Performance Evaluation of Blue Roofs to Mitigate CSO Impacts

June 21, 2012

OWEA 2012

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NYC Environmental Protection

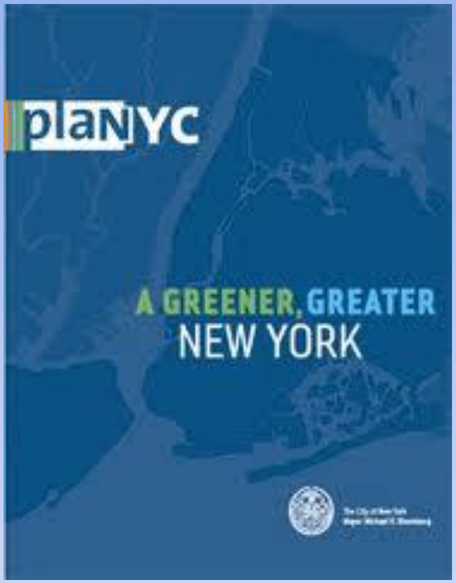
HDR | HydroQual

Outline

- NYC Sustainability Initiatives
- Challenges and Opportunities in Highly Urbanized Areas
- Blue Roof Design Evaluations and Optimization
- Performance Evaluation and Calibration
- Conclusions and Future Work

NYC Sustainability Initiatives

- PlaNYC
  - Greener New York with 10 specific goals
  - Goal 5: "*Open 90% of NYC's waterways for recreation by reducing pollution and protecting natural areas*"



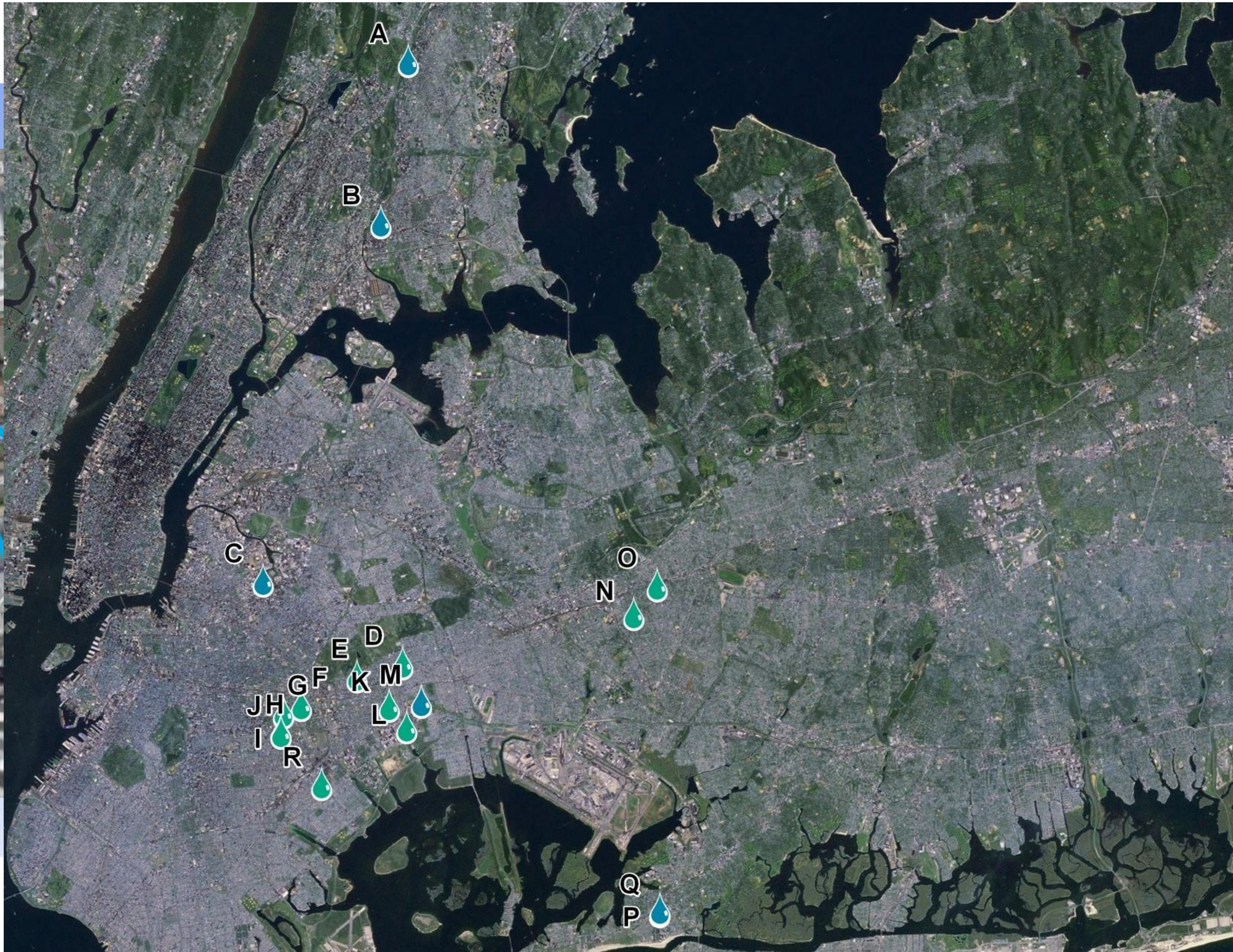
- GI Plan released in 2010, with a target of 10% reduction in directly connected impervious areas to sewers
- Detain/Retain over an additional 1 BG of stormwater

Challenges and Opportunities in Highly Urbanized Areas

- High Impervious Covers
- Aging Infrastructure
- Increase in frequency of large storms (with larger return periods)
- Increase in CSO/Stormwater volume and # of events
- Public/ private properties will be subjected to BMP/LID controls
- Different types of opportunities to be explored

Understanding Benefits

Citywide Scale



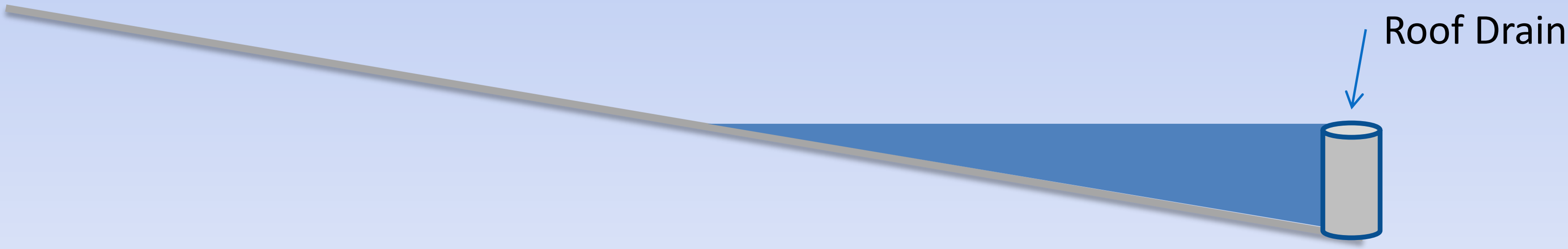
Potential for Rooftop Detention in NYC

	Total Roof Area [acre]	Estimated Total Flat Roof Area [acre]
Bronx	5,036	2,555
Brooklyn	11,547	4,782
Manhattan	4,618	3,645
Queens	13,219	4,168
Staten Island	4,050	795
	38,470	15,945

Roof Detention/Retention

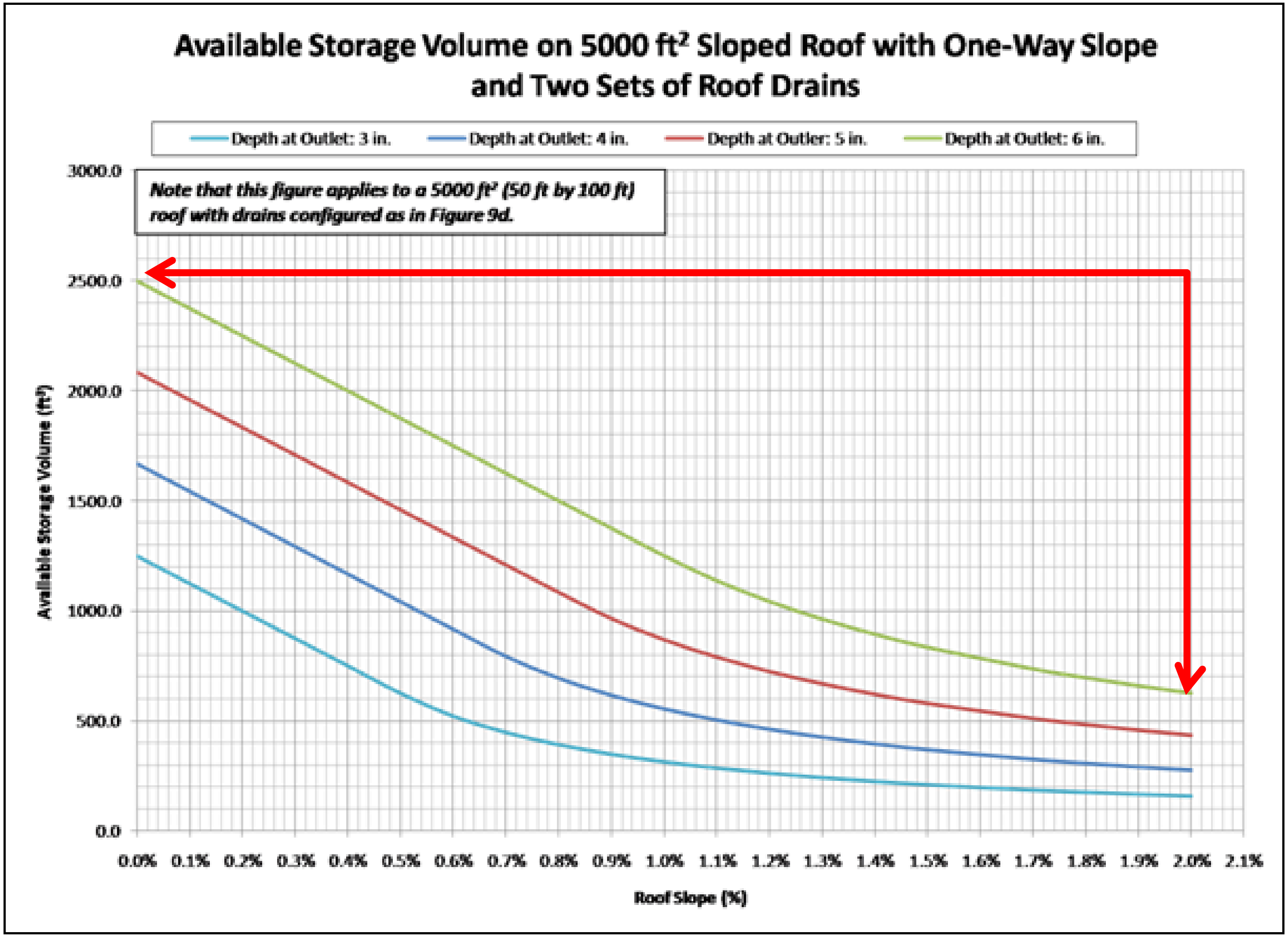
Flat roofs are not really flat

Optimal Width of Drainage Areas				
Ponding Depth (in)	3	4	5	6
Roof Slope, Percent (in/ft)	**Maximum Width of Drainage Area (ft)**			
0.5 (1/16)	50	67	83	100
1.0 (1/8)	25	33	42	50
2.0 (1/4)	13	17	21	25



2% slopes are common

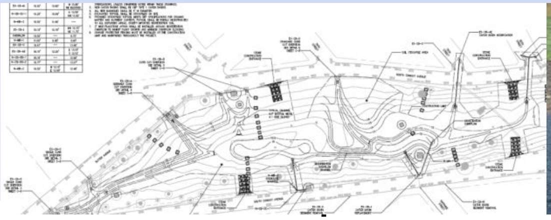
Effect of Roof Slope on Potential Storage



NYC Site Scale Green Infrastructure Pilots

- Right of Way
  - Enhanced tree pits
  - Street side swales
  - Bioretention – rain gardens
- On-site Retrofits
  - Blue roofs/Green Roofs
  - Bioretention – rain gardens
  - Subsurface detention

