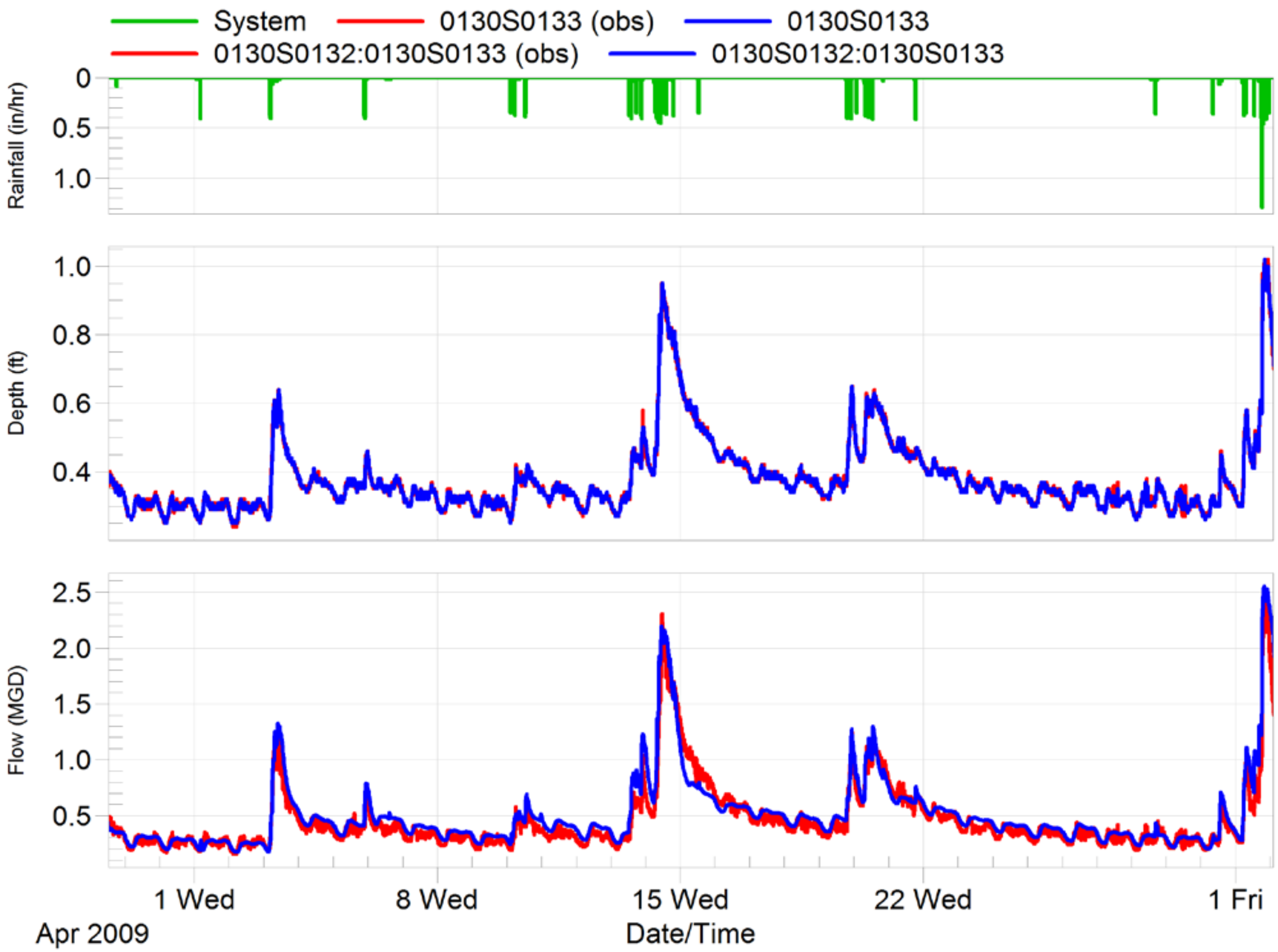
Continuous Calibration Examples – Columbus



