Green Infrastructure – Triple Bottom Line Benefits at Different Scales

eDesign Dynamics

Drexel UNIVERSITY

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AWRA-PMAS
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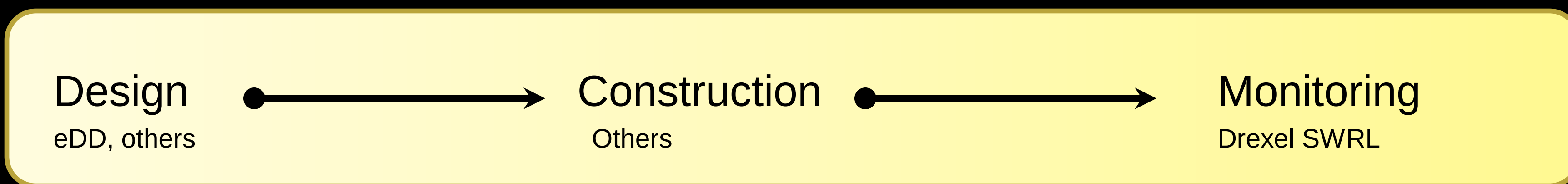
eDD / DU Partnership

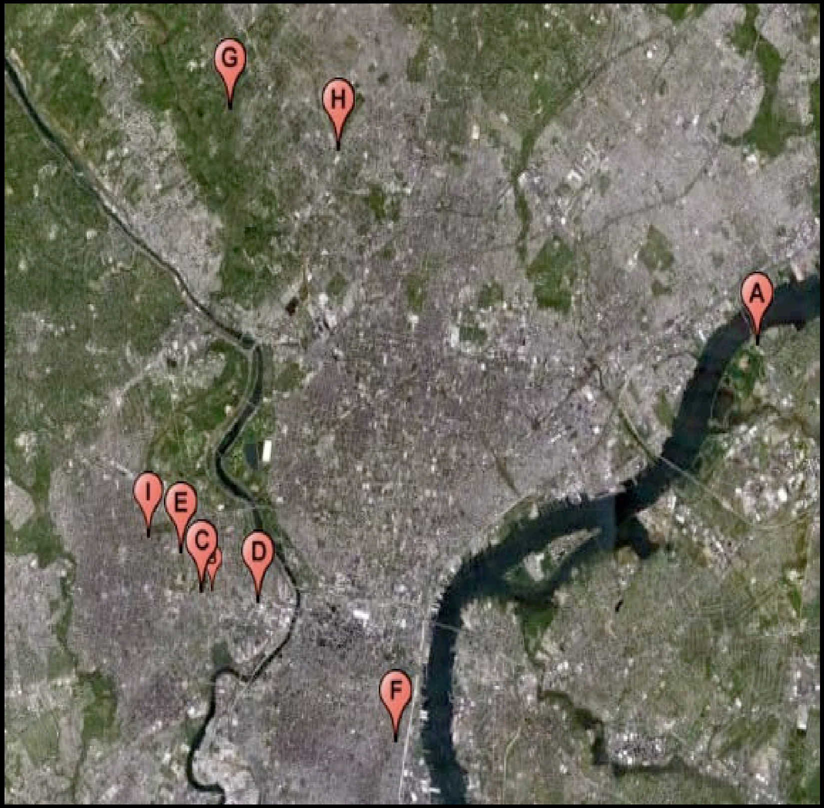


SWRE Lab

GI Monitoring Network

The Sustainable Water Resource Engineering Lab at Drexel University

New York City sites



Philadelphia sites

Commitments to GI

- NYC (2010) >$1.5 billion over 25 yrs
  - Capture first inch from 10% of impervious surfaces
  - $187 million in first 5 years (200 bioswales this year)
- Philadelphia (2009) >$1 billion over 25 yrs
  - Capture first inch of rainwater from ~47% of impervious surfaces in CSO districts
  - ~744 acres in first 5 years
- Other committed/almost committed cities:
  - Syracuse, Milwaukee, Kansas City, Portland, Chicago, St. Louis, Washington DC, Seattle, Cincinnati, Louisville

Triple (Quadruple?) Bottom Line

Economic scalability

Ecological benefits

Social value

Climate change mitigation/adaptation value

Triple (Quadruple?) Bottom Line

→ Economic scalability
- Lot-scale
- ↓
- Streetscape
- ↓
- Wetland

Ecological benefits

Social value

Climate change mitigation/adaptation value

West Ward Pride Garden (Newark, NJ)

13th Avenue School (without schoolyard)

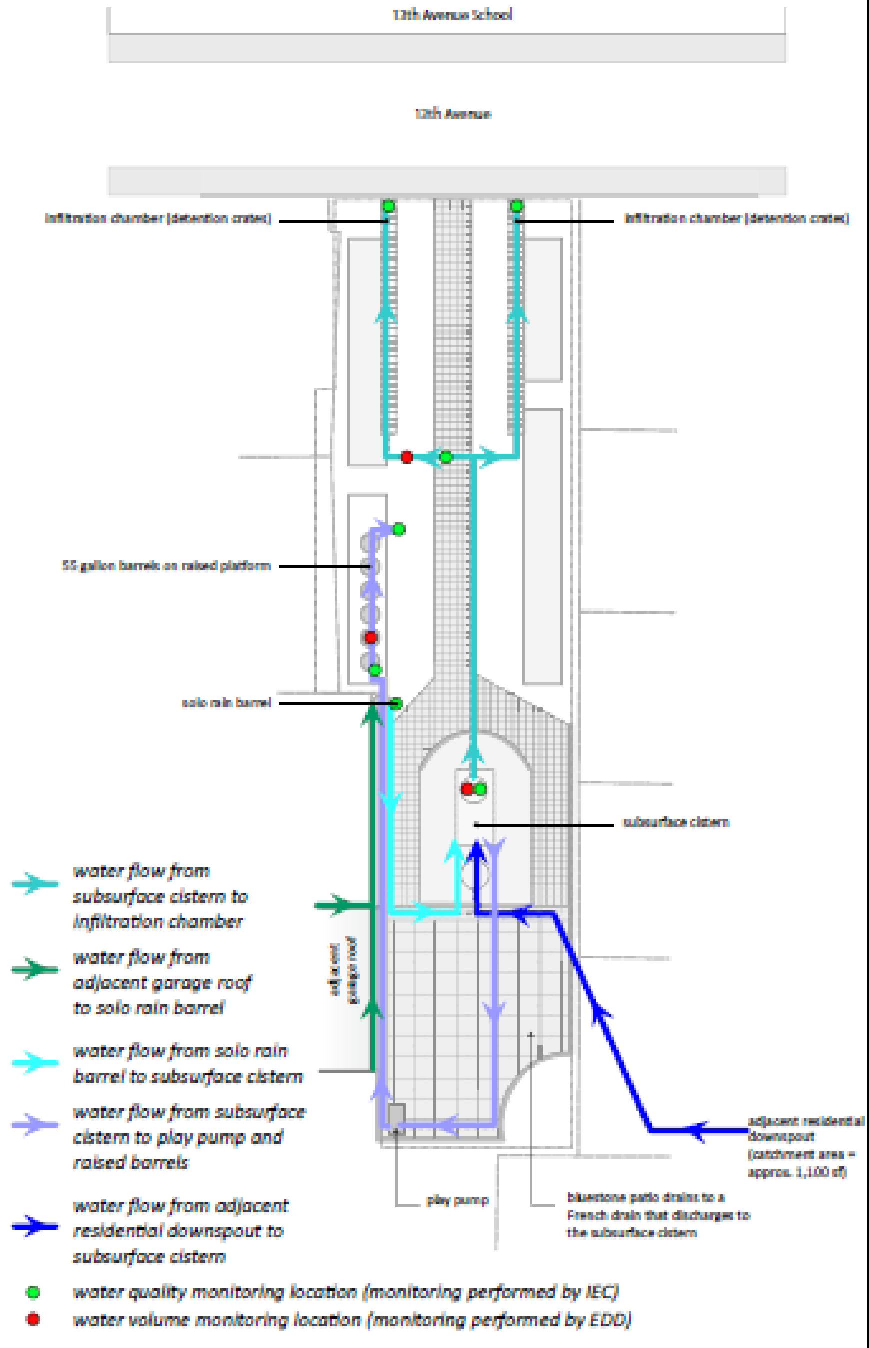
Vacant lot

Before

PROJECT SITE - BEFORE

After

PROJECT SITE - AFTER




INSTALLATION OF SUBSURFACE CISTERN (AKA STORMCHAMBER)