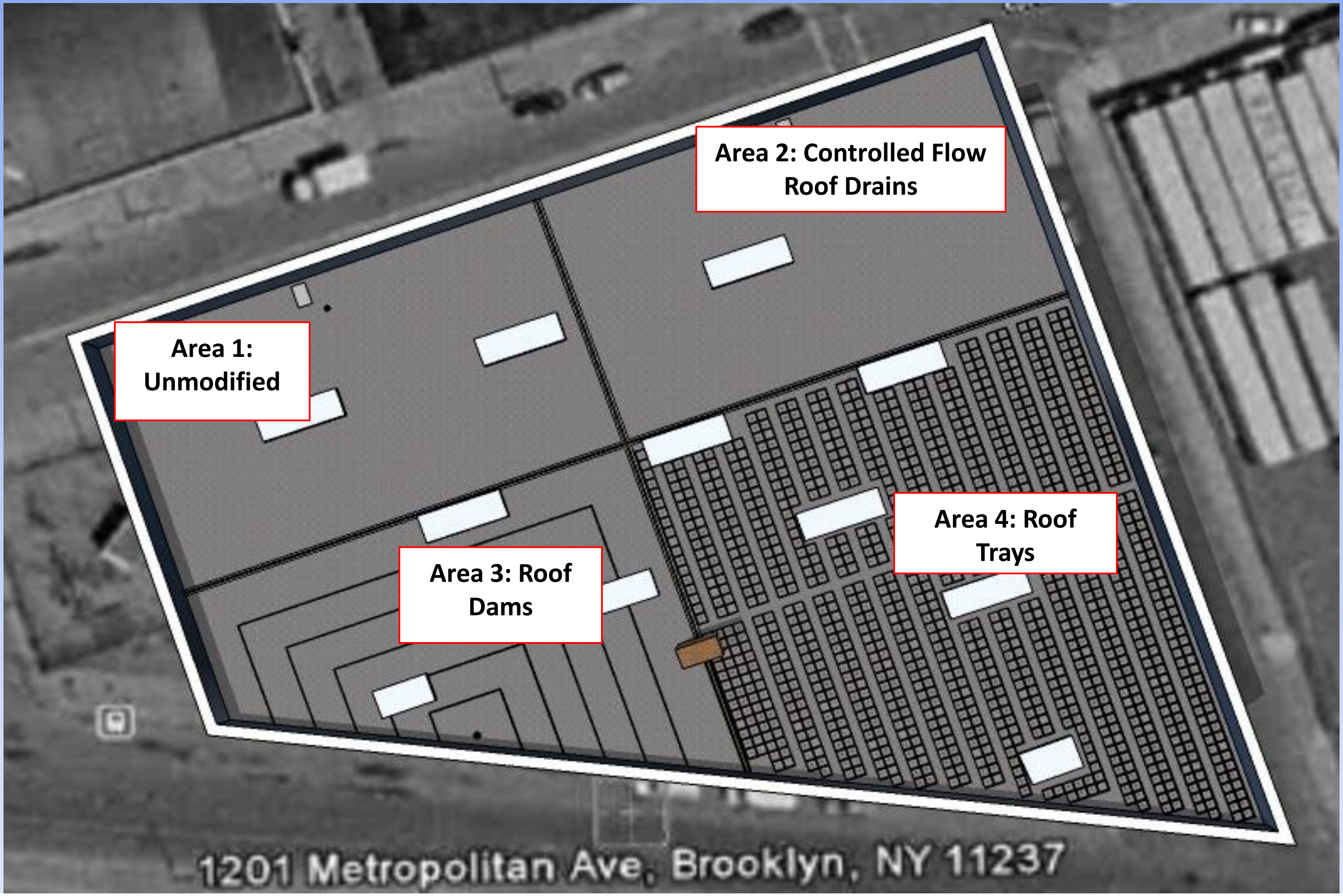
- Understand performance, costs, maintenance
- Gain insight on how to model for planning purposes
- Inform future designs



Blue Roof Pilot Study Design Objectives

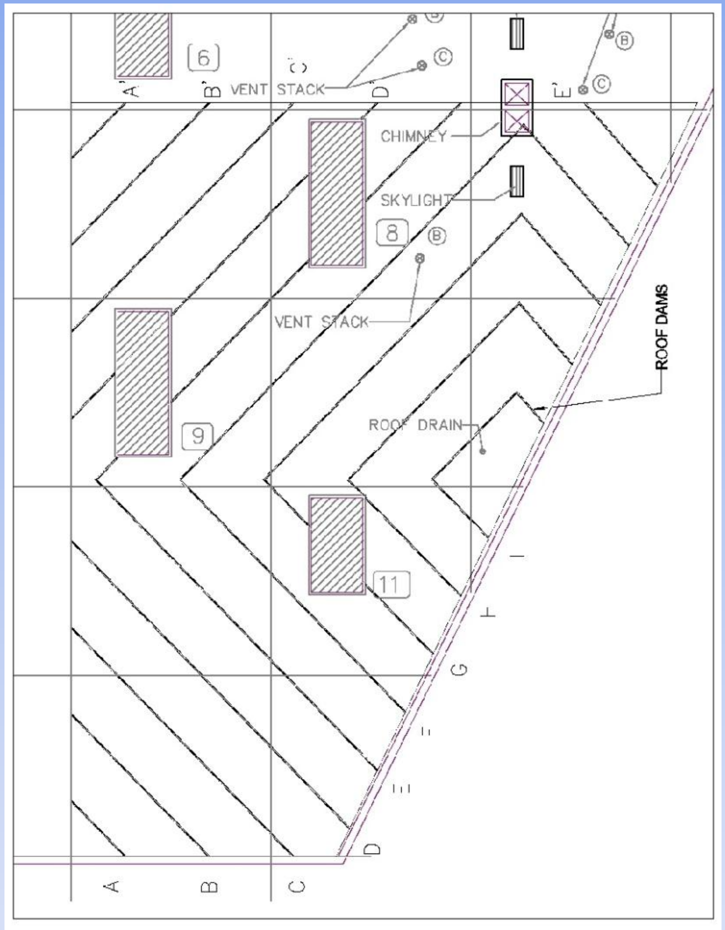
- Active vs. passive controls to induce rooftop detention
- Effect of existing roof slopes on potential storage and peak flow reduction
- Orifice size/ numbers for optimal control
- Time or peak flow attenuation to achieve target benefits (site- and/or neighborhood-scale)

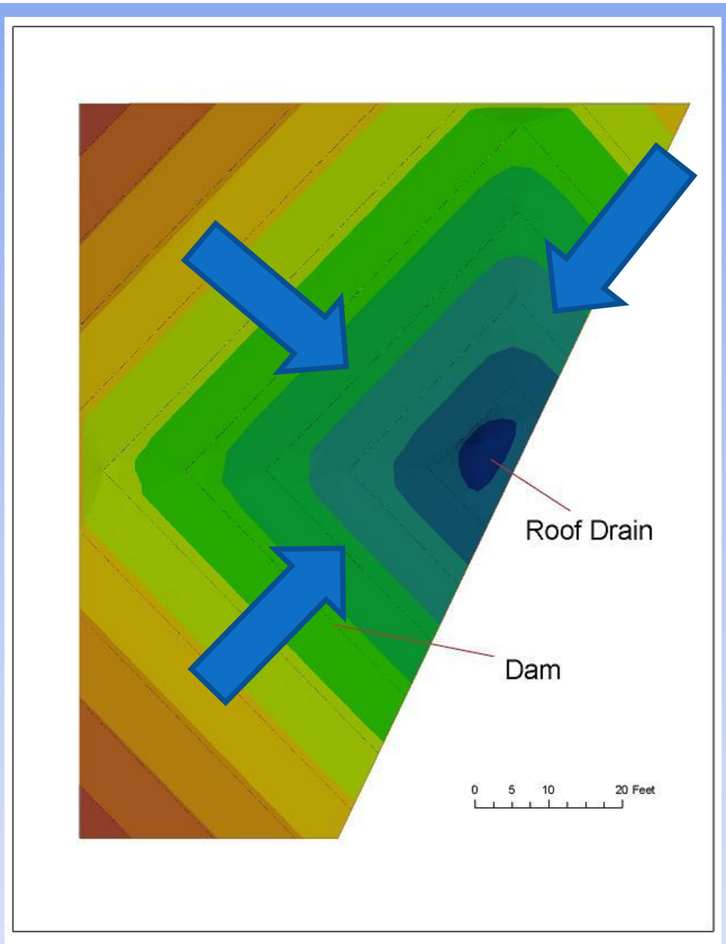
Stormwater Pilot Metropolitan Ave



Source: Routine Monitoring Protocol CSO-PlaNYC Stormwater Pilot Metropolitan Avenue, Biohabitats, HDR|HydroQual, Hazen and Sawyer, Fall 2010

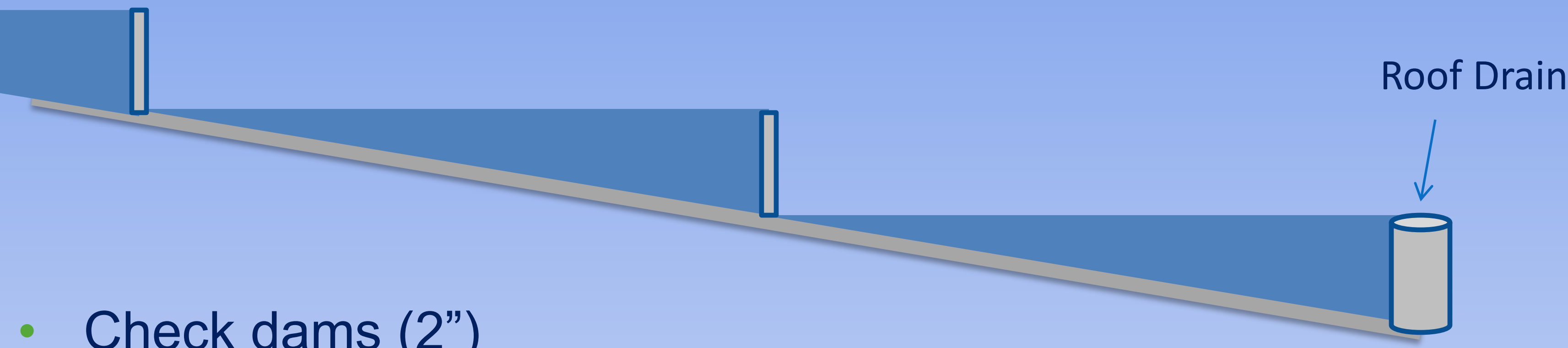
Roof Schematic – Area 3: Roof Dams



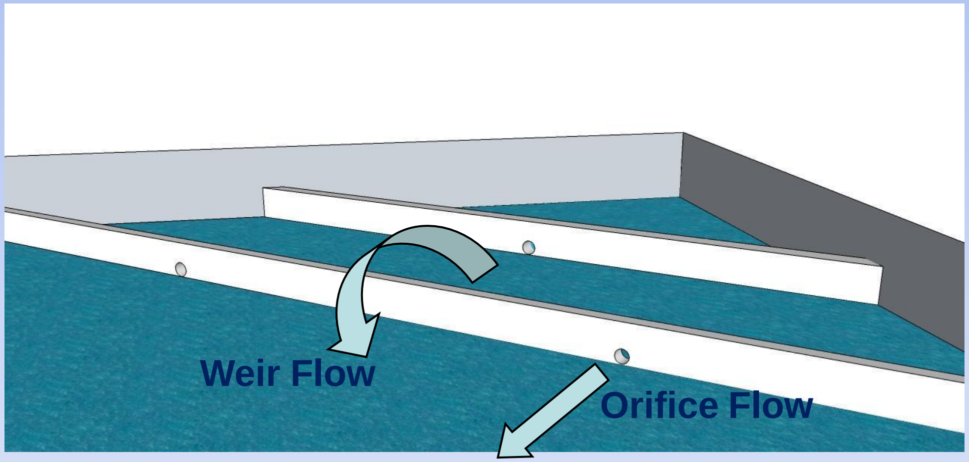


Construction Layout of the Blue Roof and corresponding Digital Elevation Model

Hydraulic Model Setup

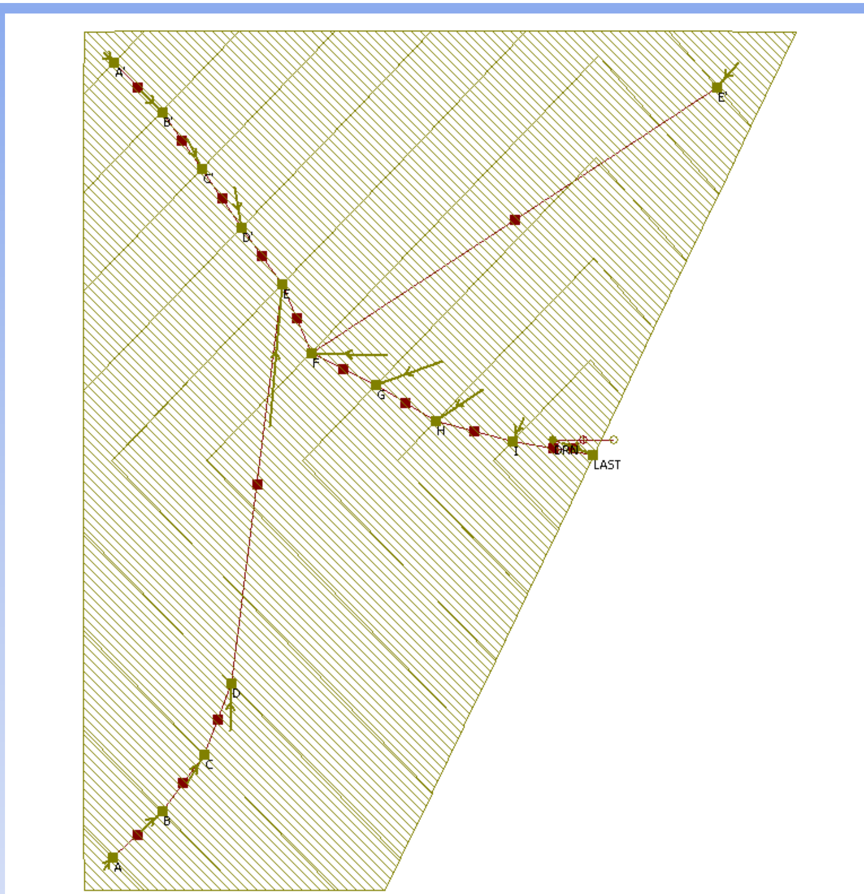


- Check dams (2”)
- Orifices drilled on each dam
- More orifices as we go from top portion towards drain
- Low flow condition: Orifice flow + water ponding between dams
- High flow condition: Orifice flow + weir flow