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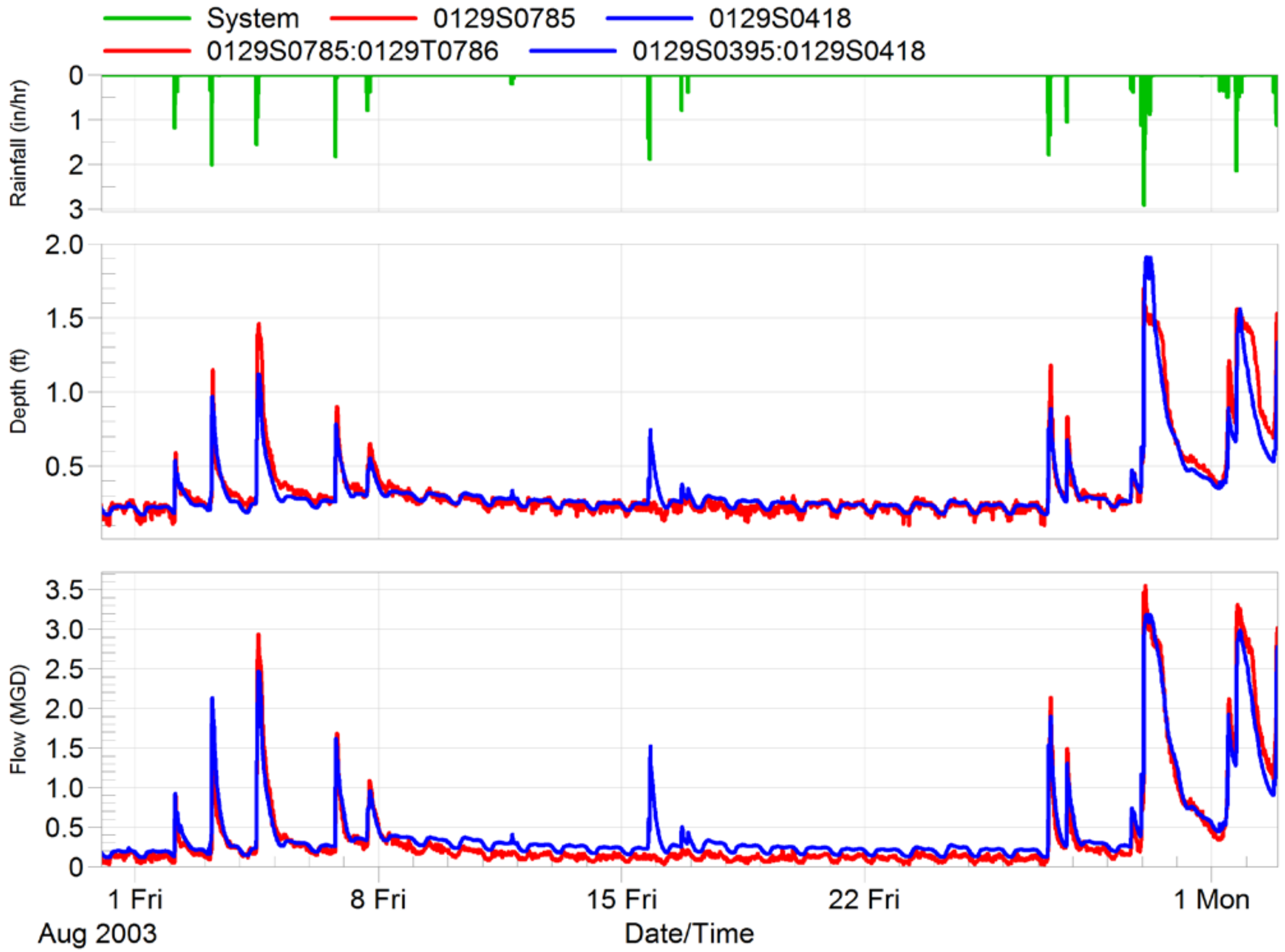