INSTALLATION OF INFILTRATION CHAMBER


INSTALLATION OF PERMEABLE PAVER WALKWAY


RAIN BARRELS ON RAISED PLATFORM WITH SPIGOT CONNECTION

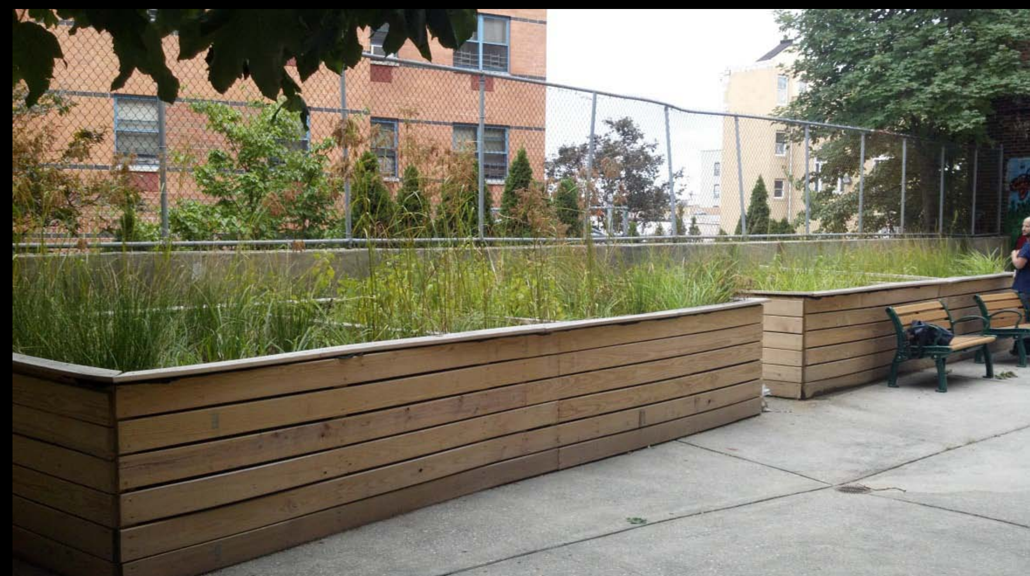

STUDENTS HAVE FUN OPERATING PLAY PUMP

Rain Event	Date	Day	Total Storm Depth (mm)	Total Storm Volume (m3)	Storm Duration (hrs)	Average Intensity (mm/hr)	Antecedent Dry Period (days)
1A	9/12/2010	9	2.8	0.37	1	2.8	18
1B	9/13/2010	10	27.1	3.58	0.5	54.2	1
2	9/16/2010	13	33.0	4.36	0.5	65.9	2
3	9/27/2010	24	25.4	3.36	6.5	3.9	9
4A	9/30/2010	27	19.0	2.51	2	9.5	1
4B	10/1/2010	28	16.8	2.22	9	1.9	0
5	10/4/2010	31	2.5	0.33	5	0.5	3
6	10/11/2010	38	55.3	7.31	4	13.8	7
7	10/14/2010	41	12.6	1.66	6	2.1	1.5
Averages			21.6	2.86	3.8	17.2	4.7

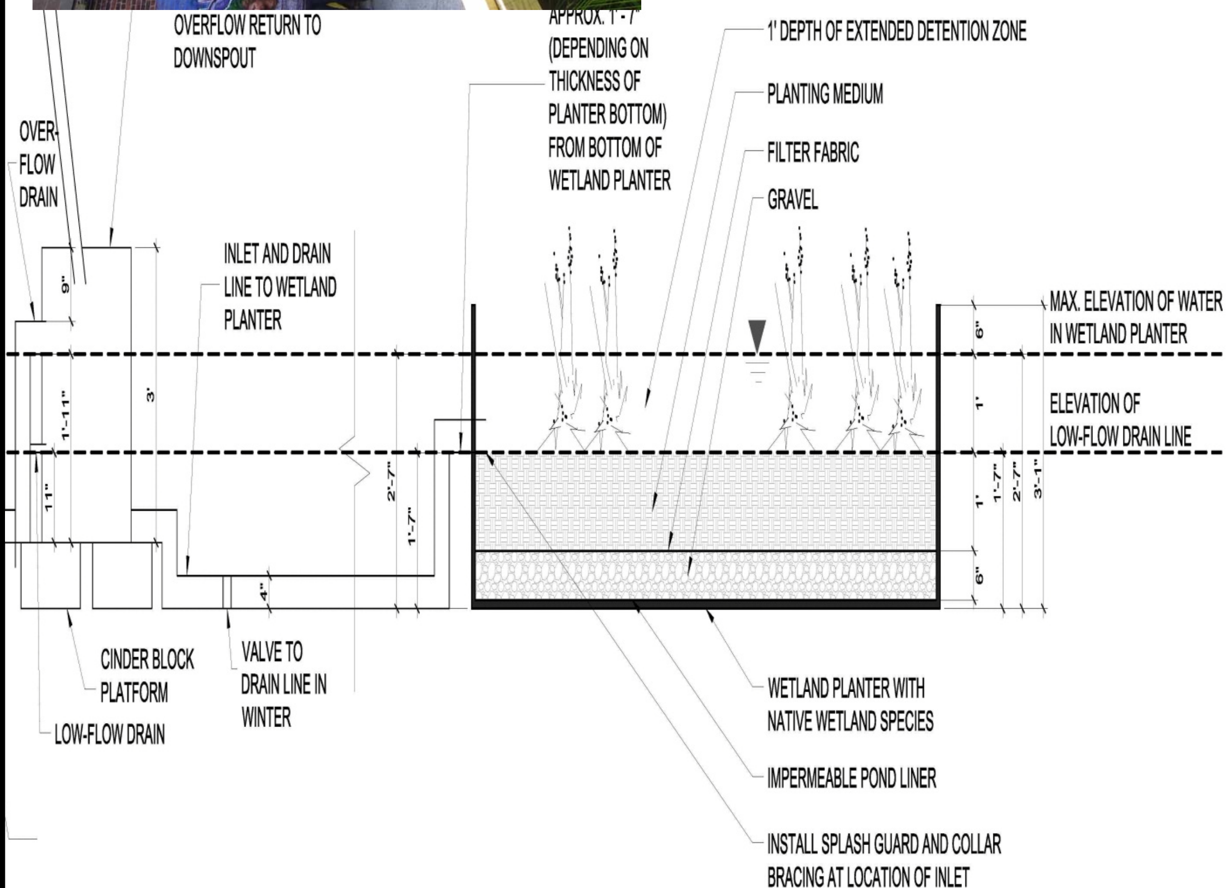
Percent of storm volume infiltrated: 4 - 69%

Rain Event	"Infiltration" Rate (Rate of Descent) (m3/day)	Available Detention Volume in Cistern (m3)	Hours at Capacity in Cistern	Total Draw-down Time (hours)	Infiltrated Volume (m3)	Percent Storm Infiltrated	Percent Storm Retained	Percent Storm Mitigated	Total Volume Mitigated (m3)
1A	0.195	0.518	0	21	0.26	69%	0%	69%	0.26
1B	0.471	0.581	0.7	11	0.13	4%	2%	6%	0.20
2	0.231	0.518	0.3	32	0.39	9%	0%	9%	0.39
3	0.281	0.715	5.8	45	0.55	16%	6%	22%	0.75
4A	0.302	0.518	5.7	22	0.27	11%	0%	11%	0.27
4B	0.258	0.282	12.6	54	0.66	30%	0%	30%	0.66
5	0.412	0.395	0.0	10	0.12	37%	0%	37%	0.12
6	0.282	0.518	0.3	31	0.38	5%	0%	5%	0.38
7	0.200	0.518	0	35	0.43	26%	0%	26%	0.43
Averages	0.292	0.507	2.8	29	0.353	23%	1%	24%	3.44
									13%

Prospect Ave, Bronx, NY



Low cost stormwater management on underutilized urban spaces



GREEN INFRASTRUCTURE CONSULTAN

eDesign Dynamics
338 West 39th Street, 10F
New York, NY 10018
P) 646.688.3113
F) 646.688.3664

CLIENT:

NYC Soil and Water Conse
121 Avenue of the Americas,
New York, NY 10013
P) 212.431.9676
F) 212.965.1859

PROJECT NAME:

970 PROSPECT AV

DRAWING TITLE:

DOWNSPOUT + PLA

DRAWN: AB

CHECK

DATE: 5.02.2011

SCALE:

DESCRIPTION:

SCHEMATIC DRAW

DRAWING NO.: **L-102.00**

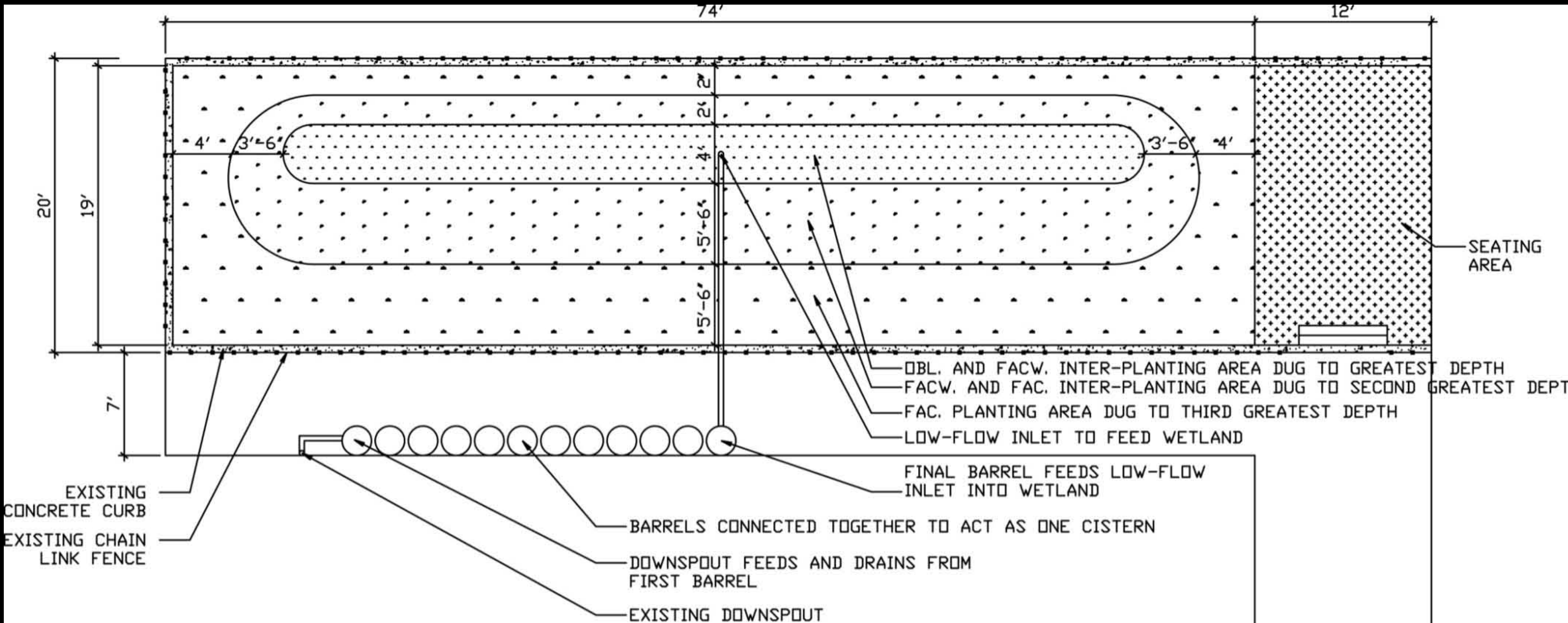
PAGE:

STORMWATER FALLING ON 3,600SF IMPERVIOUS ROOF CATCHMENT DURING ONE-INCH STORM
= 2,244 gallons

ENGINEERED MAXIMUM STORAGE VOLUME
= 3,638 gallons

% OF STORMWATER DETAINED DURING ONE-INCH STORM
= 100%


West 150th Street, NYC


74'
12'
20'
19'
7'
2'
2'
4'
3'-6"
3'-6"
4'
4'
5'-6"
5'-6"
SEATING AREA
OBL. AND FACW. INTER-PLANTING AREA DUG TO GREATEST DEPTH
FACW. AND FAC. INTER-PLANTING AREA DUG TO SECOND GREATEST DEPTH
FAC. PLANTING AREA DUG TO THIRD GREATEST DEPTH
LOW-FLOW INLET TO FEED WETLAND
FINAL BARREL FEEDS LOW-FLOW INLET INTO WETLAND
BARRELS CONNECTED TOGETHER TO ACT AS ONE CISTERN
DOWNSPOUT FEEDS AND DRAINS FROM FIRST BARREL
EXISTING DOWNSPOUT
EXISTING CONCRETE CURB
EXISTING CHAIN LINK FENCE
12'
NORTH

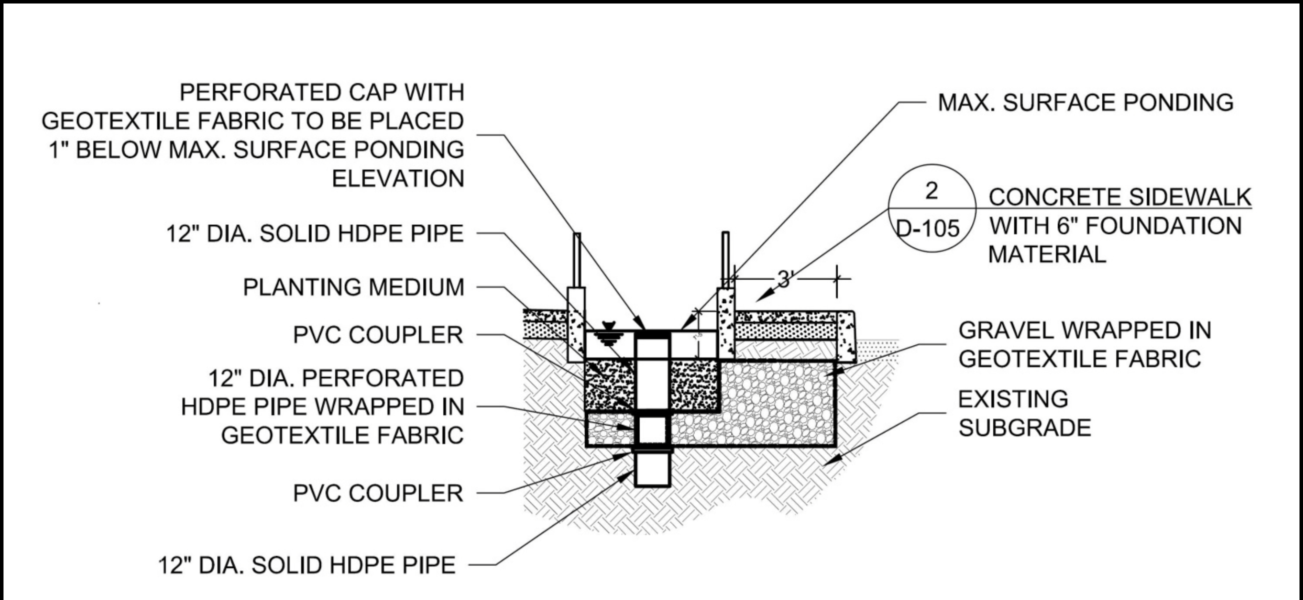
STORMWATER FALLING ON 2,648SF IMPERVIOUS ROOF DURING ONE-INCH STORM
= 1,651 gallons

ENGINEERED MAX STORAGE VOLUME
= 4,040 gallons

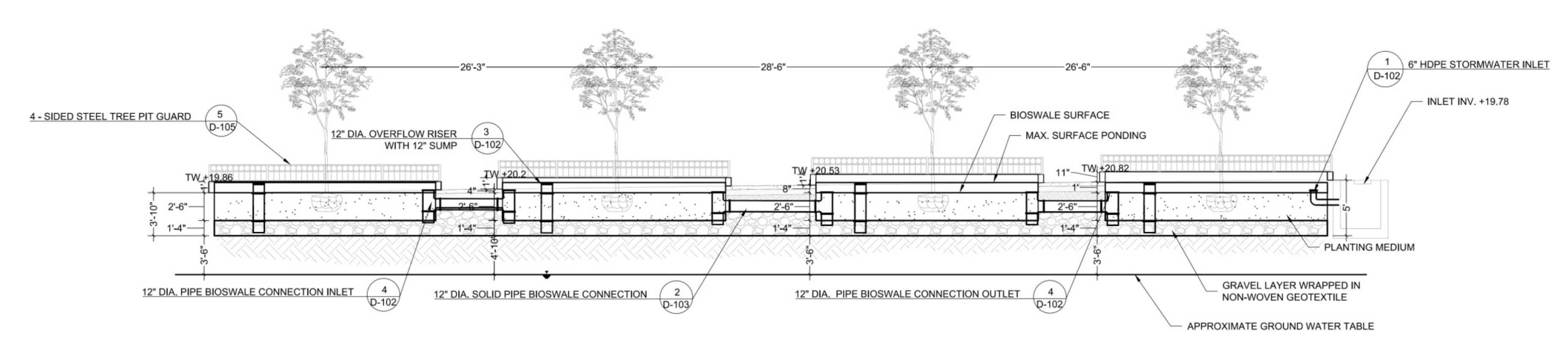
% OF ONE-INCH STORM DETAINED/RETAINED
= 100%

The Sixth Street Green Corridor (Brooklyn, NY)

Section (proposed modification to NYCDEP standard bioswale)