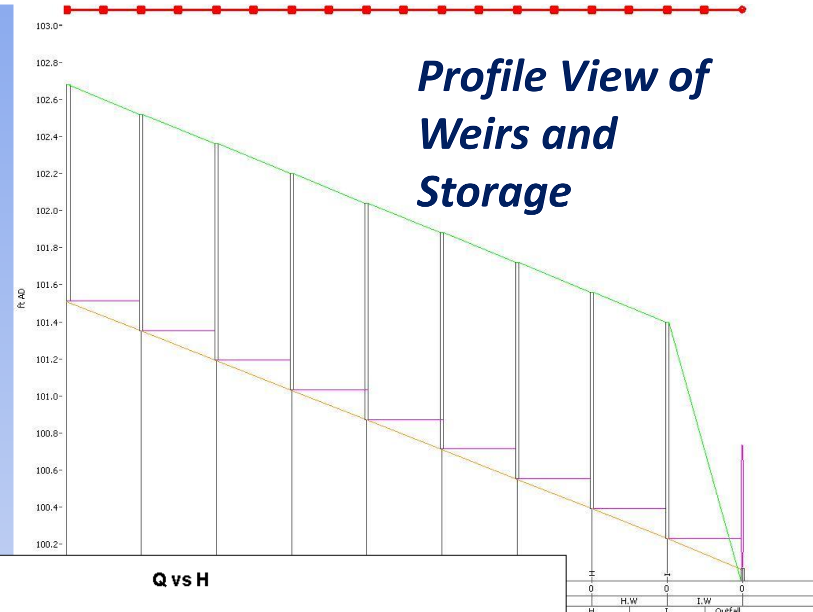


3-D Schematic

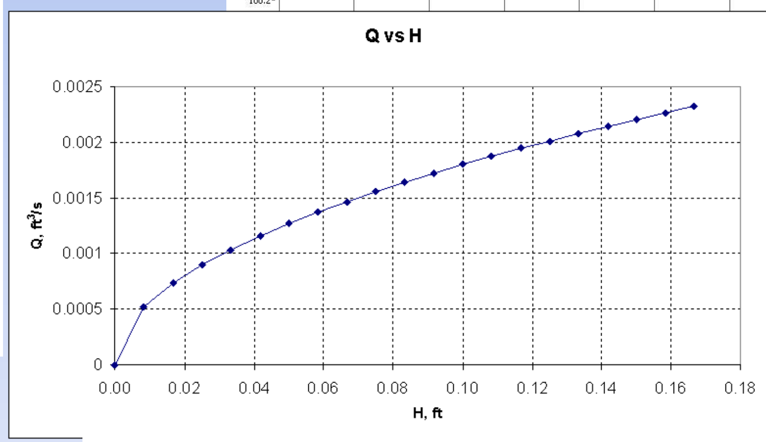
InfoWorks CS Layout



Subcatchment Layout and 1D Network

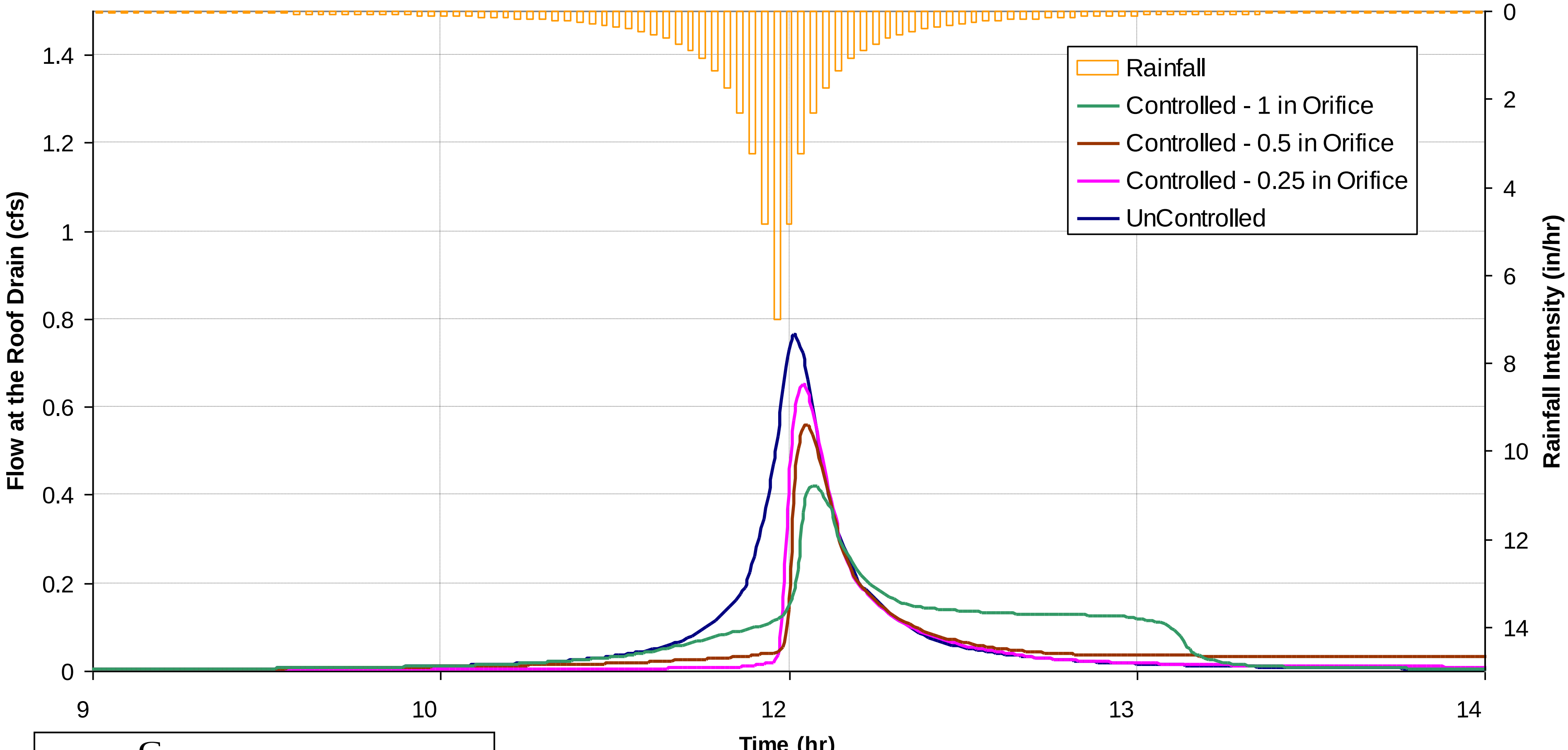


Profile View of Weirs and Storage



*** For Multiple Orifices equation nQ vs. H is applied**

Varying Orifice Size –
10 Yr 24 hr DEP Rainfall Intensity [7”/hr]

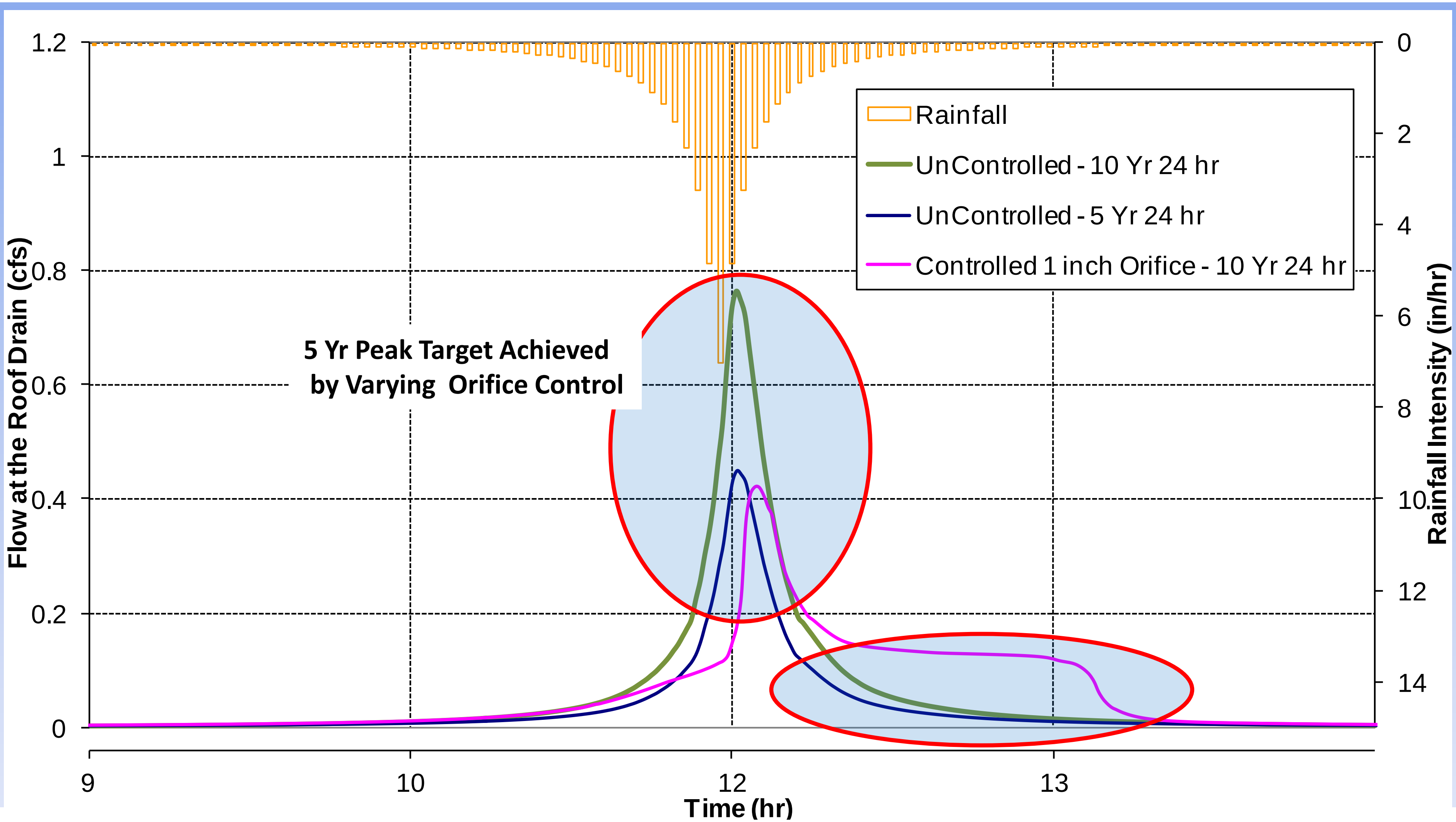


$$I = \frac{C_1}{(t_C + C_2)}$$

For DEP 10-Yr 24Hr Intensity

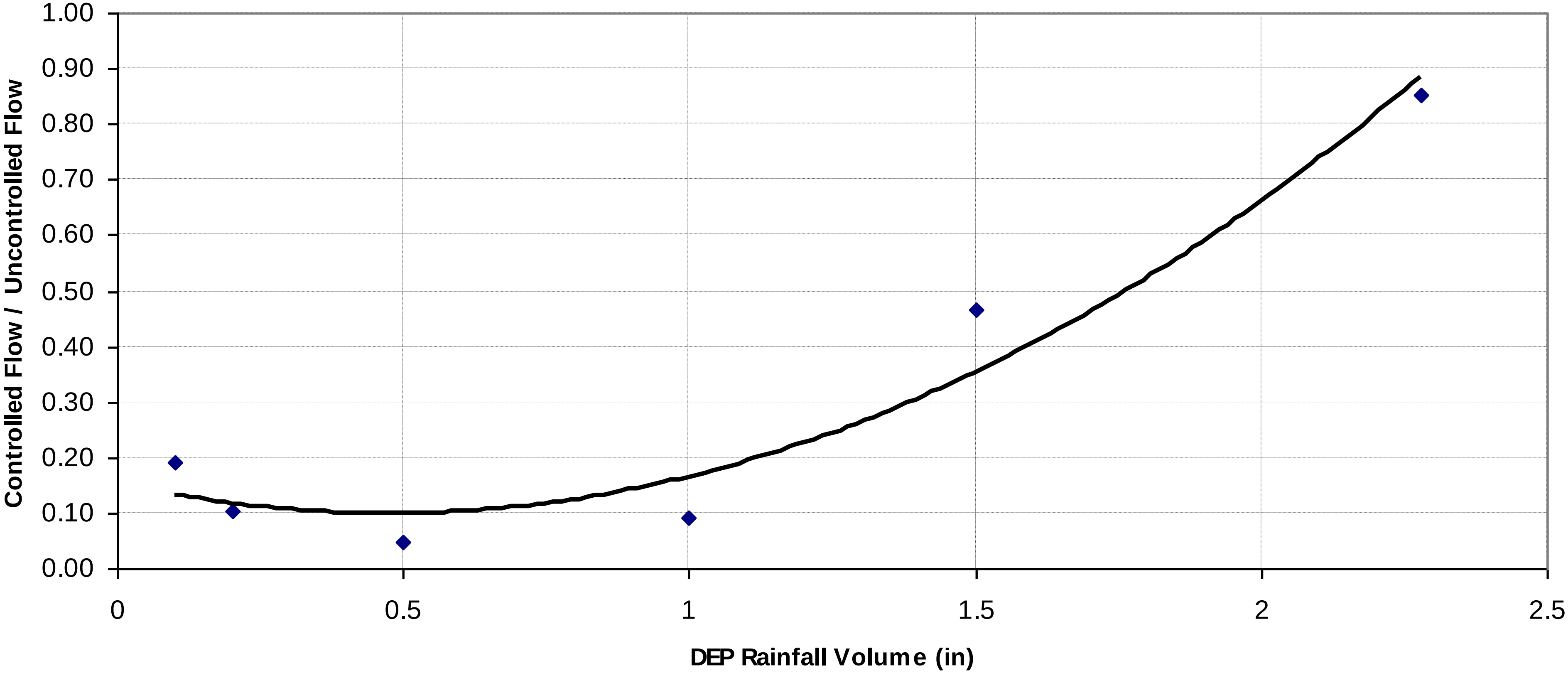
$C_1 = 140, C_2 = 15$

Peak Flow Attenuation to Achieve the Target



Larger Orifice Size Causes longer high flow receding curve.