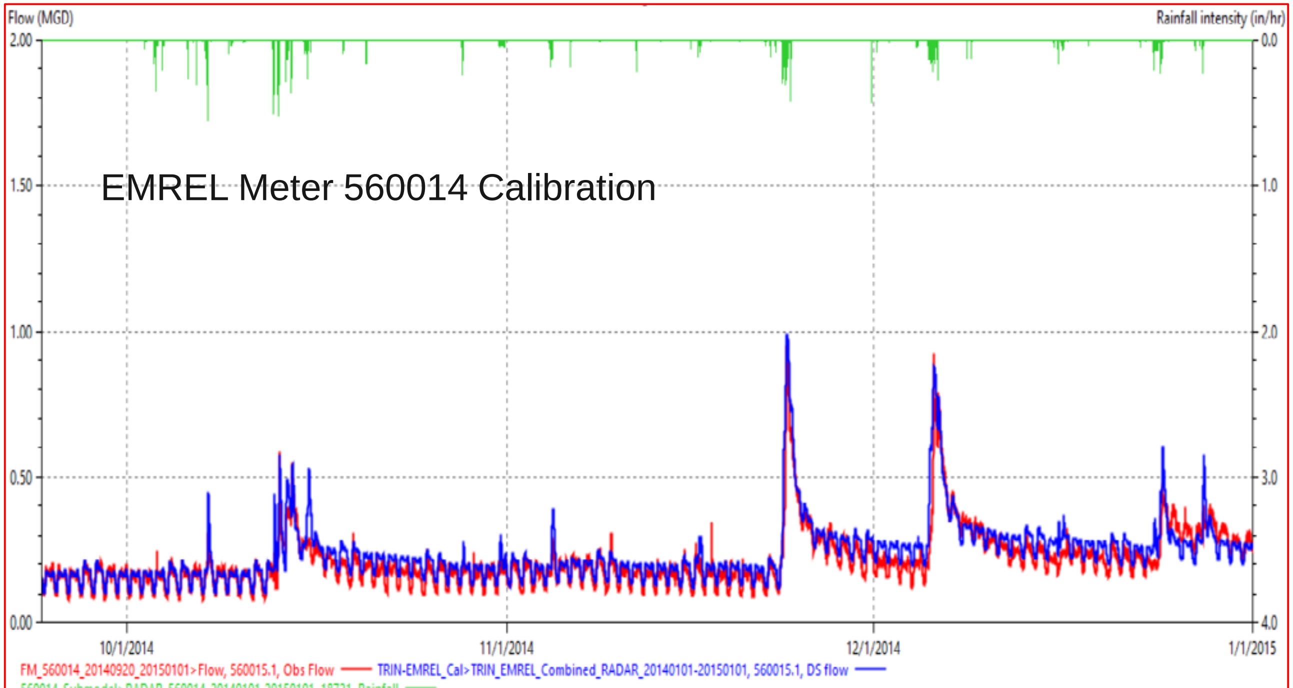
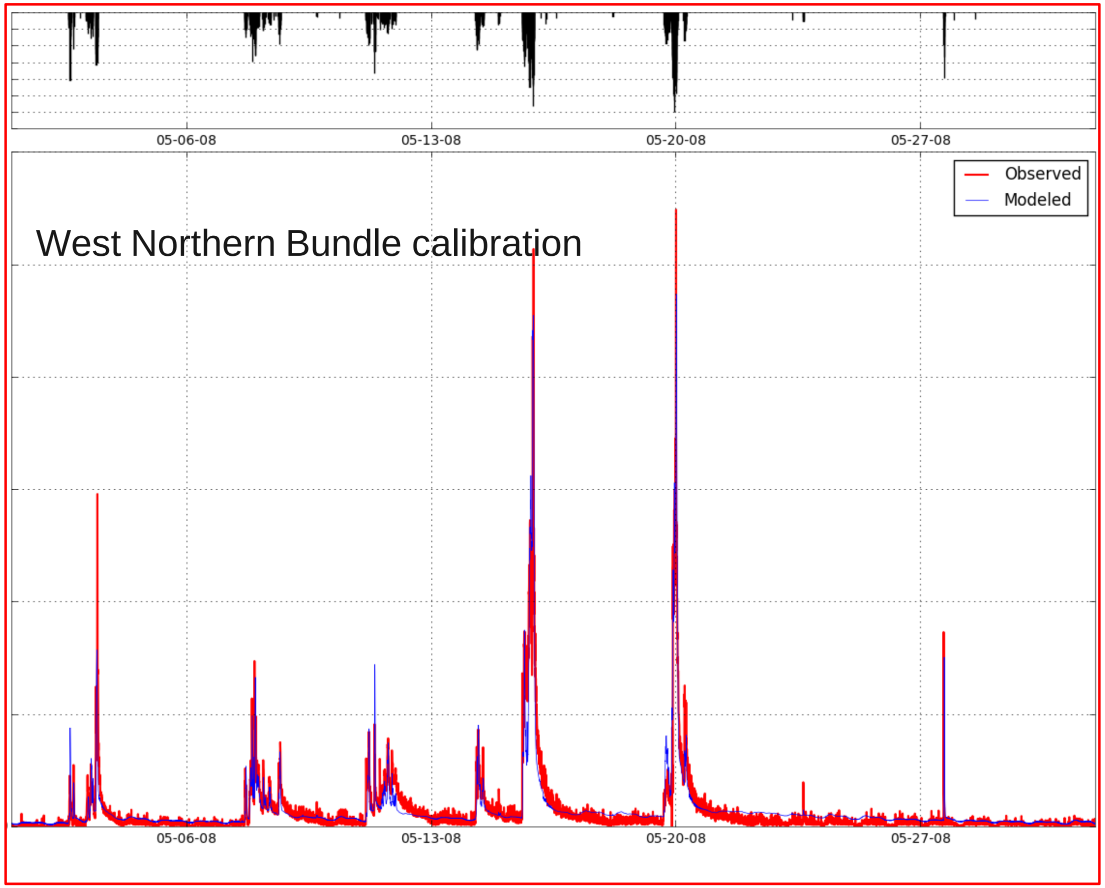