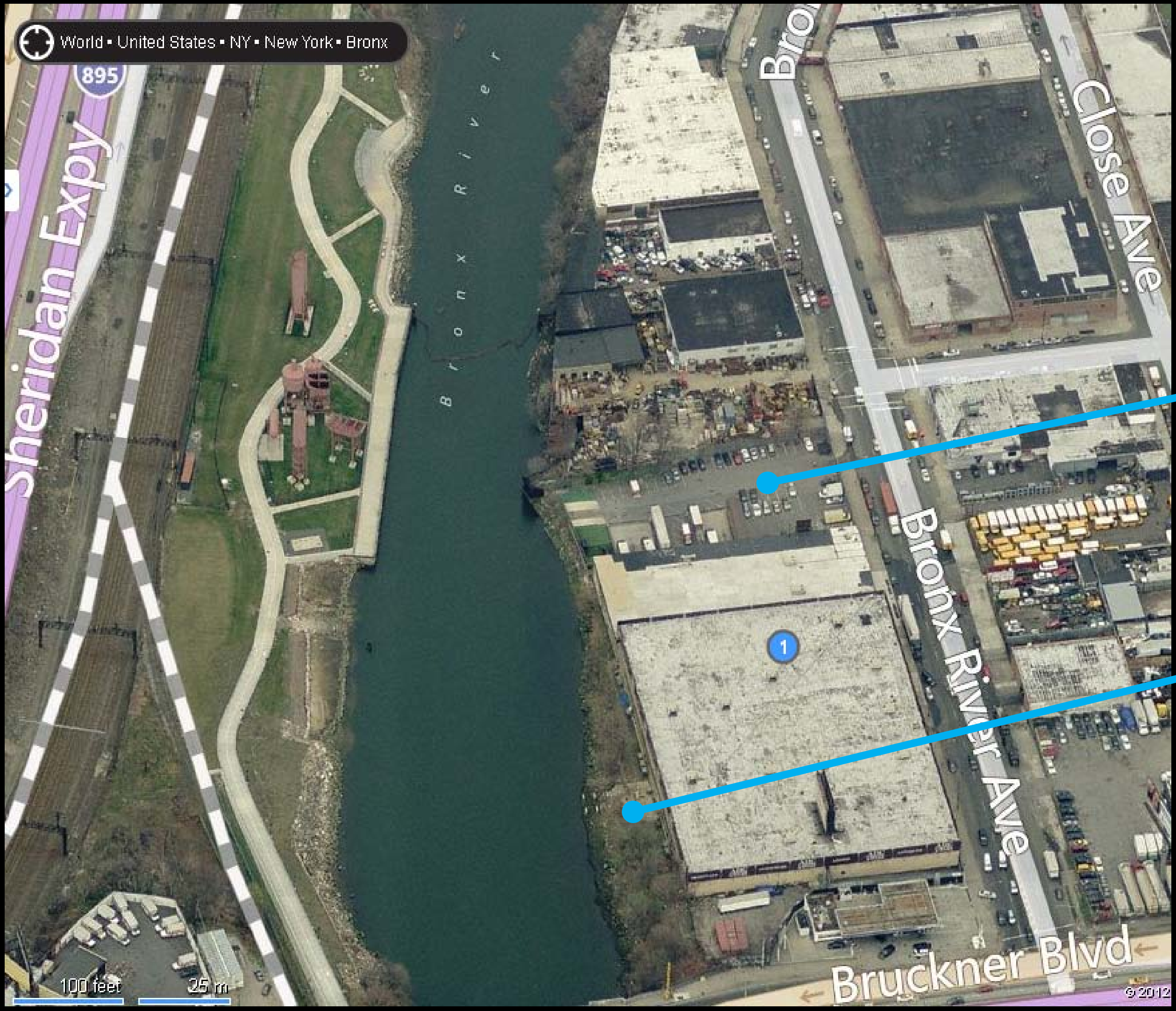


Elevation



Construction to begin 2013

ABC Carpet (Bronx, NY)

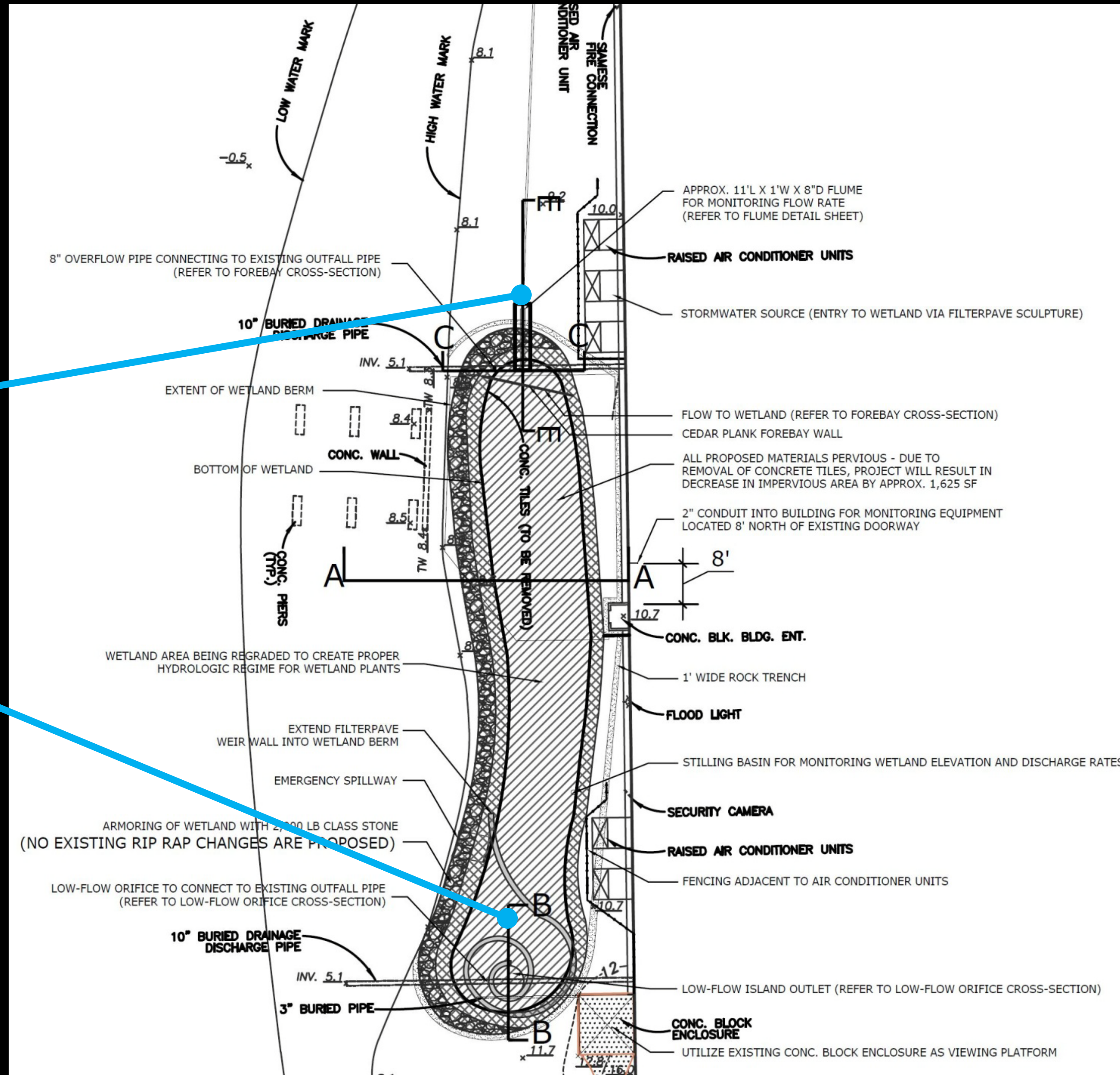


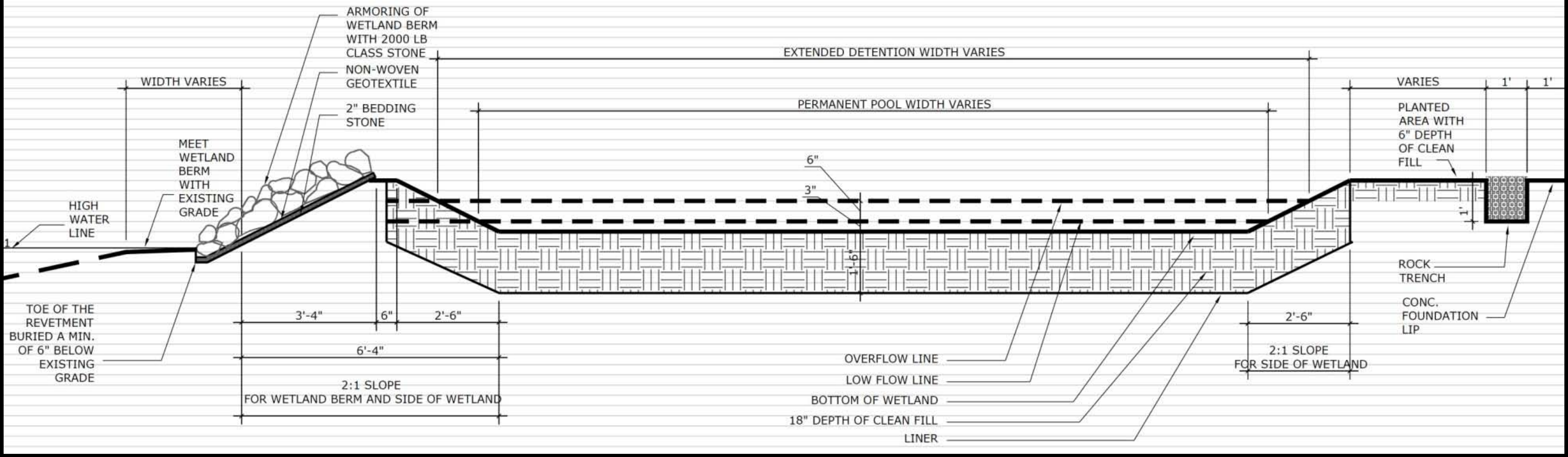
Impervious parking lot draining to Bronx River