Peak Flow Reduction – 0.25”



$$I = \frac{C_1}{(t_C + C_2)}$$

For DEP 10 - Yr 24Hr Intensity

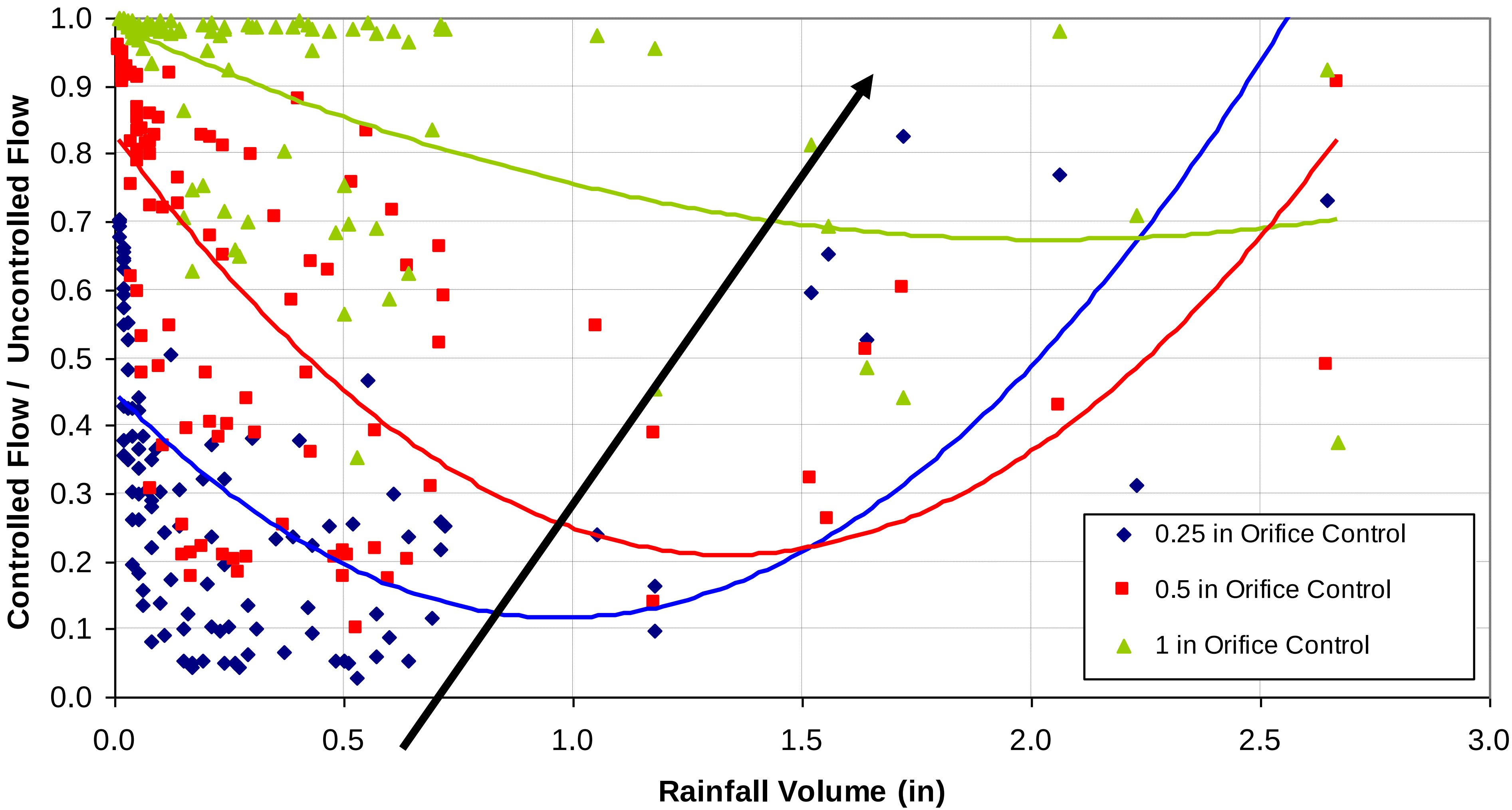
$C_1 = 140, C_2 = 15$

Storm Statistics – 1988 JFK

- Long-term Average Annual Precipitation
- Inter-event time of four hours
- More than 70% storms have volume less than or equal to 0.5 inches.

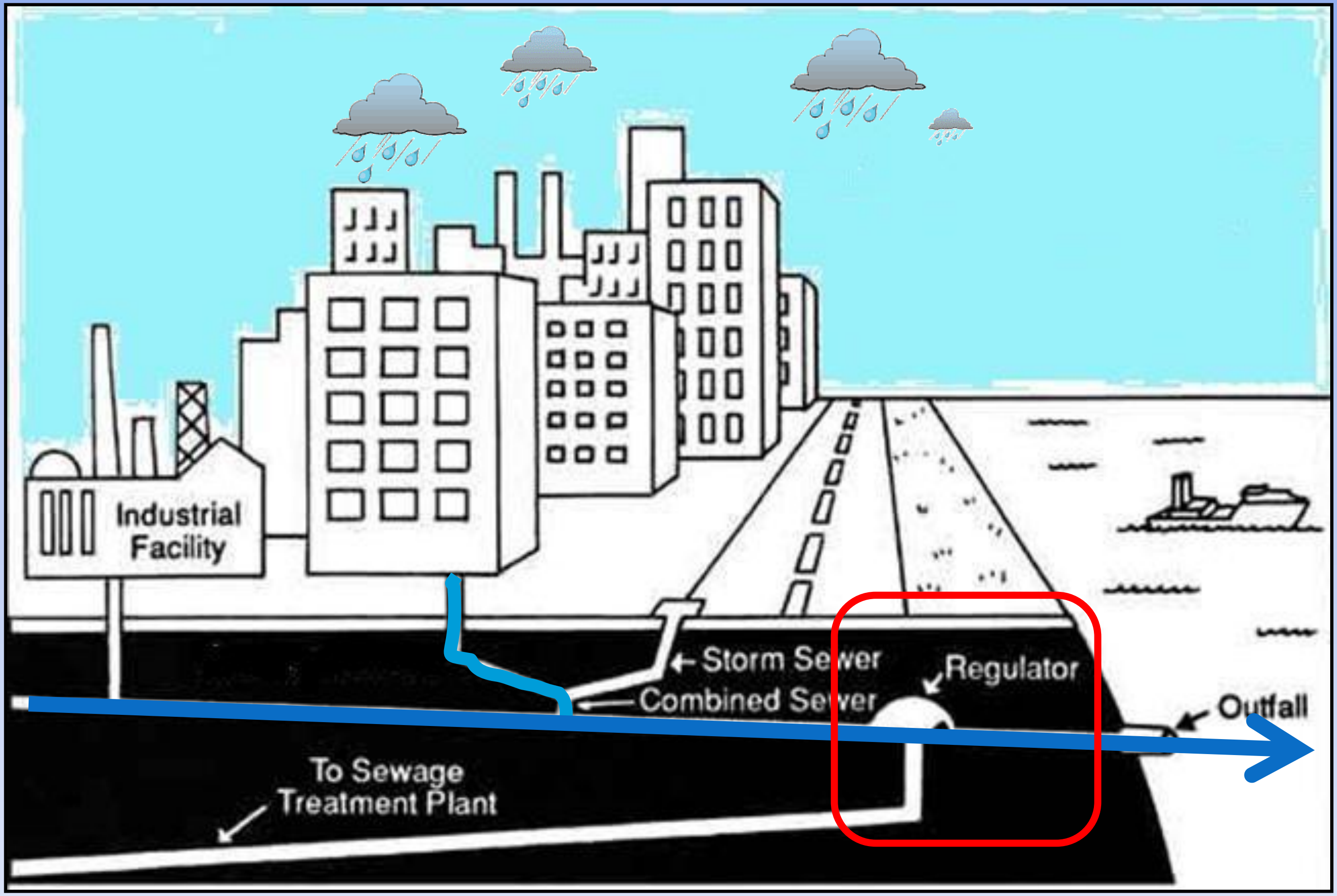
Range	***Number of Storm Events***
(0 - 0.5] inch	73
(0.5 - 1.0] inch	16
(1.0 - 1.5] inch	5
(1.5 - 2.0] inch	3
(2.0 - 2.5] inch	3

Peak Flow Reduction vs. Rainfall Volume

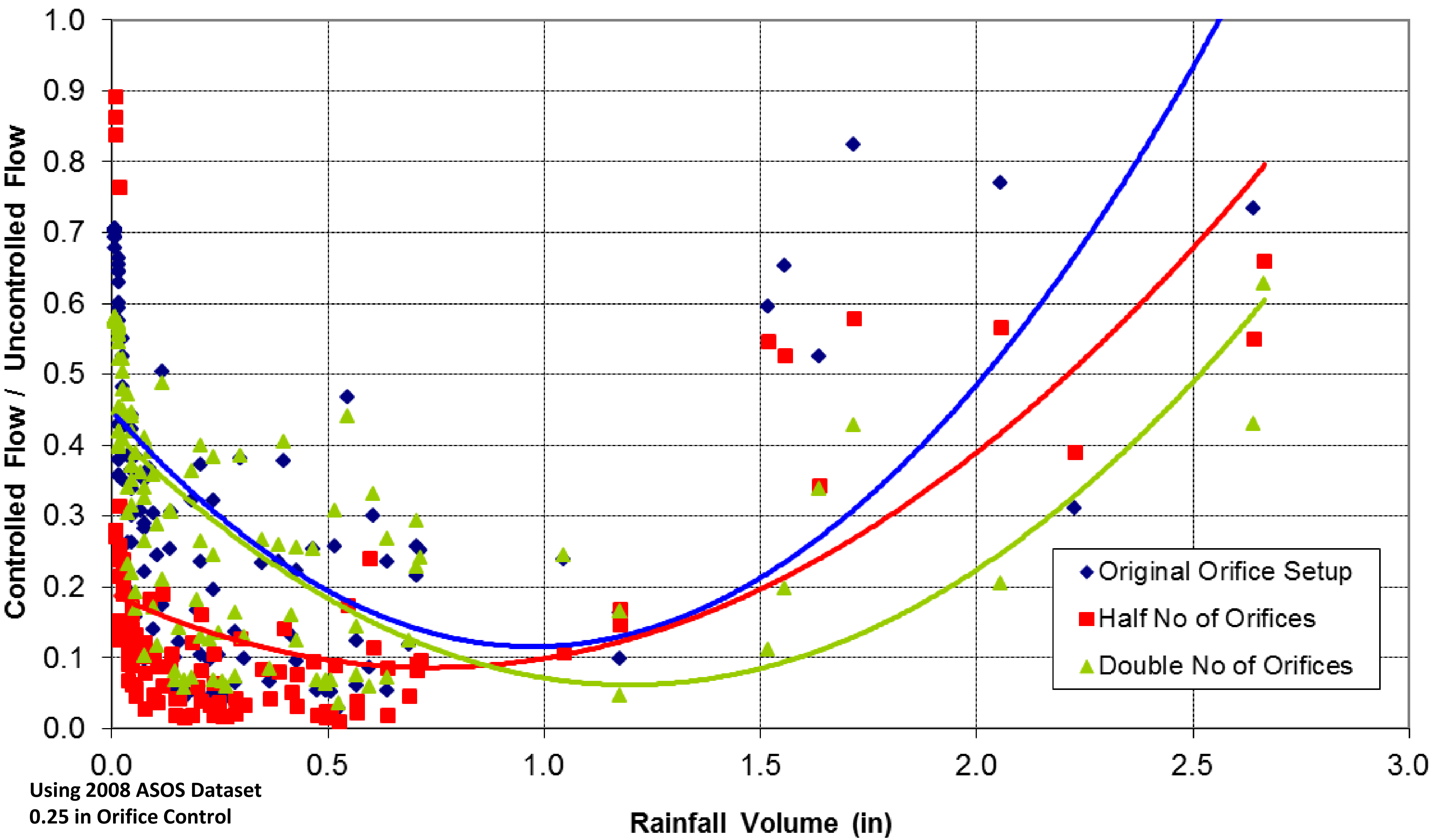


Using 2008 ASOS Dataset

Applicability of Orifice Size Variation



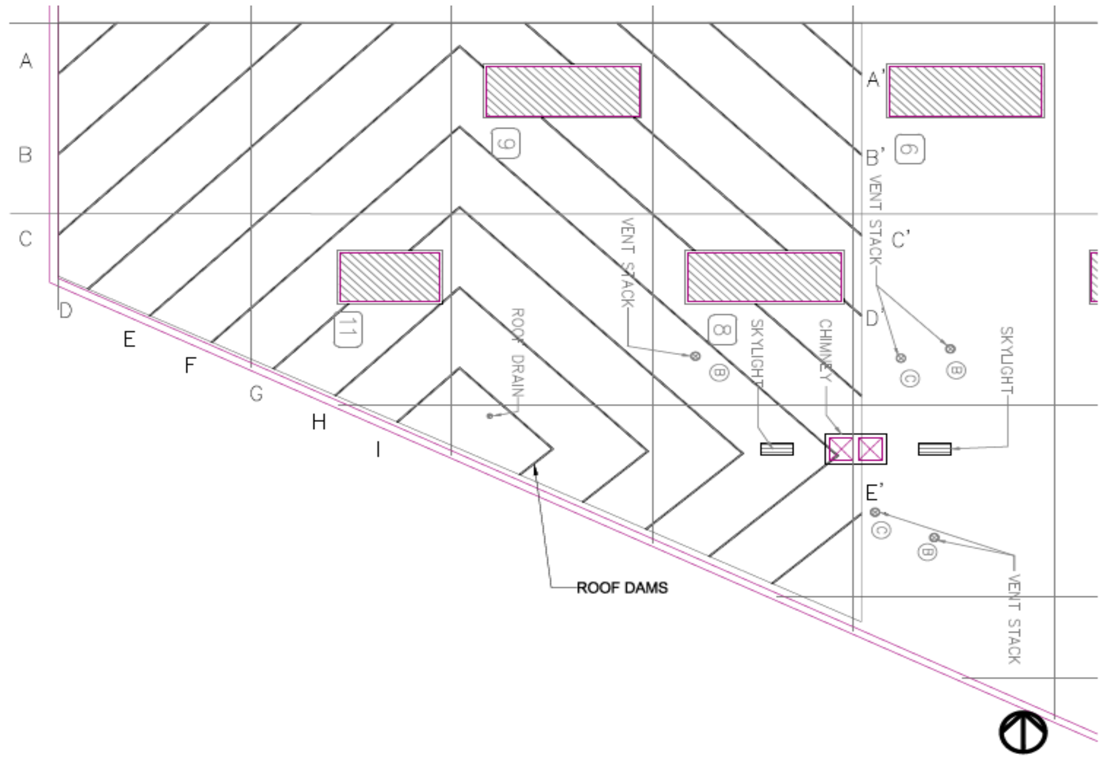
Sensitivity Analysis for the Number of Orifices



Using 2008 ASOS Dataset
0.25 in Orifice Control

Final Layout in Metropolitan Ave

Dam ID	Dam Length (ft)	# of Orifice Holes	Hole Spacing (ft)
A	10	1	5
B	27	2	13
C	43	3	14
D	53	4	13
E	123	9	14
F	129	12	11
G	97	14	7
H	65	14	5
I	32	14	2
A'	10	1	5
B'	27	2	13
C'	43	3	14
D'	59	4	15
E'	15	1	15
controlled flow drain	N/A	N/A	N/A
SUM	731		



*Roof dam discharge equivalent intensity

Roof dams shall be constructed of 2"x1/4" fiberglass angle in the configuration shown in the design drawings.