Continuous Calibration Examples – Indianapolis

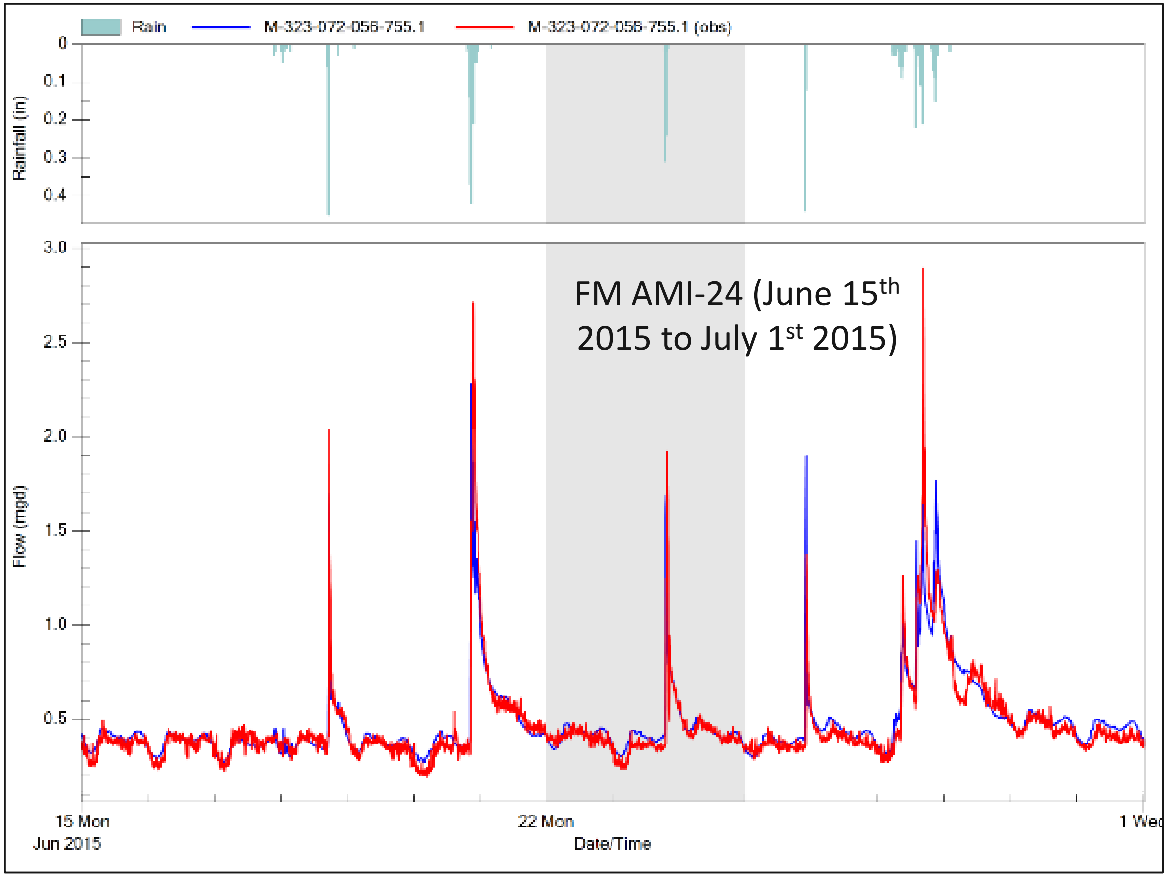


	Obs Flow			DS flow			Rainfall		
	Min (MGD)	Max (MGD)	Volume (US Mgal)	Min (MGD)	Max (MGD)	Volume (US Mgal)	Min (in/hr)	Max (in/hr)	Rainfall depth (in)
...0101>Flow, 560015.1	0.073	0.953	21.056						
...1-20150101, 560015.1				0.101	0.989	23.335			
...101-20150101, 18721							0.000	0.552	7.898