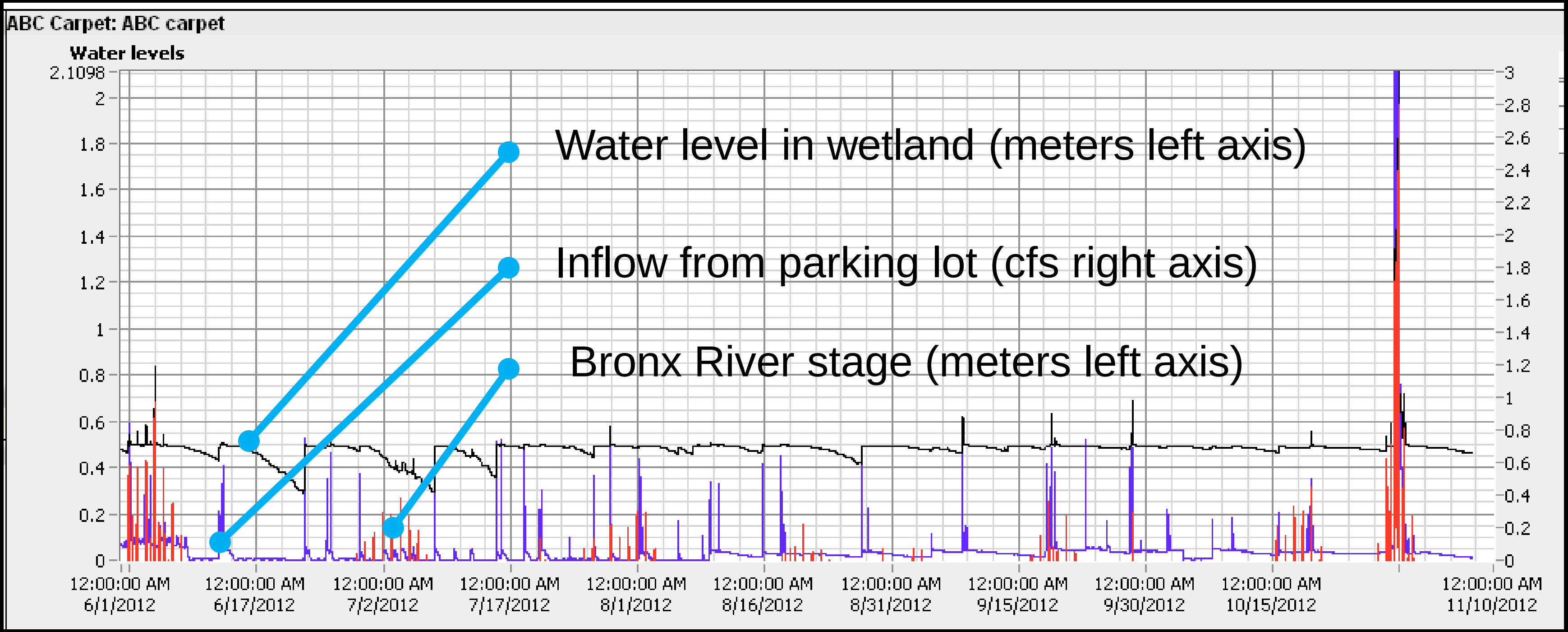
Underutilized riparian land

Inflow from parking lot

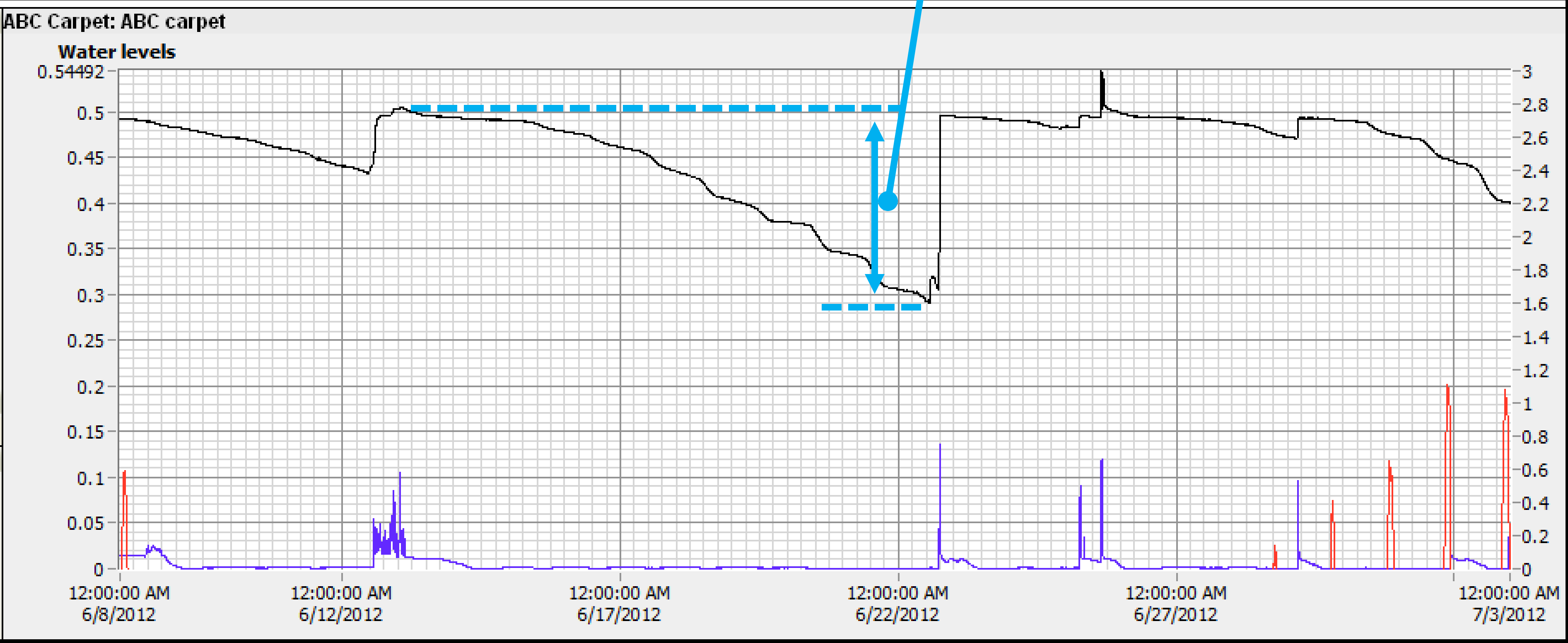
Overflow to river

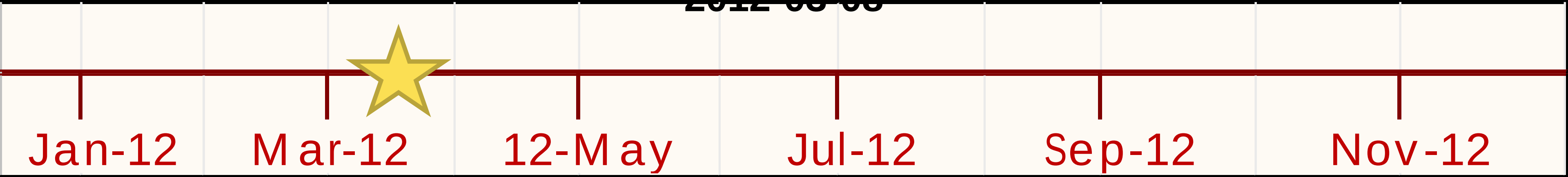


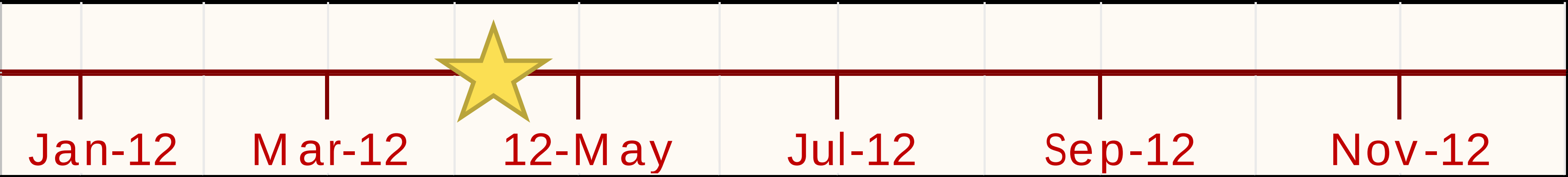

ARMORING OF WETLAND BERM WITH 2000 LB CLASS STONE
NON-WOVEN GEOTEXTILE
2" BEDDING STONE
EXTENDED DETENTION WIDTH VARIES
WIDTH VARIES
PERMANENT POOL WIDTH VARIES
VARIES
1'
1'
PLANTED AREA WITH 6" DEPTH OF CLEAN FILL
MEET WETLAND BERM WITH EXISTING GRADE
HIGH WATER LINE
6"
3"
1'-6"
1'
ROCK TRENCH
CONC. FOUNDATION LIP
TOE OF THE REVETMENT BURIED A MIN. OF 6" BELOW EXISTING GRADE
3'-4"
6"
2'-6"
6'-4"
2:1 SLOPE FOR WETLAND BERM AND SIDE OF WETLAND
2'-6"
2:1 SLOPE FOR SIDE OF WETLAND
OVERFLOW LINE
LOW FLOW LINE
BOTTOM OF WETLAND
18" DEPTH OF CLEAN FILL
LINER