1/4" holes shall be drilled at the bottom of the angle, to act as drainage for the roof dams, at the spacings shown in the table.

Total number of holes per dam shall not exceed the number shown in the table. A minimum of 1 hole shall be drilled in each orthogonal face of the dams.

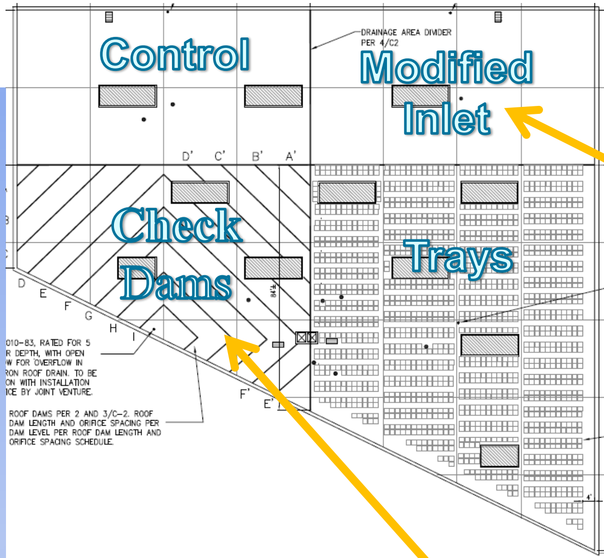
Source: Facility Drawing NYC DEP, Biohabitats, HDR|HydroQual, Hazen and Sawyer (2010)

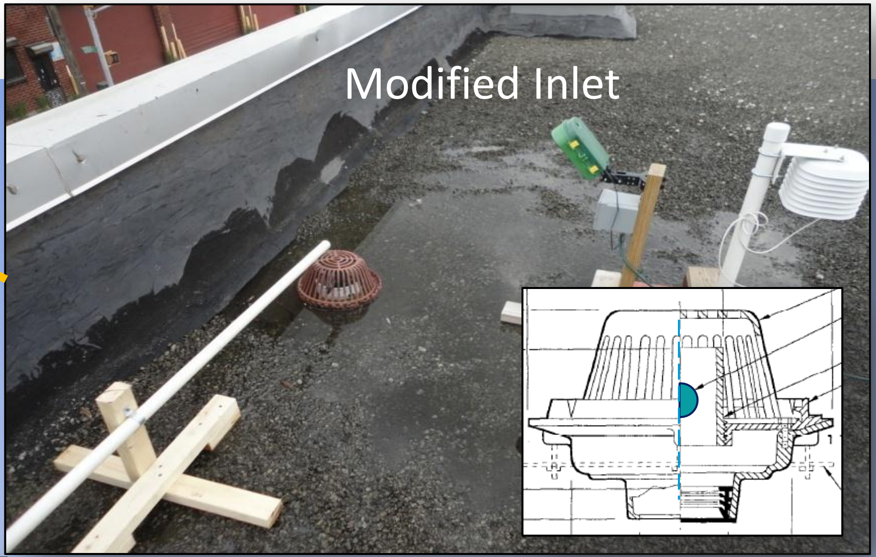
Scale Model of Check Dam Concept

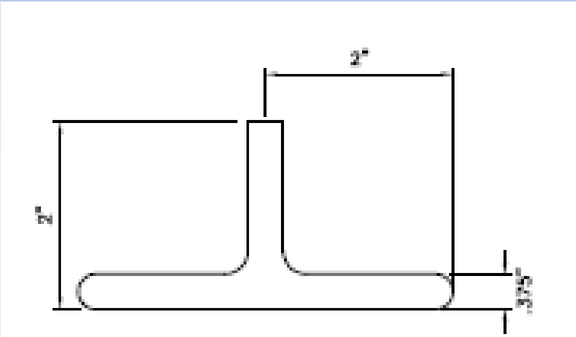

Orifice flow


Weir flow

Blue Roof Systems



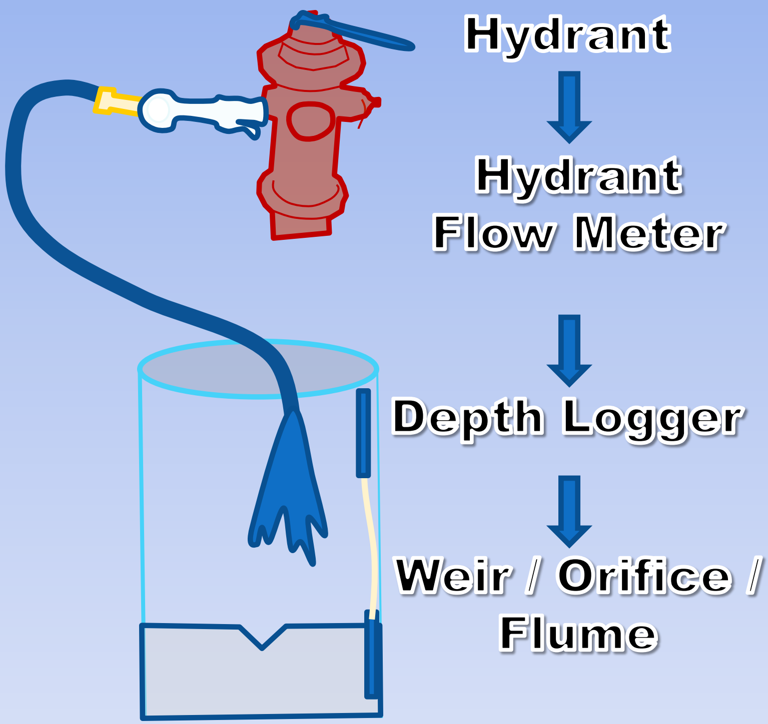




Section view of dam

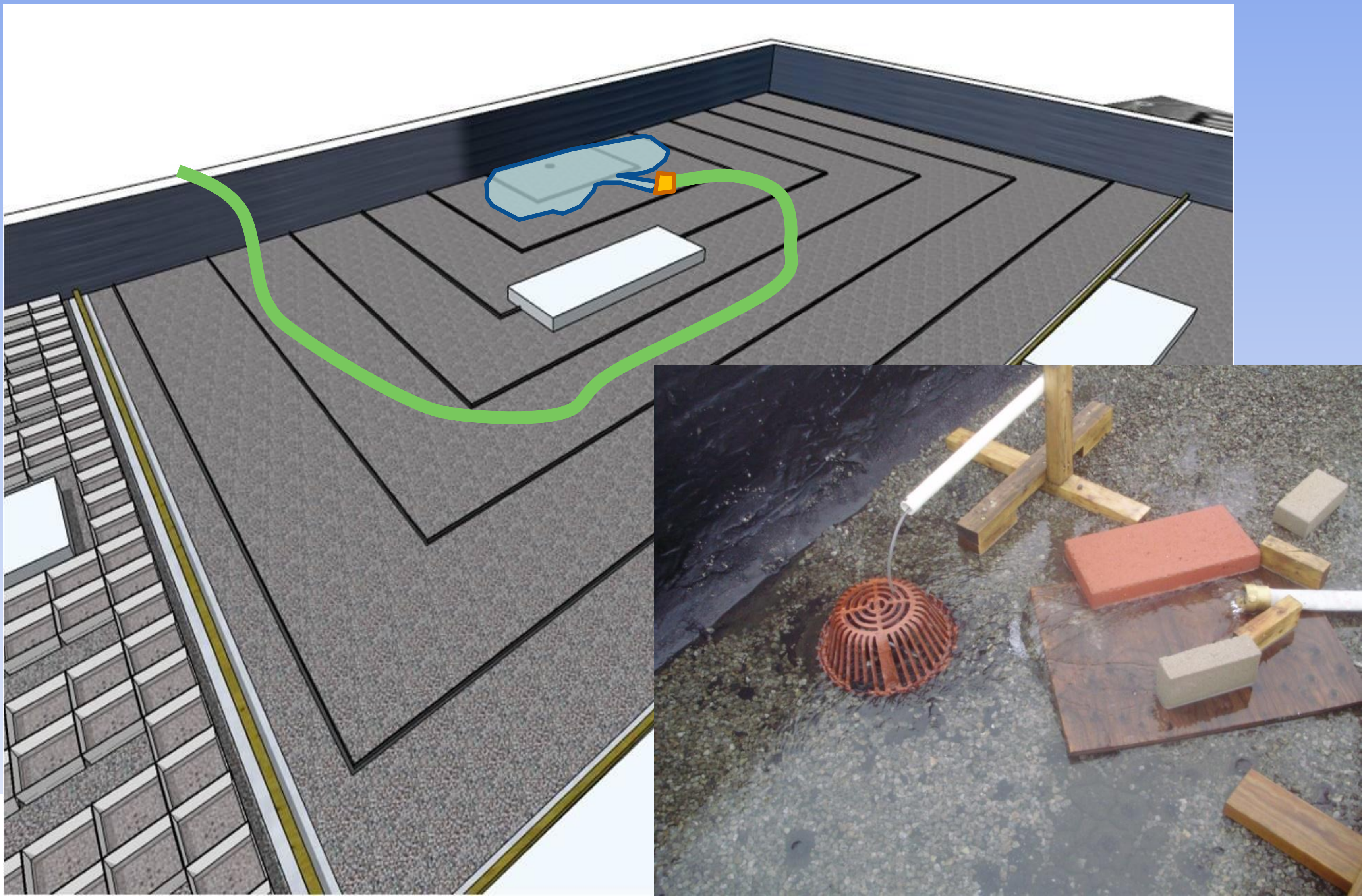
Roof Trays

Hydrant Testing

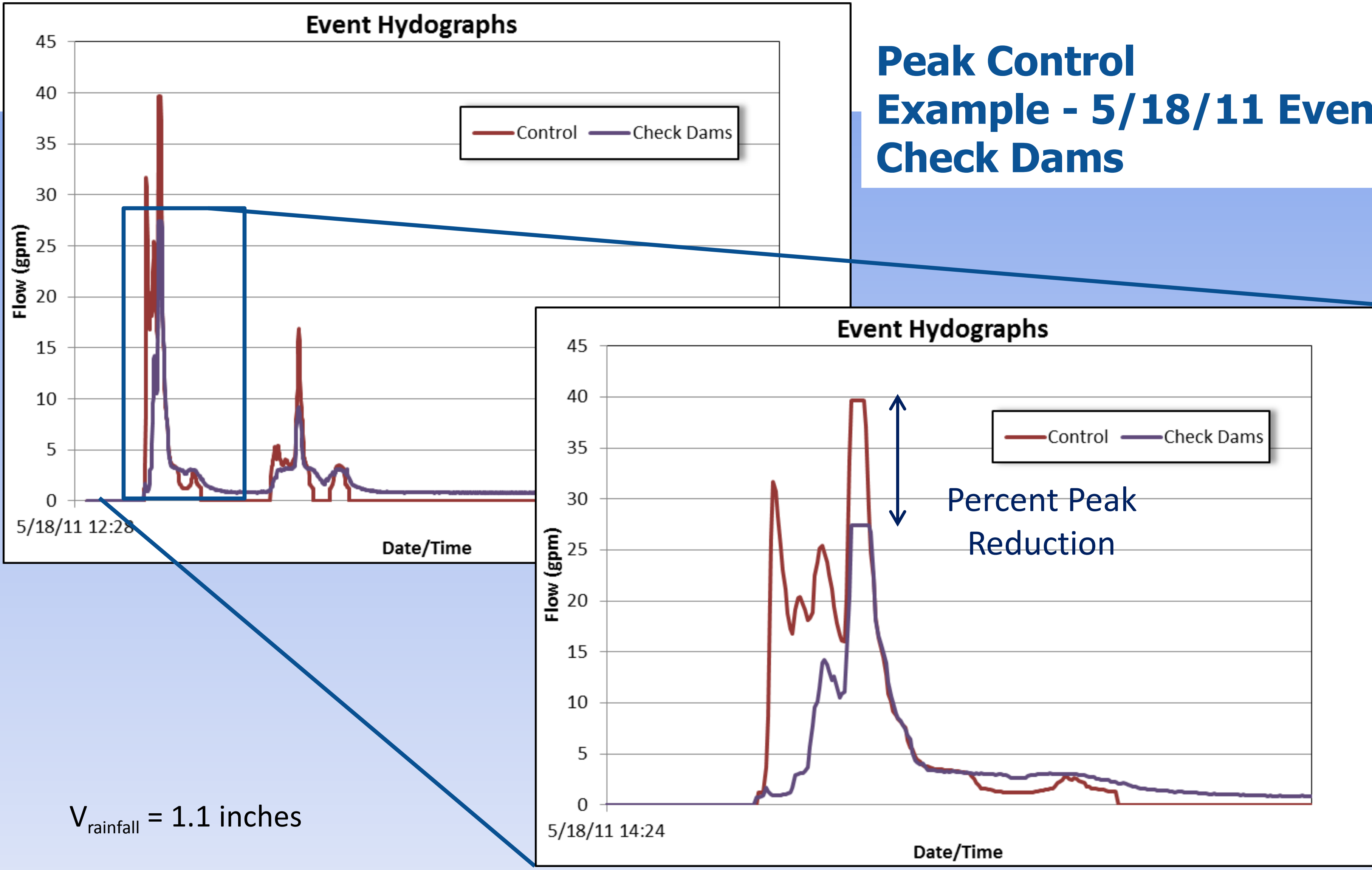


- Calibrate equipment in the field for better quality data
- Ensure that the monitoring equipment is functioning as intended
- Identify equipment maintenance needs