Continuous Calibration Examples – Cincinnati



Continuous Calibration Examples – Washington DC



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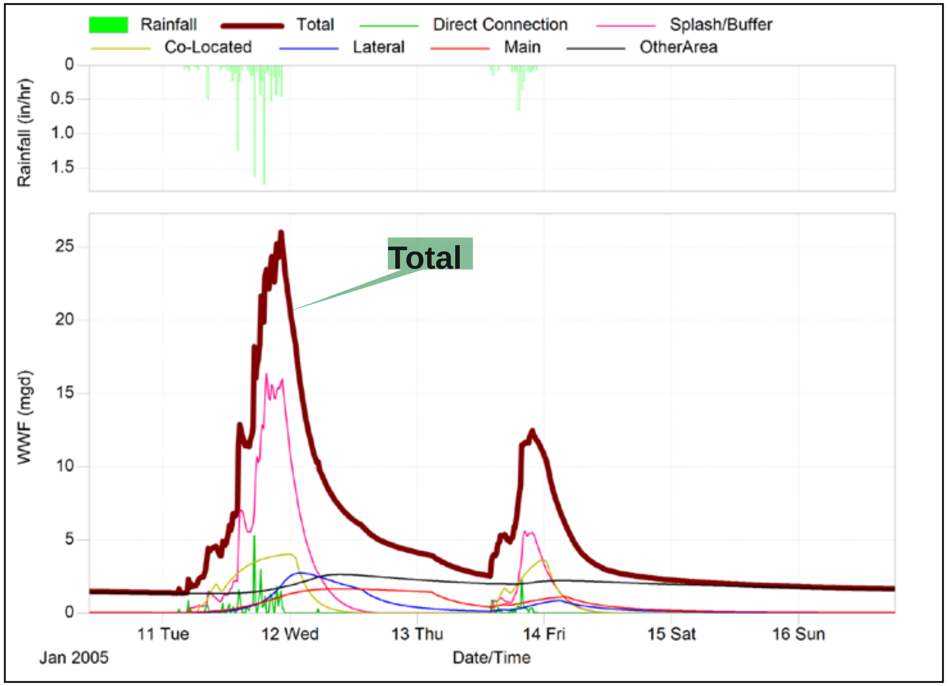
Isolating I/I Sources