ABC Carpet: ABC carpet
Water levels
2.1098
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12:00:00 AM 6/1/2012
12:00:00 AM 6/17/2012
12:00:00 AM 7/2/2012
12:00:00 AM 7/17/2012
12:00:00 AM 8/1/2012
12:00:00 AM 8/16/2012
12:00:00 AM 8/31/2012
12:00:00 AM 9/15/2012
12:00:00 AM 9/30/2012
12:00:00 AM 10/15/2012
12:00:00 AM 11/10/2012
Water level in wetland (meters left axis)
Inflow from parking lot (cfs right axis)
Bronx River stage (meters left axis)

8000 gallons of stormwater (20 cm over 1625 sf wetland area) evaporated over one 10 day period

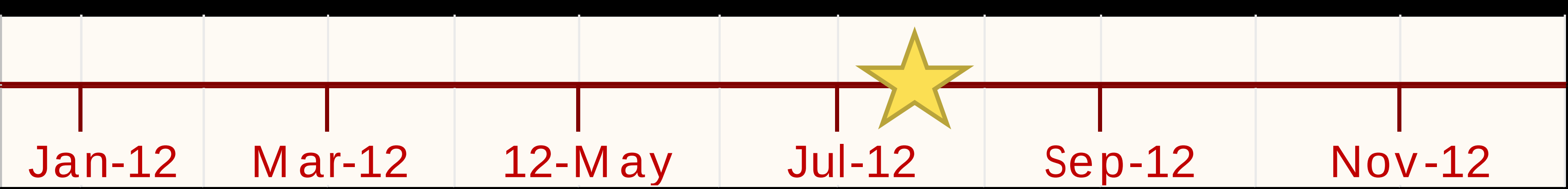


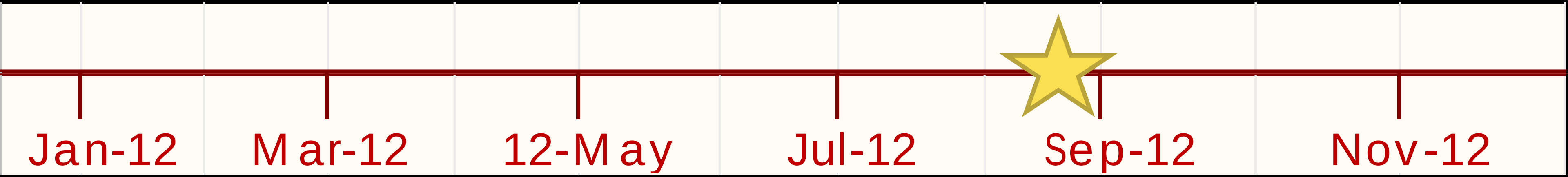

Jan-12
Mar-12
12-May
Jul-12
Sep-12
Nov-12

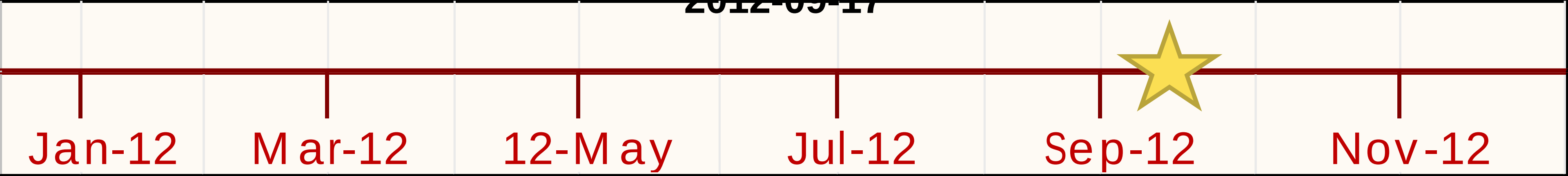


Jan-12
Mar-12
12-May
Jul-12
Sep-12
Nov-12

Jan-12 Mar-12 12-May Jul-12 Sep-12 Nov-12


Jan-12
Mar-12
12-May
Jul-12
Sep-12
Nov-12


Jan-12
Mar-12
12-May
Jul-12
Sep-12
Nov-12

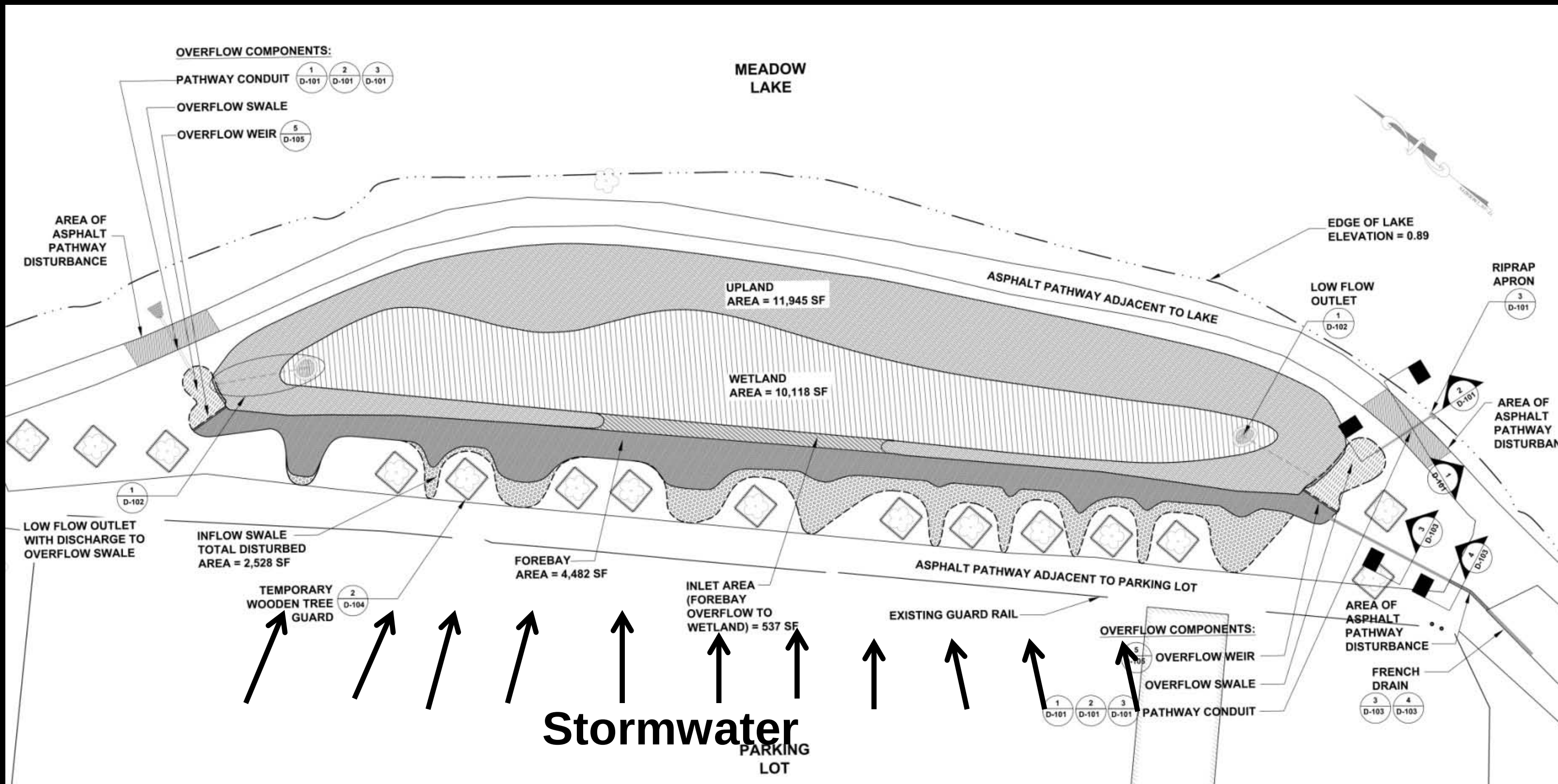

Jan-12
Mar-12
12-May
Jul-12
Sep-12
Nov-12

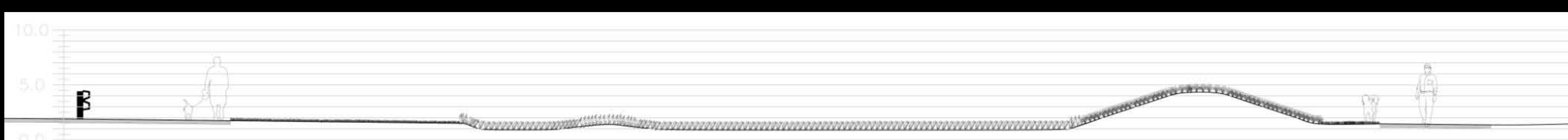
Jan-12 Mar-12 12-May Jul-12 Sep-12 Nov-12