Rooftop Hydrant Testing

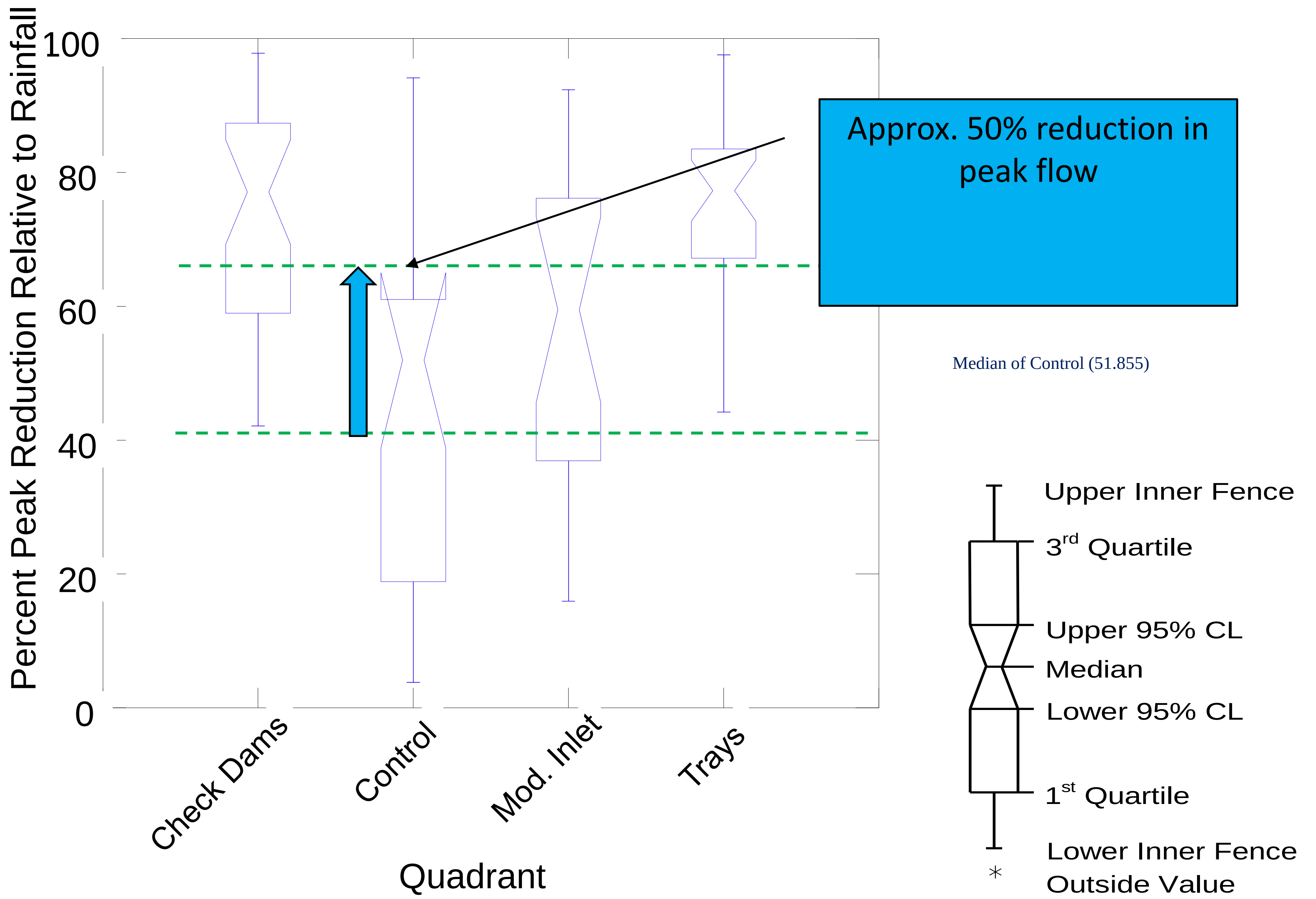


Peak Control Example - 5/18/11 Event Check Dams

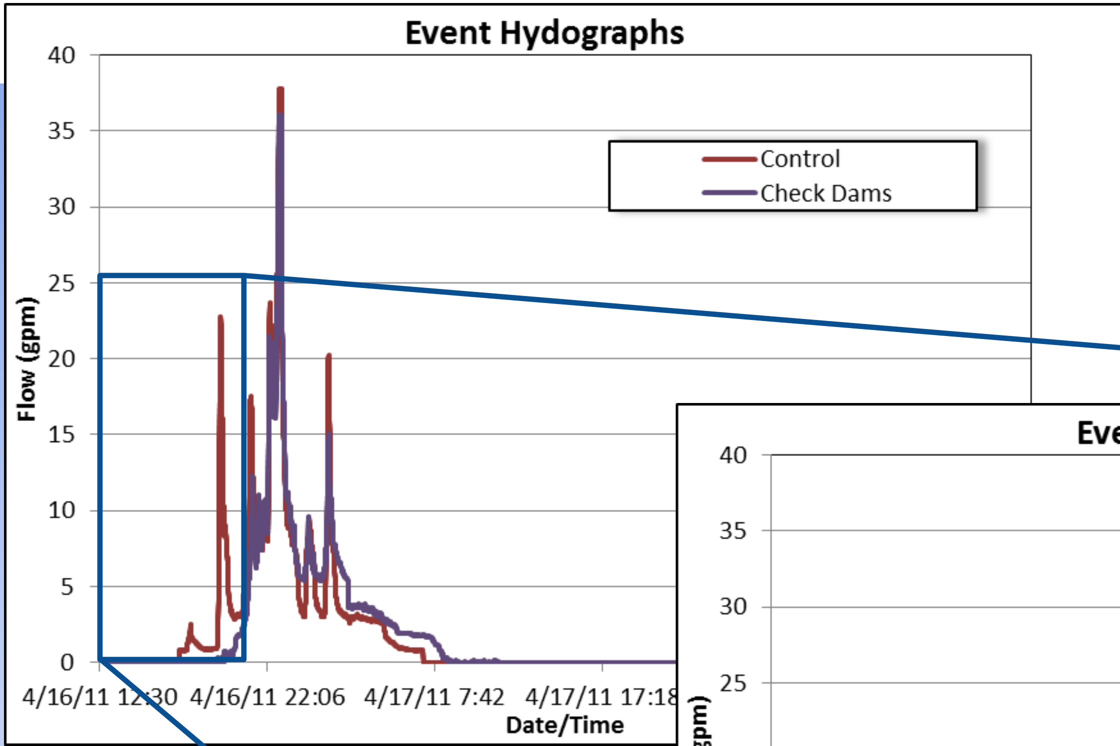


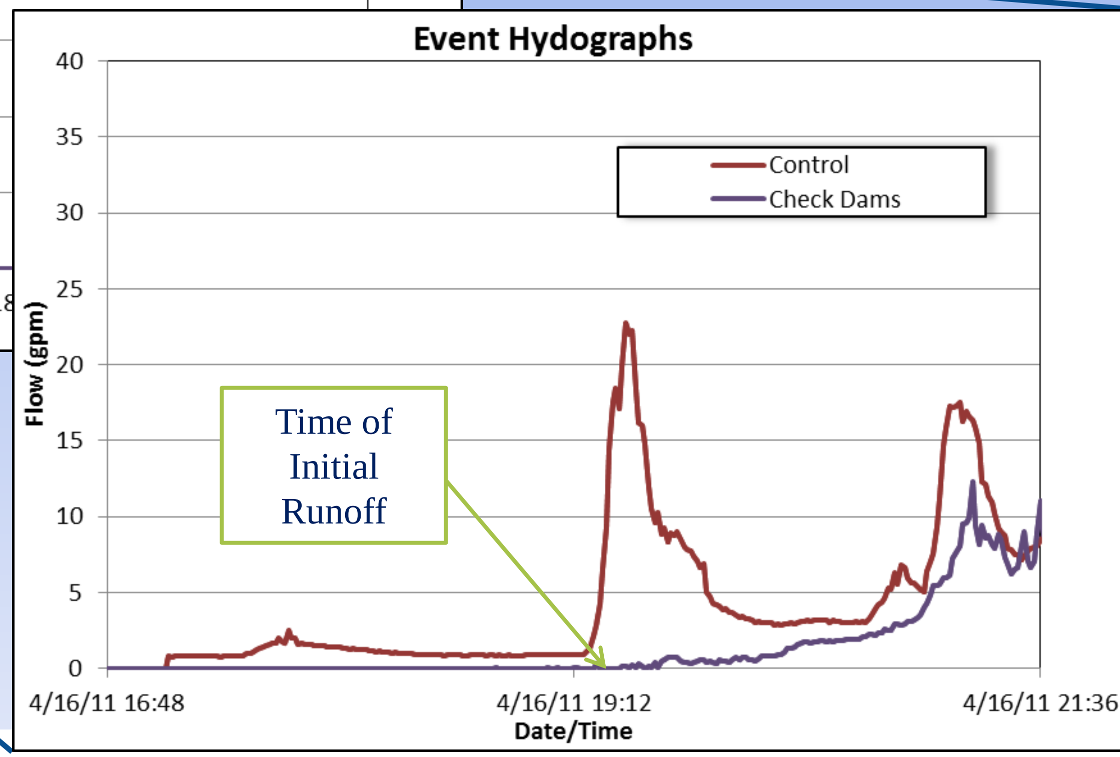
$V_{rainfall}$ = 1.1 inches

$Peak_{rainfall}$ = 2.0 inches/hour


Percent Peak Reduction Relative to Rainfall
100
80
60
40
20
0
Check Dams
Control
Mod. Inlet
Trays
Quadrant
Approx. 50% reduction in peak flow
Median of Control (51.855)
Upper Inner Fence
3rd Quartile
Upper 95% CL
Median
Lower 95% CL
1st Quartile
Lower Inner Fence
Outside Value

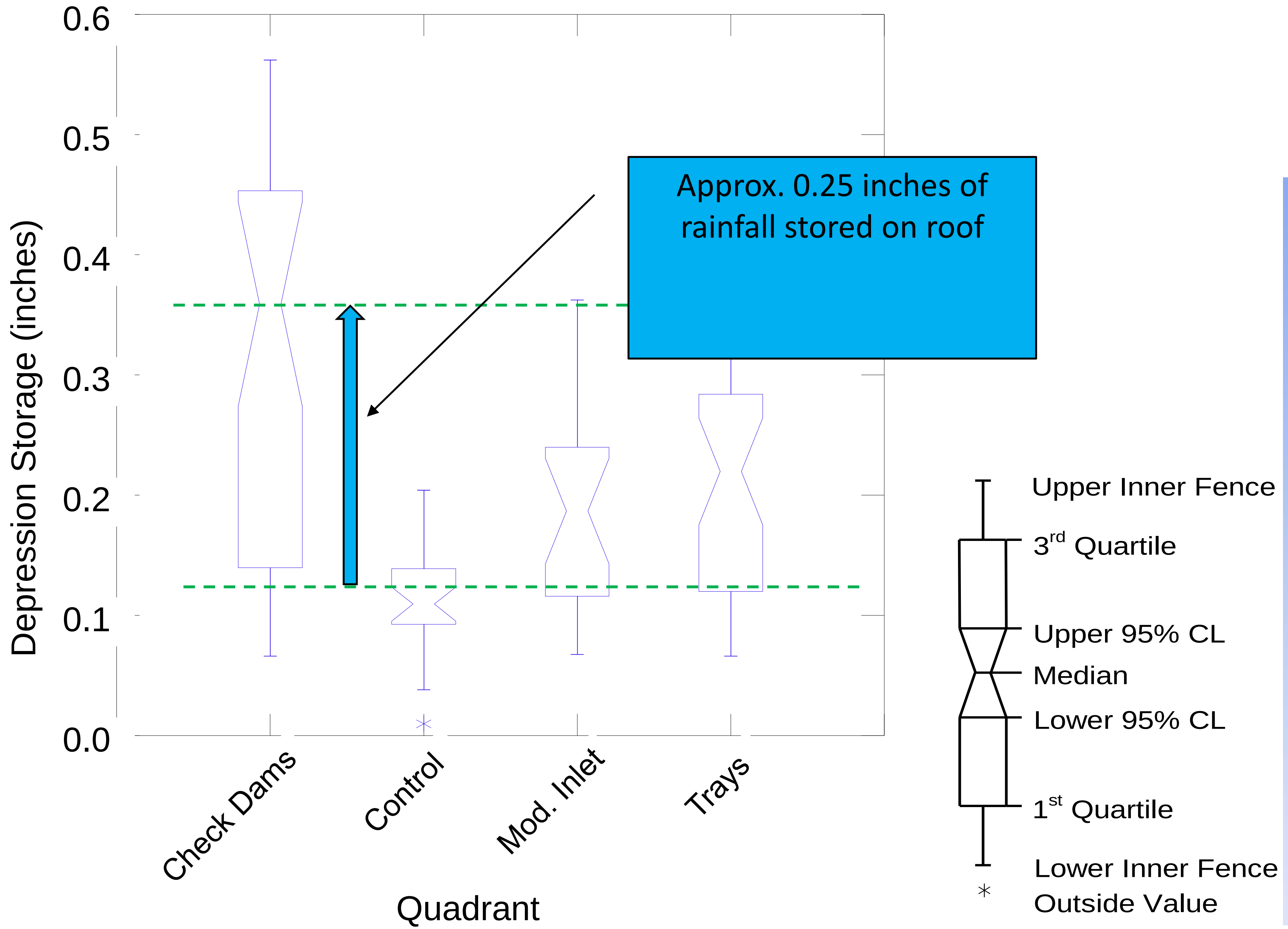
Depression Storage Example - 4/16/11 Event Check Dams