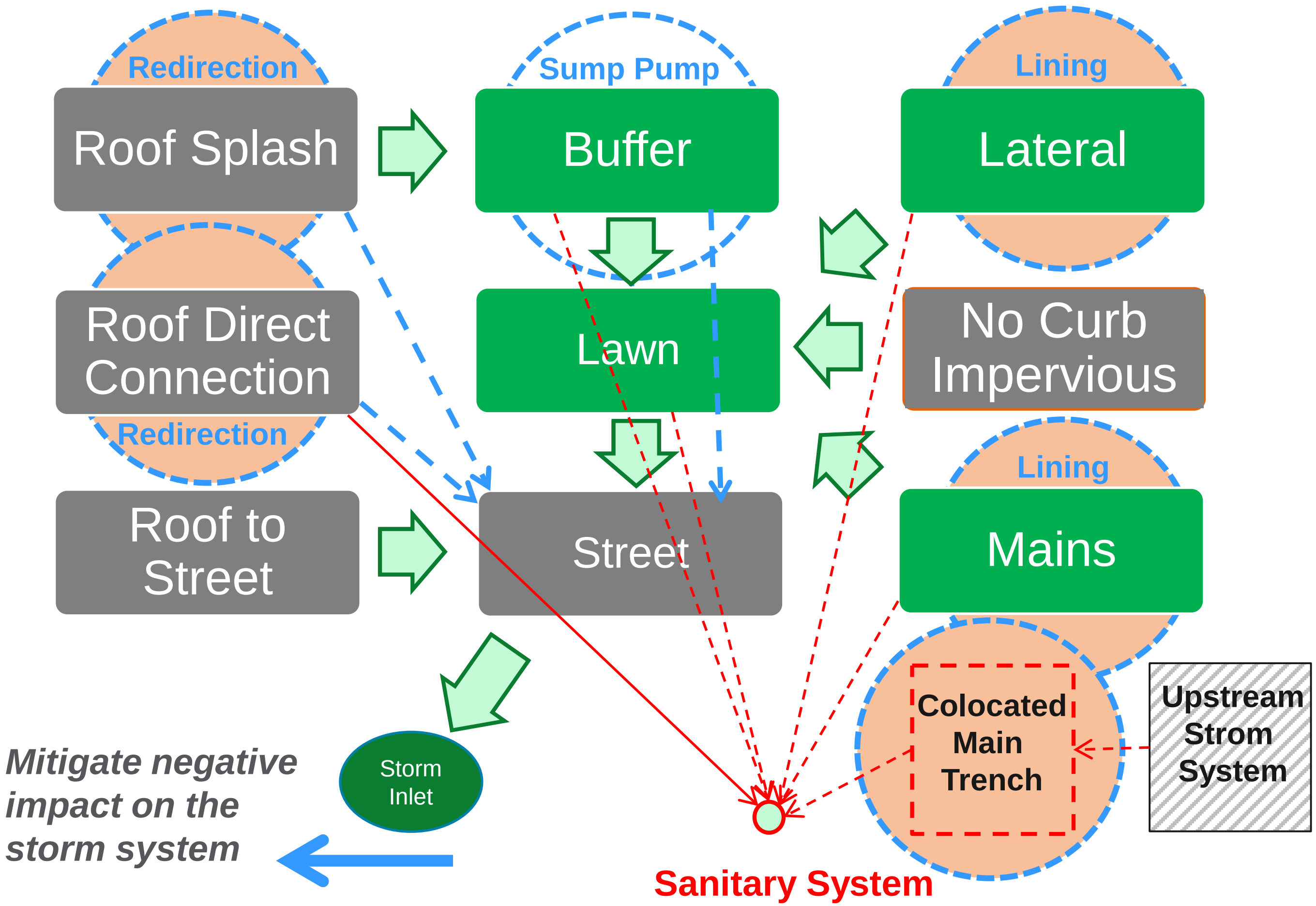


Contributing Source	Remediation
Roof with direct connection	Disconnect downspout
Splash/Buffer through foundation drain	Redirect roof drainage
Storm trench leaking into co-located sanitary trench	Storm and sewer lining
Buffer area above laterals	Lateral lining
Buffer area above mains	Sewer main lining
Lawn and remaining pervious area through FDs and sewers leaks	Lining

The Model Approach provides quantification of RDII sources

Subareas – RDII

- Split the area into its RDII sources (GIS)