Flushing Meadows Corona Park (Queens, NY)

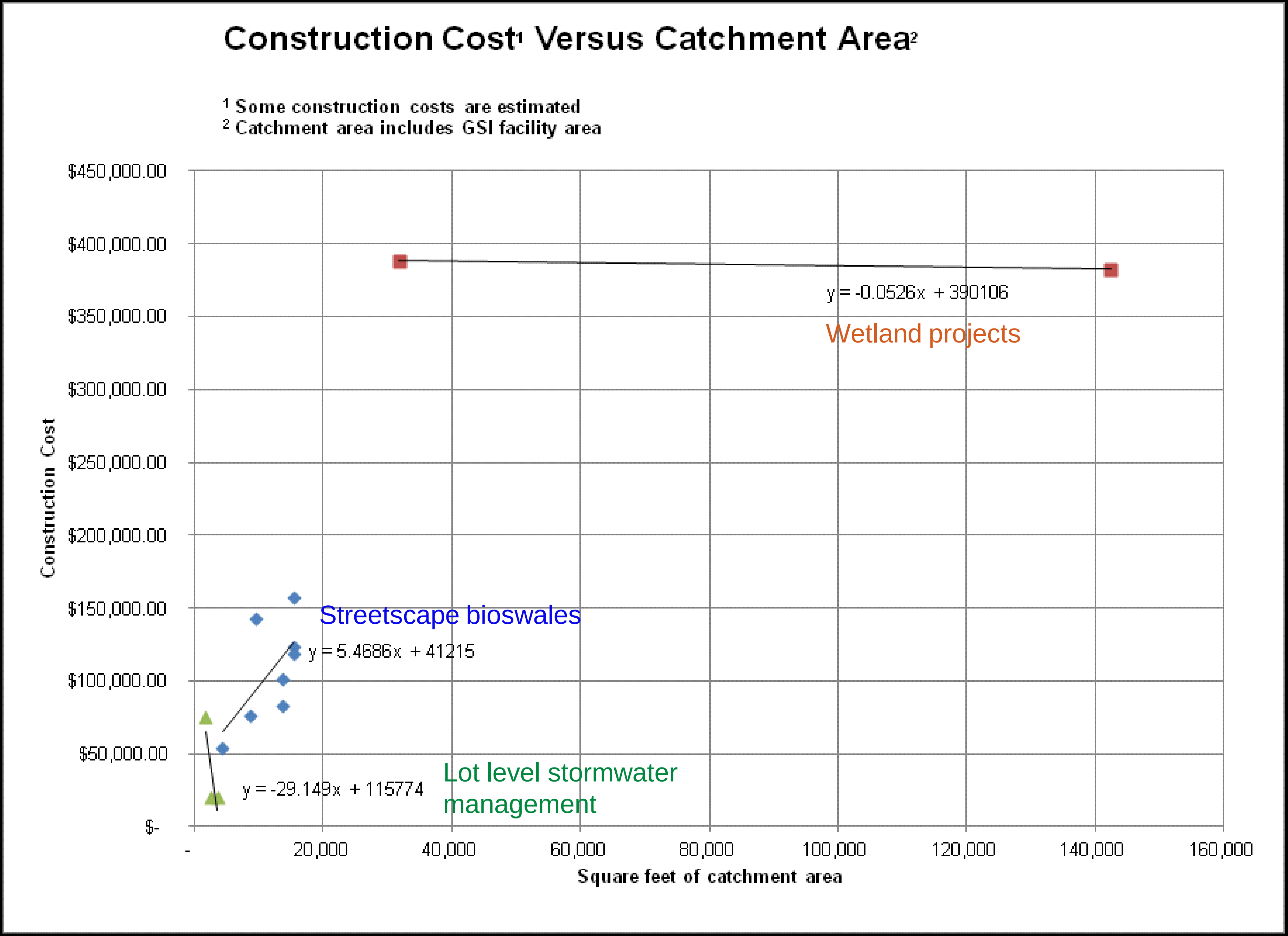
Underutilized lawn

Impervious parking lot (drains to lake)