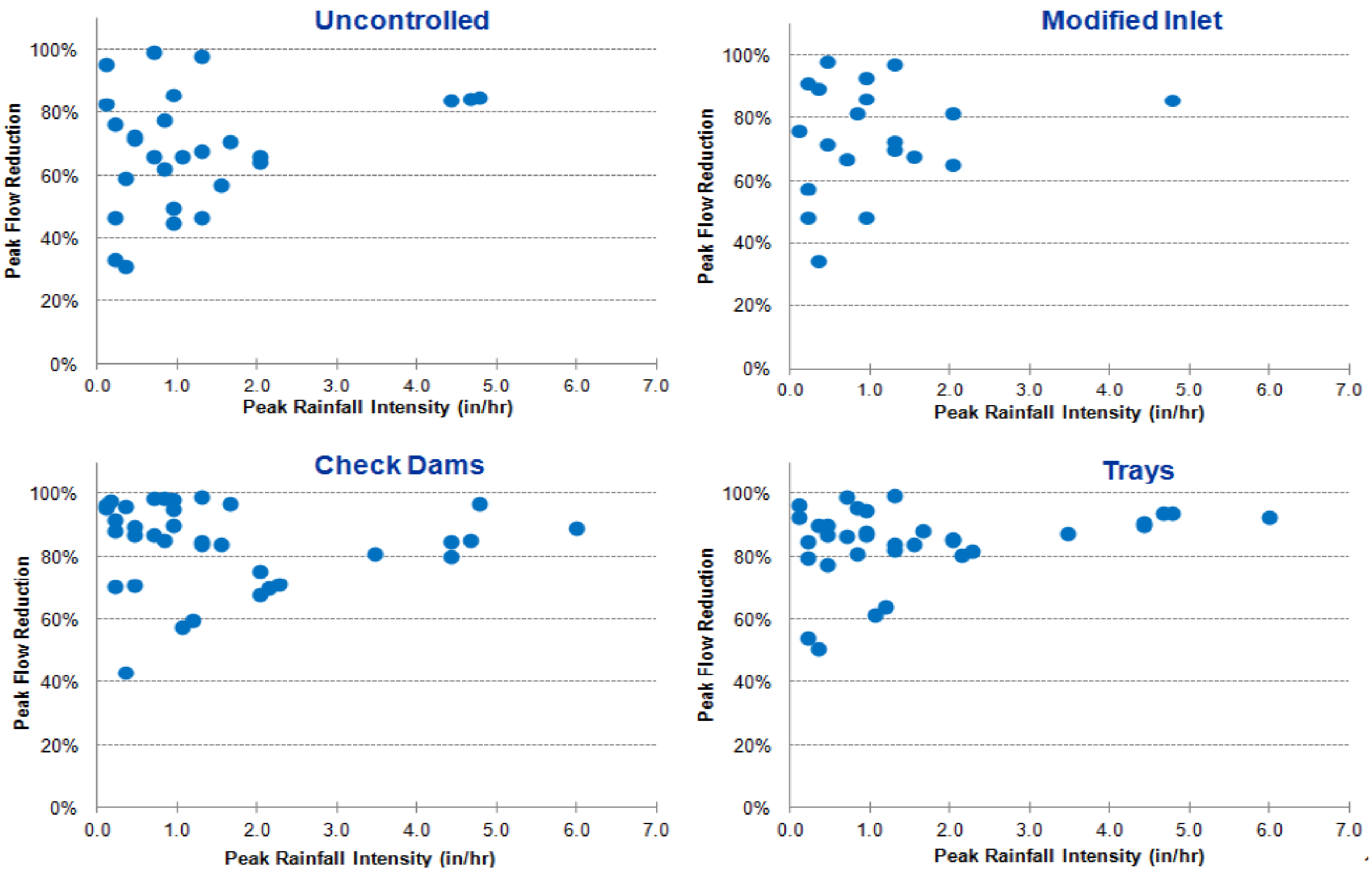


$V_{rainfall}$ = 1.6 inches

$Peak_{rainfall}$ = 2.1 inches/hour


Approx. 0.25 inches of rainfall stored on roof
Depression Storage (inches)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Check Dams
Control
Mod. Inlet
Trays
Quadrant
Upper Inner Fence
3rd Quartile
Upper 95% CL
Median
Lower 95% CL
1st Quartile
Lower Inner Fence
Outside Value

Observed 2011 Peak Flow Reductions



How did the H&H Model do?

7.48 gpm actual

- Design basis
  - Design peak flow = 5 gpm (0.12 cfs) – during orifice flow
  - Design storage = 490 cu. ft. (3,600 gallons)

2,400 gallons actual

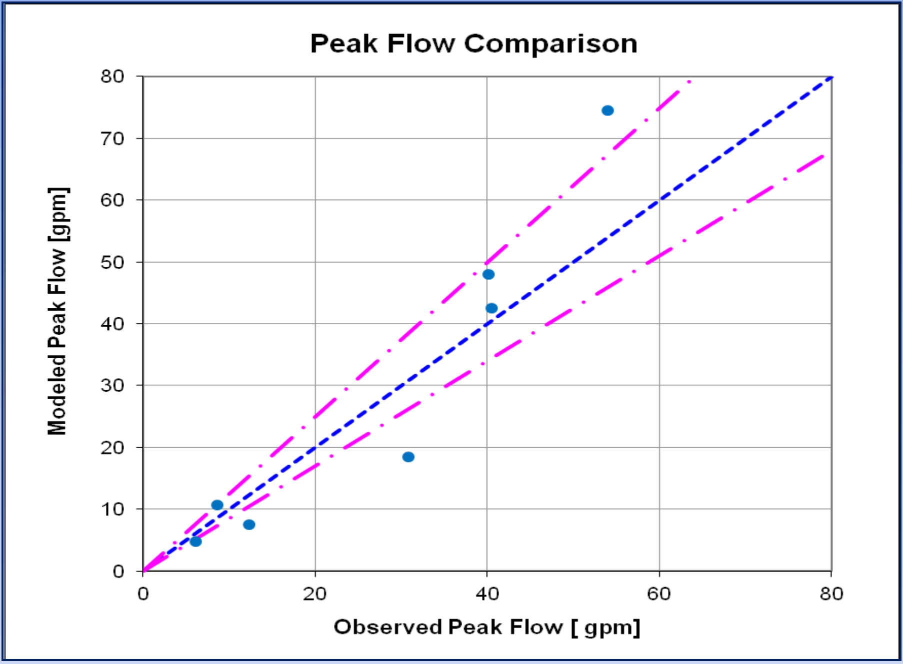
Model Calibration

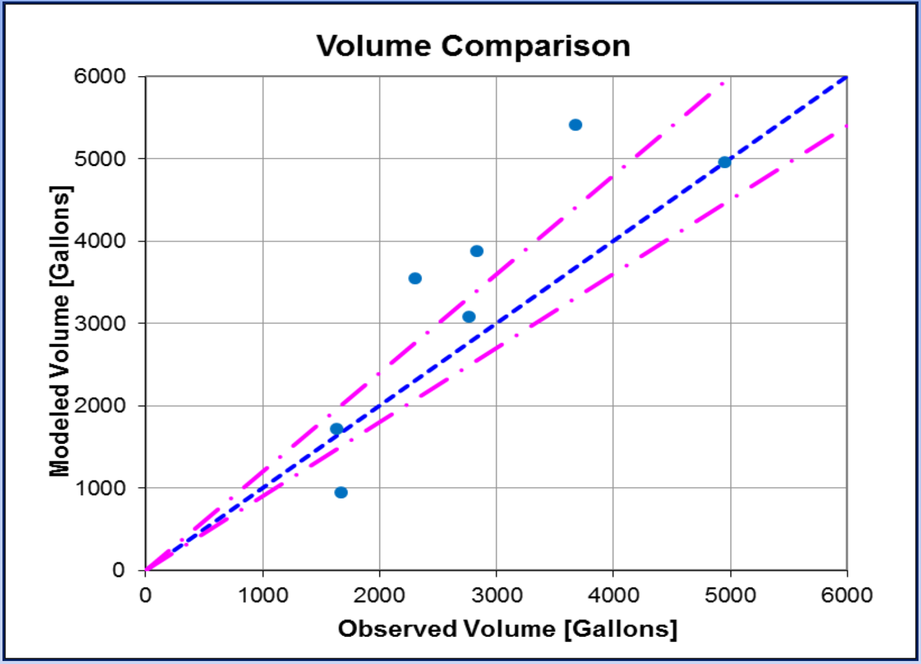
- Parameter Adjustment
  - Varying Dam Elevation
  - Spatially Varying Depression Storage
  - Monthly Varying Evaporation

Selected Events

	Peak Intensity (in/hr)	**Rainfall Volume (in)**
Event 1	*3.6*	*1.59*
Event 2	*1.8*	*0.56*
Event 3	*4.2*	*1.05*
Event 4	*3*	*1.06*
Event 5	*1.8*	*1.68*
Event 6	*4.8*	*1.26*

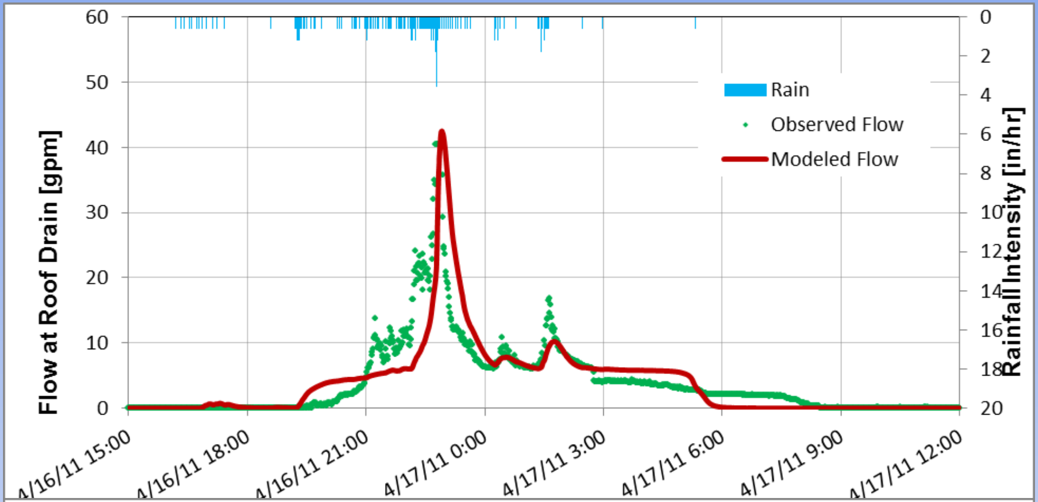
Modeled vs. Observed – Volume and Peak Flow