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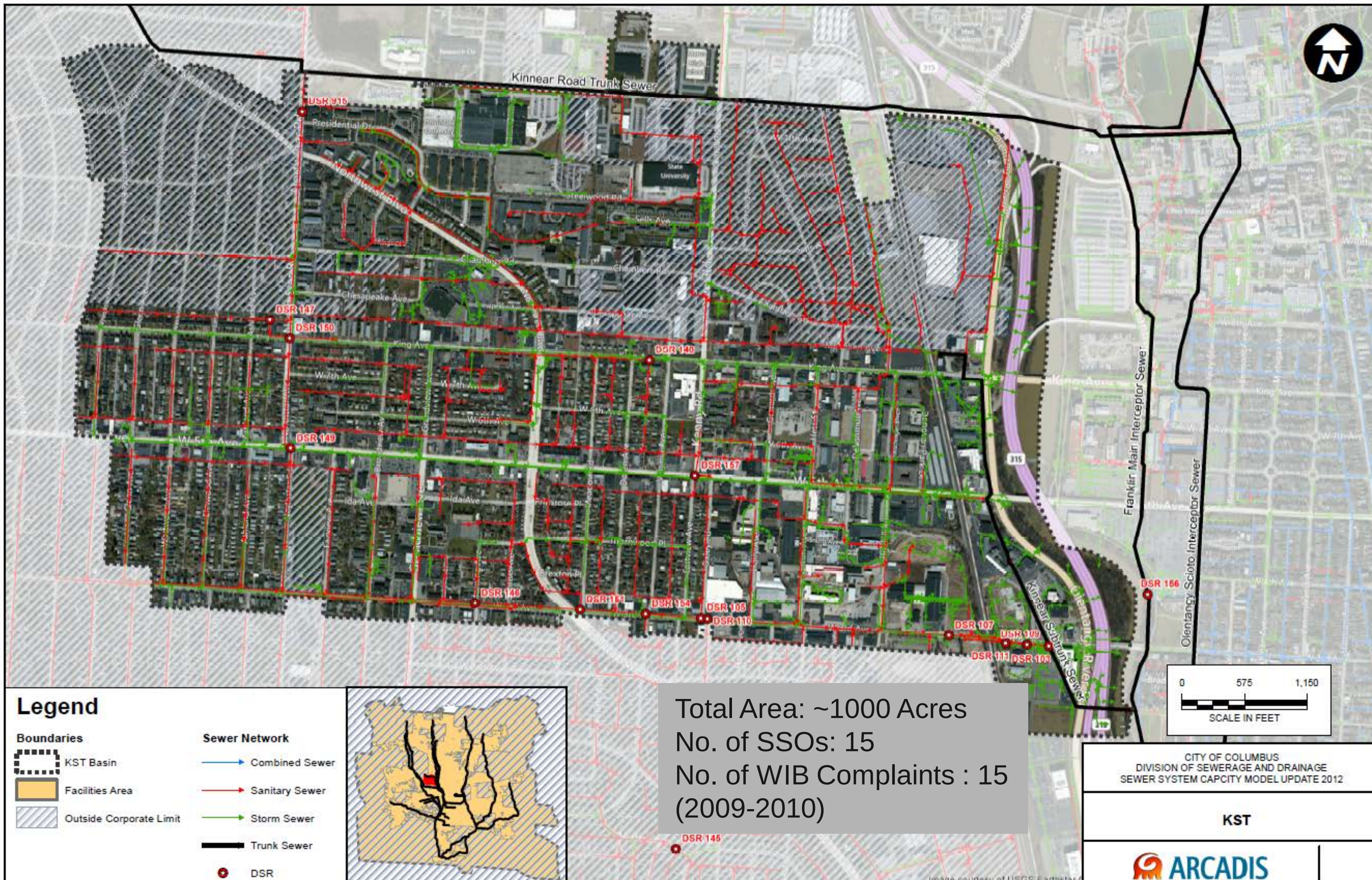
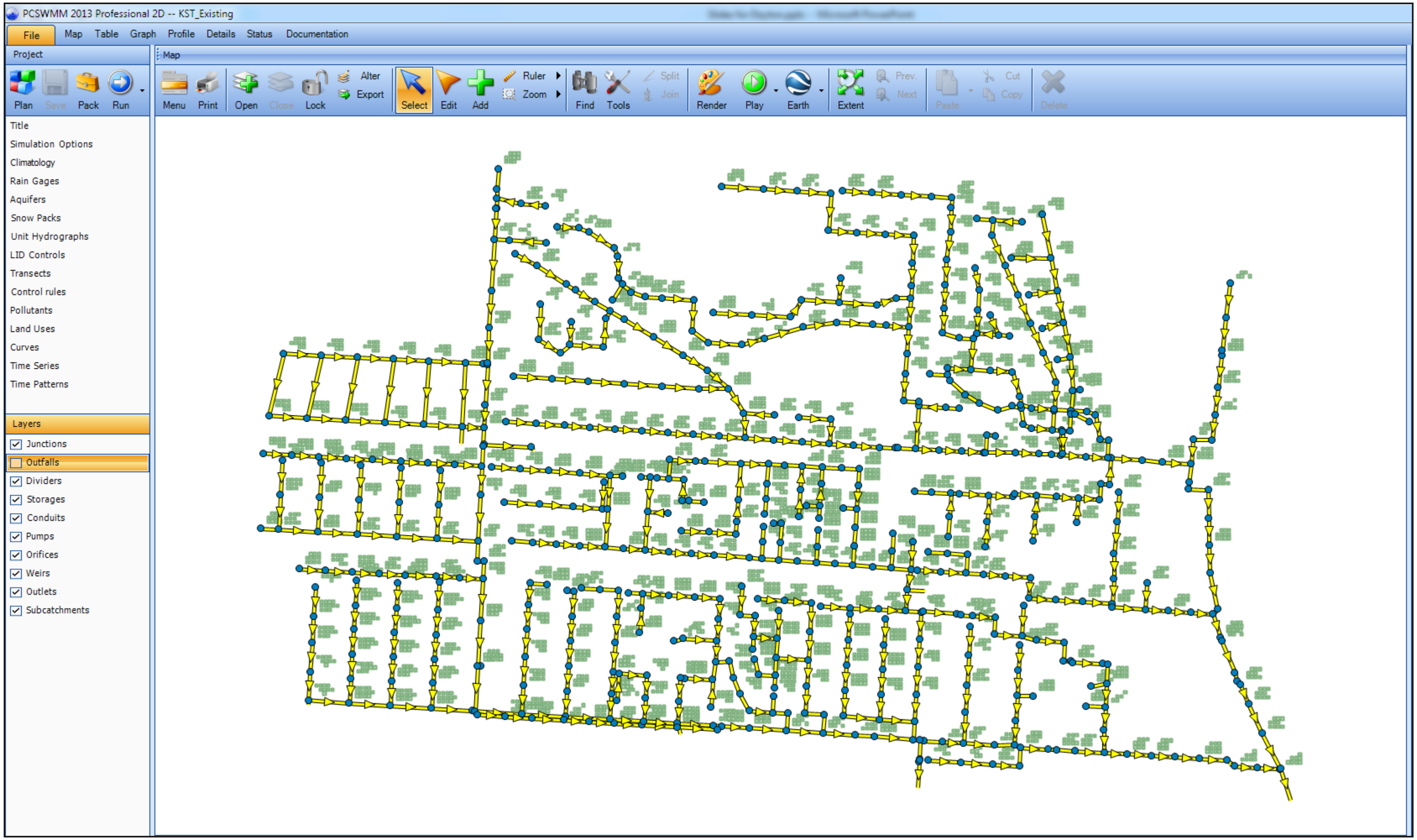
Columbus - West Fifth I/I Study Area