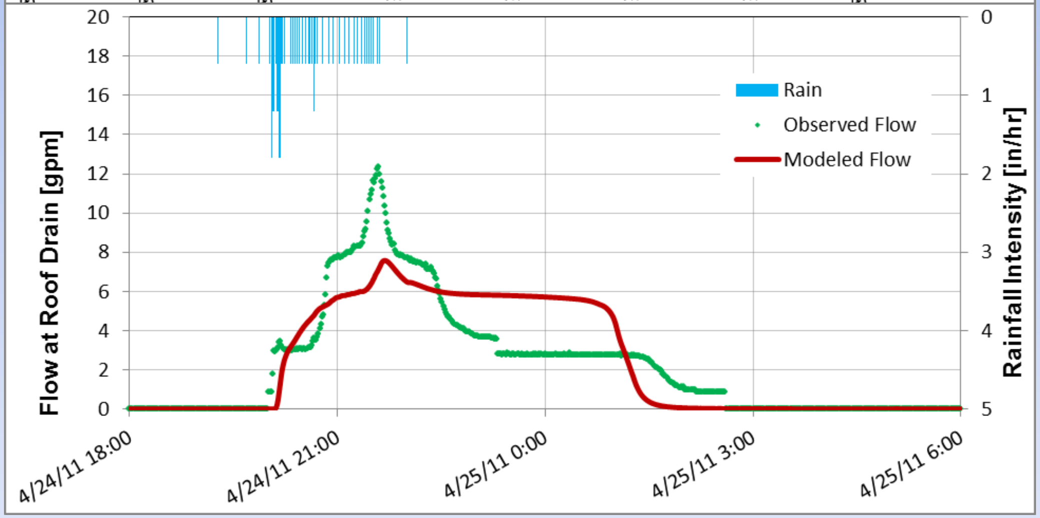




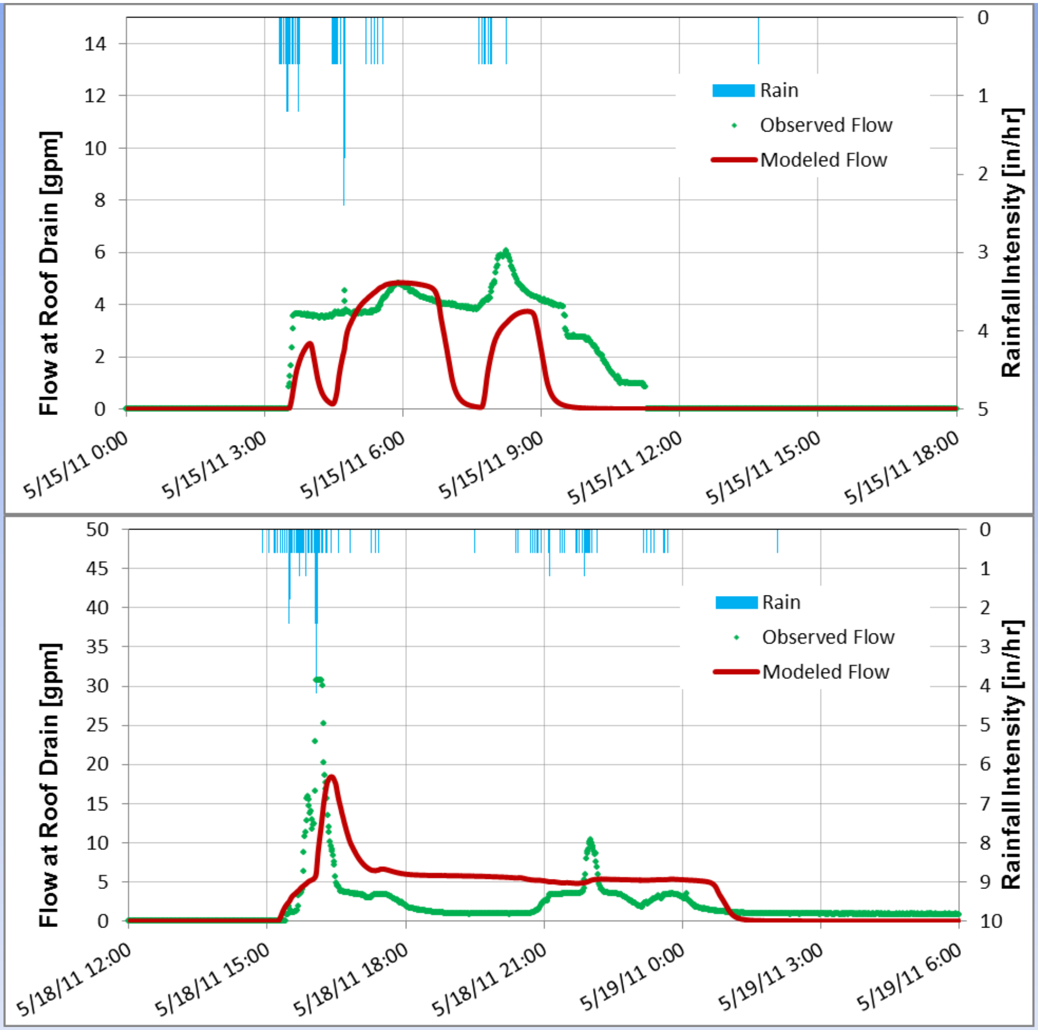
1:1 Line
Upper Bound of Observed Data (+20% for Volume, +25% for Peak Flow)
Lower Bound of Observed Data (-10% for Volume, -15% for Peak Flow)

Modeled vs. Observed – Storm 1 and 2

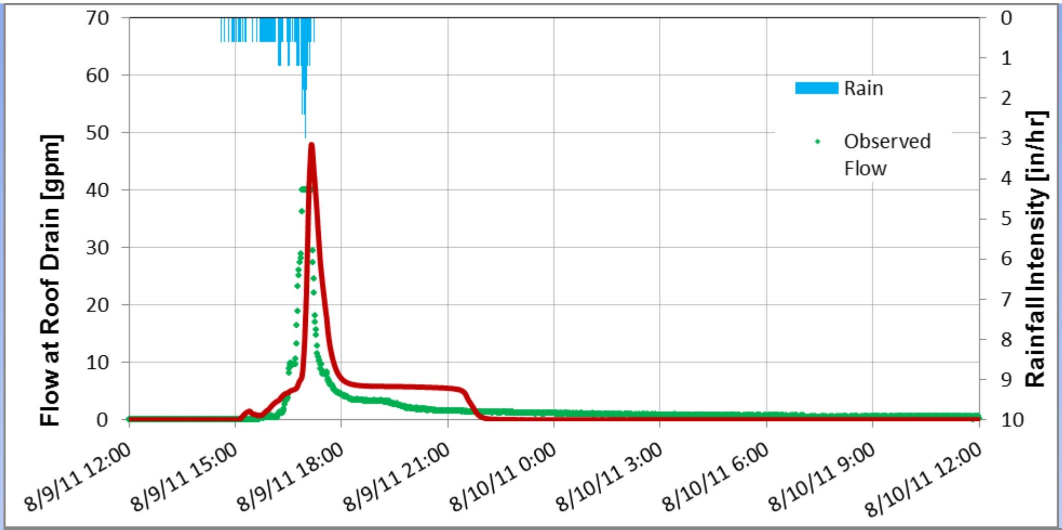


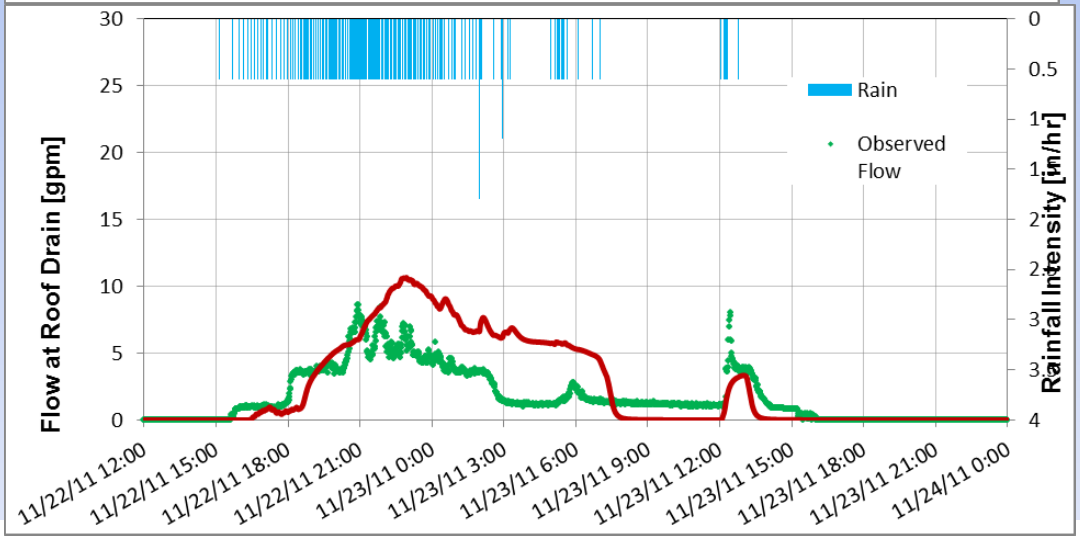


Modeled vs. Observed – Storm 3 and 4

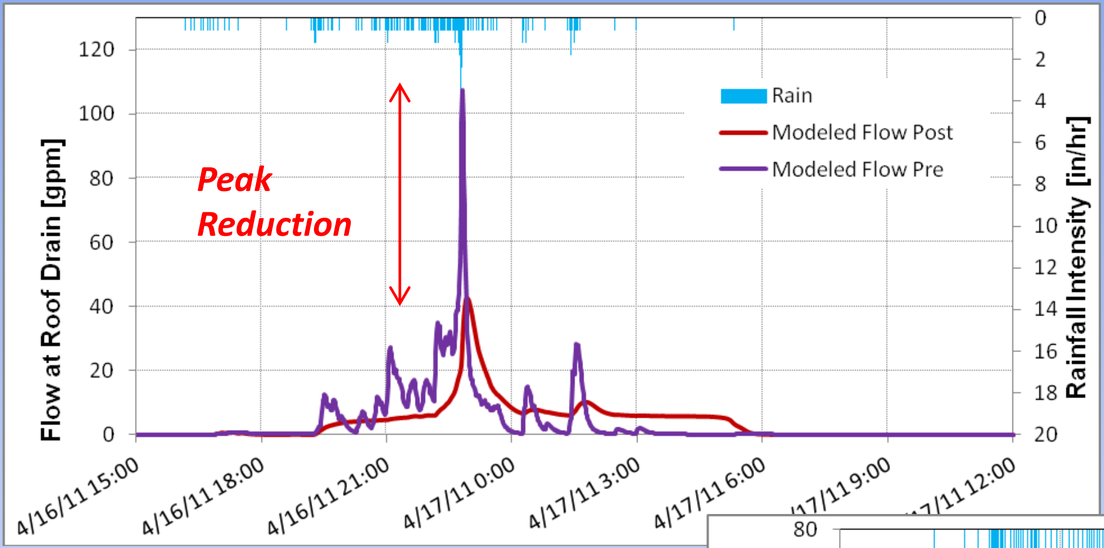


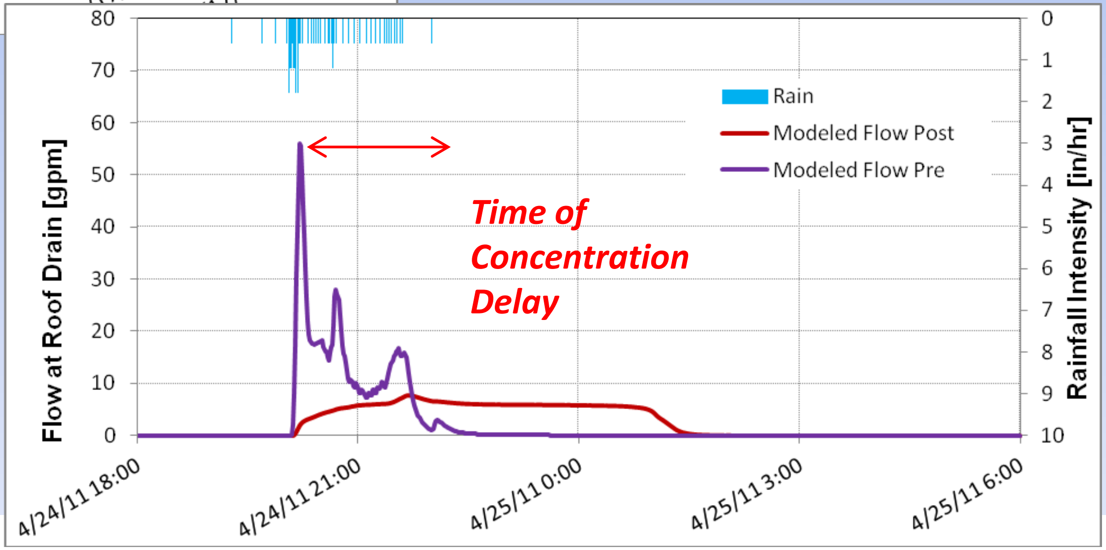
Modeled vs. Observed – Storm 5 and 6





Blue Roof Implementation Benefits using Calibrated Model





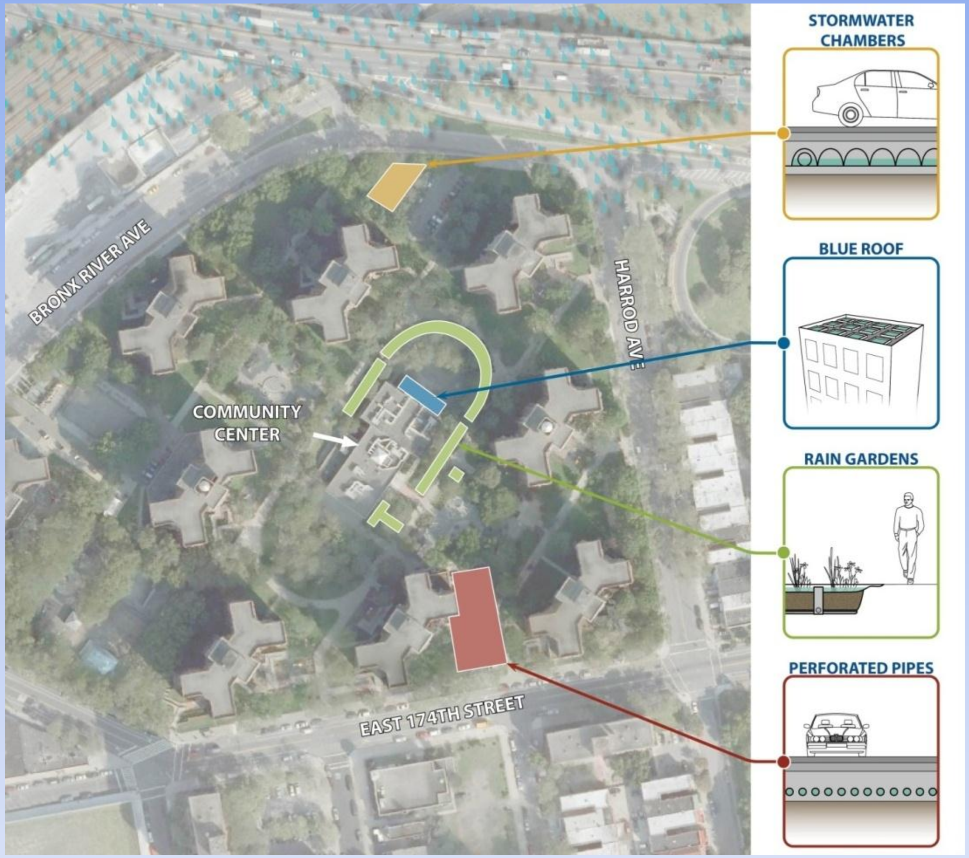
Conclusions and Future Work

- Blue roof can be effective in reducing peak flows
- More amenable for implementation with minimal retrofitting requirements (based on existing slopes)
- Orifice size, number and weir configuration are design parameters that are target climate-specific
- Target can be varied based on site or neighborhood goals or relative location to CSO outfall

Conclusions and Future Work

Neighborhood- or watershed-scale analysis will be performed as the next step to utilize site scale modeling results

Multi Blue Roof Evaluation



Multi Green/Grey Infrastructure Practice Evaluation

Questions?

- **Program Elements**
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