Total Area: ~1000 Acres
No. of SSOs: 15
No. of WIB Complaints : 15
(2009-2010)

Model Overview



RDII Sub-Areas

Sources	Contributing Area (acres)	Percentage (%)
Roofs, Direct Connection	5.4	0.5%
Roofs, To Street	86.1	8.6%
Roofs, Splash	101.2	10.1%
Buffers	82.0	8.2%
Garages	11.8	1.2%
Lateral	43.6	4.4%
Main	44.7	4.5%
Street, Impervious Area	389.0	38.9%
Lawn, Pervious Area	235.7	17.5%
Total	**999.4**	**100%**

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Overflow Frequency

19 years continuous simulation

	Locations	DSR 103	DSR 109	DSR 111	DSR 105	DSR 149	DSR 150	DSR 148	DSR 157
Overflow Summary (1995-2013)	**Volume (MG)**	**48.05**	**61.47**	**18.38**	**31.94**	**1.42**	**0.58**	**1.05**	**3.48**
	Duration (Hrs)	**523**	**834**	**605.5**	**970**	**65.25**	**64**	**71.25**	**261**
	Number of Activations	**62**	**83**	**74**	**182**	**24**	**16**	**24**	**61**
	LOS (in years)	**0.31**	**0.23**	**0.26**	**0.1**	**0.8**	**1.21**	**0.8**	**0.31**
Top 20 Events with Highest Volume (MG)	1st	6.79	7.51	2.21	2.38	0.16	0.1	0.13	0.21
	…	…	…	…	…	…	…	…	…
	20th	0.64	0.95	0.27	0.37	0.02		0.01	0.06
Top 20 Events with Highest Peak (MGD)	1st	5.45	4.21	1.74	1.64	1.57	0.55	1.07	0.83
	…	…	…	…	…	…	…	…	…
	20th	3.92	3.57	1.27	1.36	0.43		0.21	0.44

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RDII Contributions

Sources	Peak Flow Percentage (1/12/2005)	Flow Volume Percentage (12/01/2004-02/01/2005)
Roofs, Direct Connection	5.8%	1.4%
Roofs, Splash	34.2%	13.7%
Buffers	29.9%	29%
Col-Located	15.2%	17.0%
Lateral	8.9%	18.3%
Main	6.1%	20.7%

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RDII Mitigation Results (one event, 1/3/2005)

Scenarios	Number of Active SSOs	Total Overflow Volume (MG)	Peak Overflow (MGD)	Peak Flow to Down Stream
Existing	10	5.14	8.5	10.2
Disconnect Direct Connection Roofs	10	4.38	5.9	10.2
Redirect Splashed Roof drainage	6	2.65	5.7	8.7
Laterals Lining (all the way to the 4"x 6")	9	1.9	6.4	10.0
Main Sewers Lining	9	2.82	7.8	9.9
Storm Sump Pump	1	0.91	1.5	7.2
Disconnect Direct Connected Roofs + Lateral Lining + Main Lining	7	0.61	3.4	9.6
Disconnect Direct Connected Roofs + Redirect Splashed Roofs + Lateral Lining + Main Lining	0	0	0	7.4

Summary

- Runoff areas contributing to RDII sources are quantifiable
- Manmade aquifers in urban Midwest are independent due to clay condition
- Fluctuation in moisture content in the unsaturated zones is used to track groundwater condition and RDII
- Most parameters are physically based, easing the continuous calibration since number of unknown parameters is limited
- The modeling approach results in a model platform suitable for planning RDII mitigation technologies at the source

Thank You

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Imagine the result