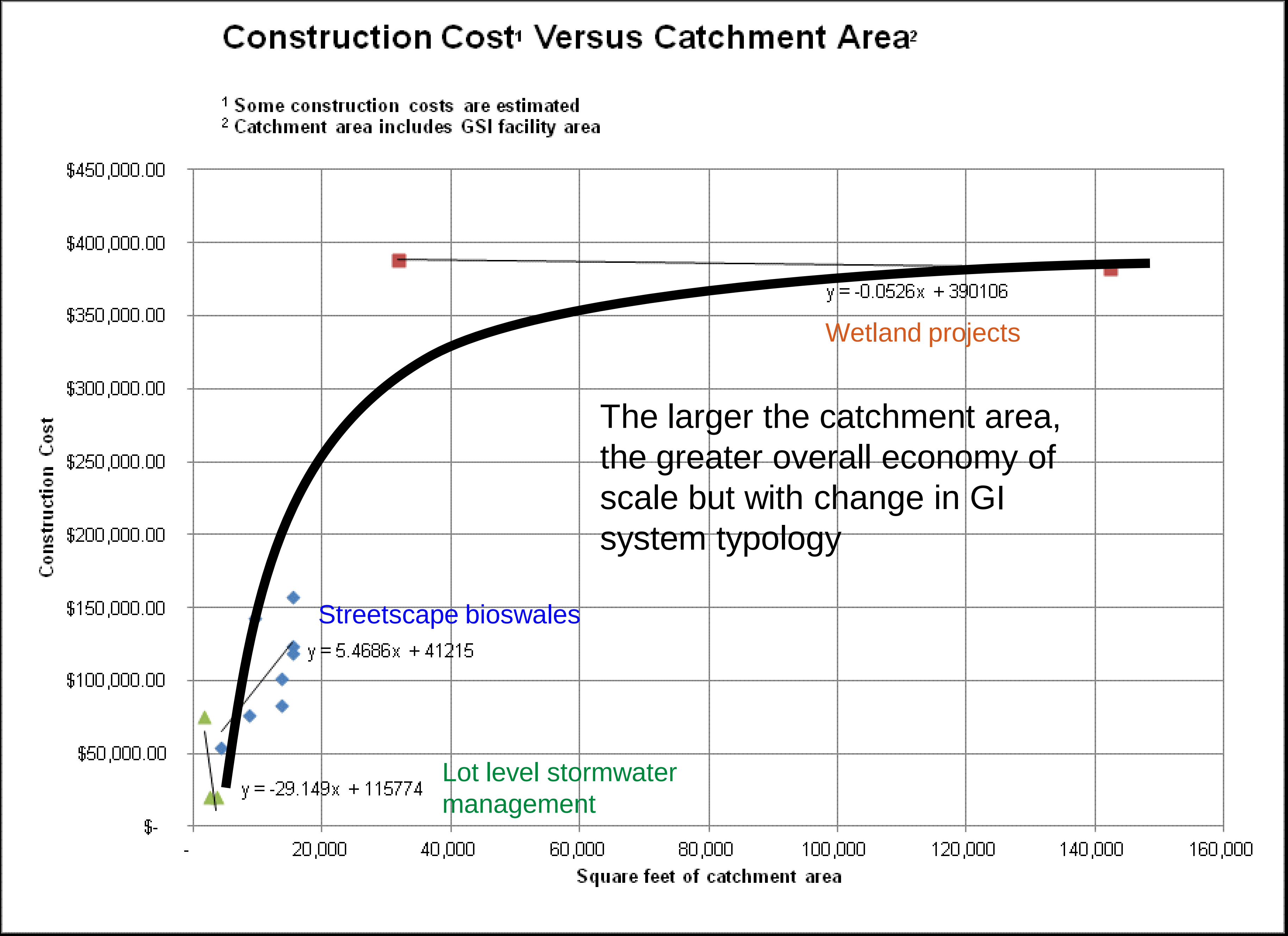




Construction to begin Spring 2013



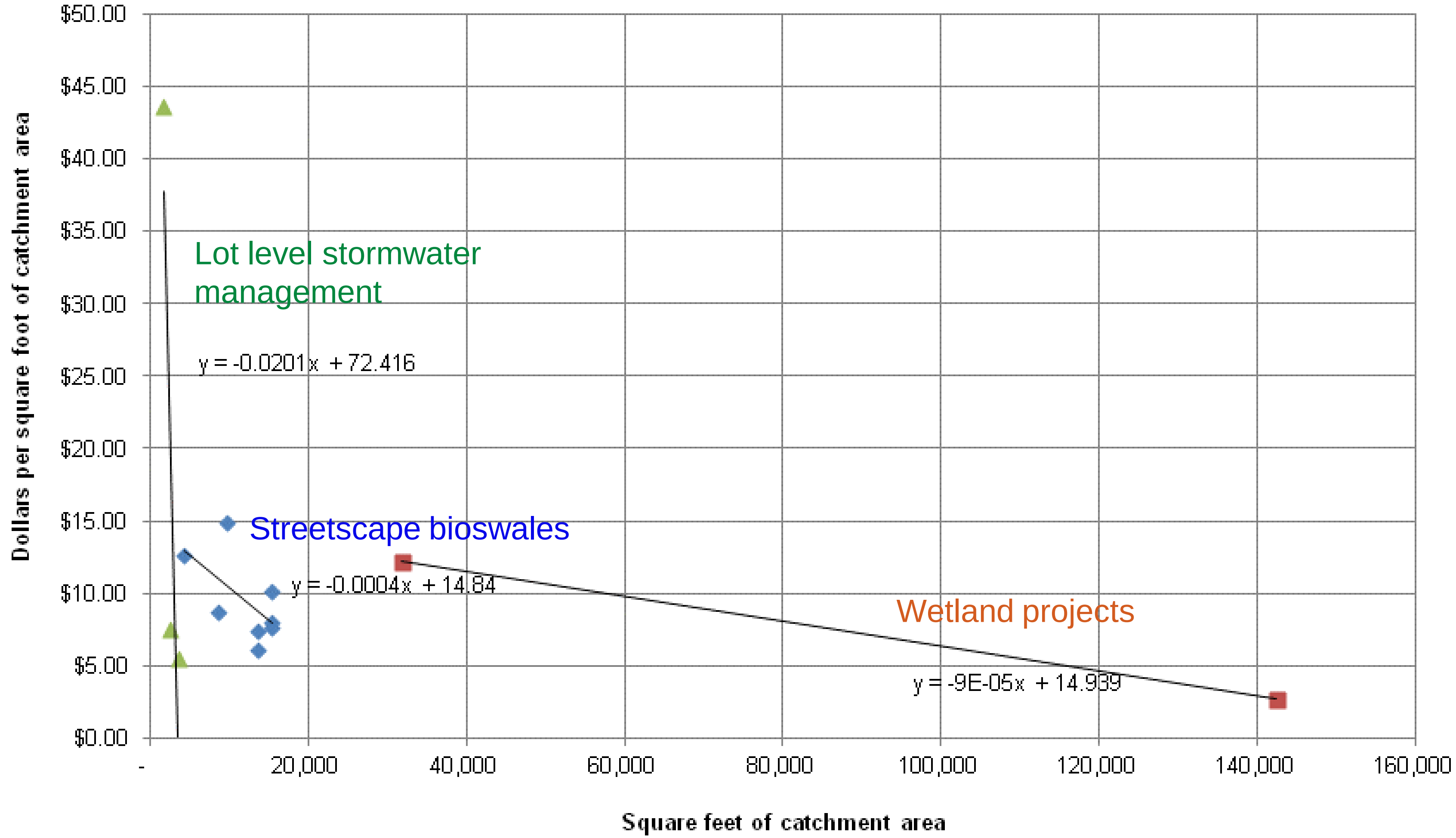
Construction Cost[1] Versus Catchment Area[2]
[1] Some construction costs are estimated
[2] Catchment area includes GSI facility area
$450,000.00
$400,000.00
$350,000.00
$300,000.00
$250,000.00
$200,000.00
$150,000.00
$100,000.00
$50,000.00
$-
Construction Cost
y = -0.0526x + 390106
Wetland projects
Streetscape bioswales
y = 5.4686x + 41215
y = -29.149x + 115774
Lot level stormwater management
-
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Square feet of catchment area

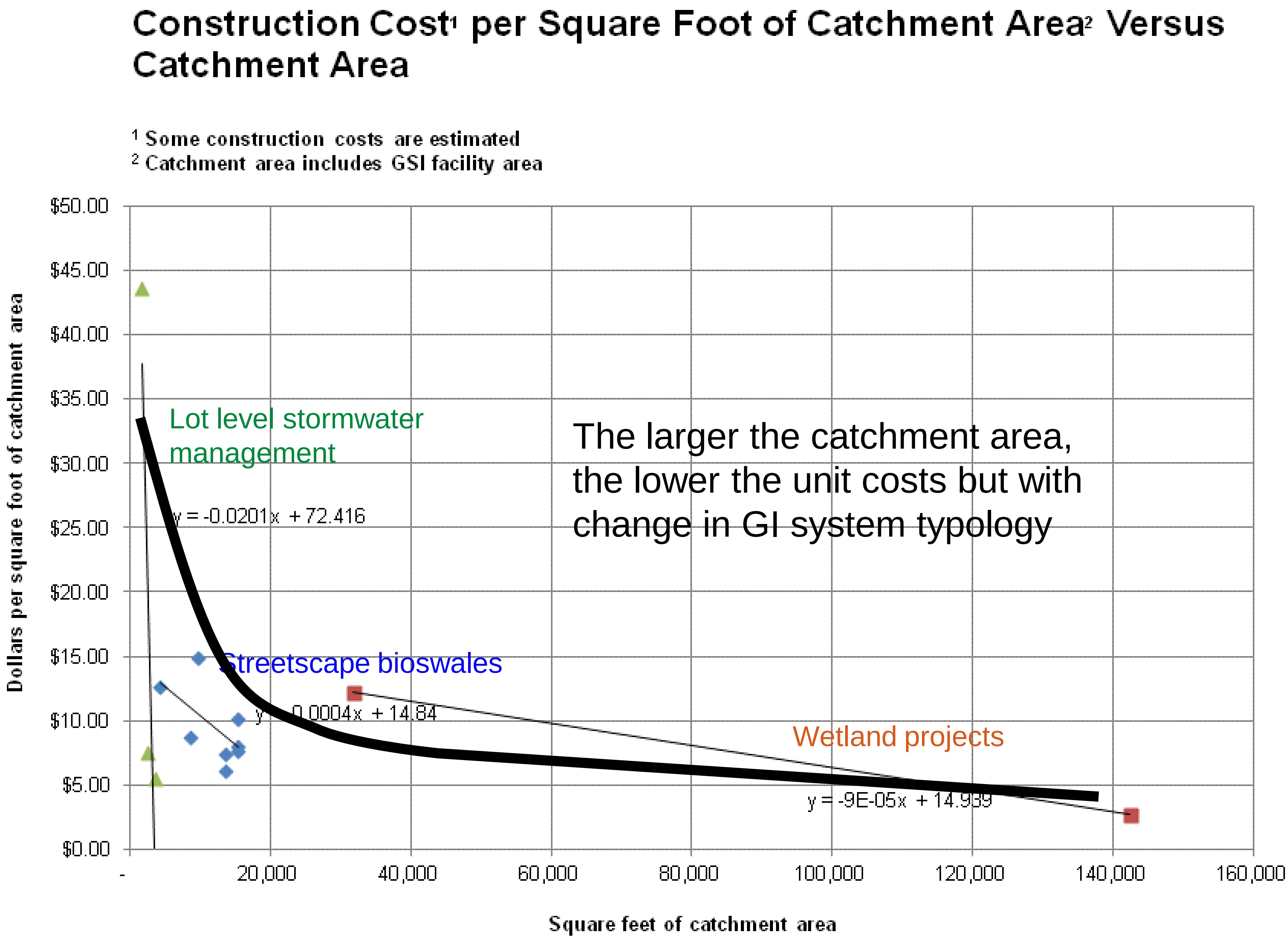


Construction Cost¹ Versus Catchment Area²
¹ Some construction costs are estimated
² Catchment area includes GSI facility area
$450,000.00
$400,000.00
$350,000.00
$300,000.00
$250,000.00
$200,000.00
$150,000.00
$100,000.00
$50,000.00
$-
Construction Cost
-
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Square feet of catchment area
y = -0.0526x + 390106
Wetland projects
The larger the catchment area, the greater overall economy of scale but with change in GI system typology
Streetscape bioswales
y = 5.4686x + 41215
y = -29.149x + 115774
Lot level stormwater management

Construction Cost[1] per Square Foot of Catchment Area[2] Versus Catchment Area

[1] Some construction costs are estimated
[2] Catchment area includes GSI facility area





Construction Cost1 per Square Foot of Catchment Area2 Versus Catchment Area
1 Some construction costs are estimated
2 Catchment area includes GSI facility area
$50.00
$45.00
$40.00
$35.00
$30.00
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
Dollars per square foot of catchment area
Lot level stormwater management
y = -0.0201x + 72.416
The larger the catchment area, the lower the unit costs but with change in GI system typology
Streetscape bioswales
y = -0.0004x + 14.84
Wetland projects
y = -9E-05x + 14.939
-
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Square feet of catchment area

Triple (Quadruple?) Bottom Line

Economic scalability

→ **Ecological benefits**

- Interception
  ↓
- Evaporation
  ↓
- Infiltration

Social value

Climate change mitigation/adaptation value

More specifically…..

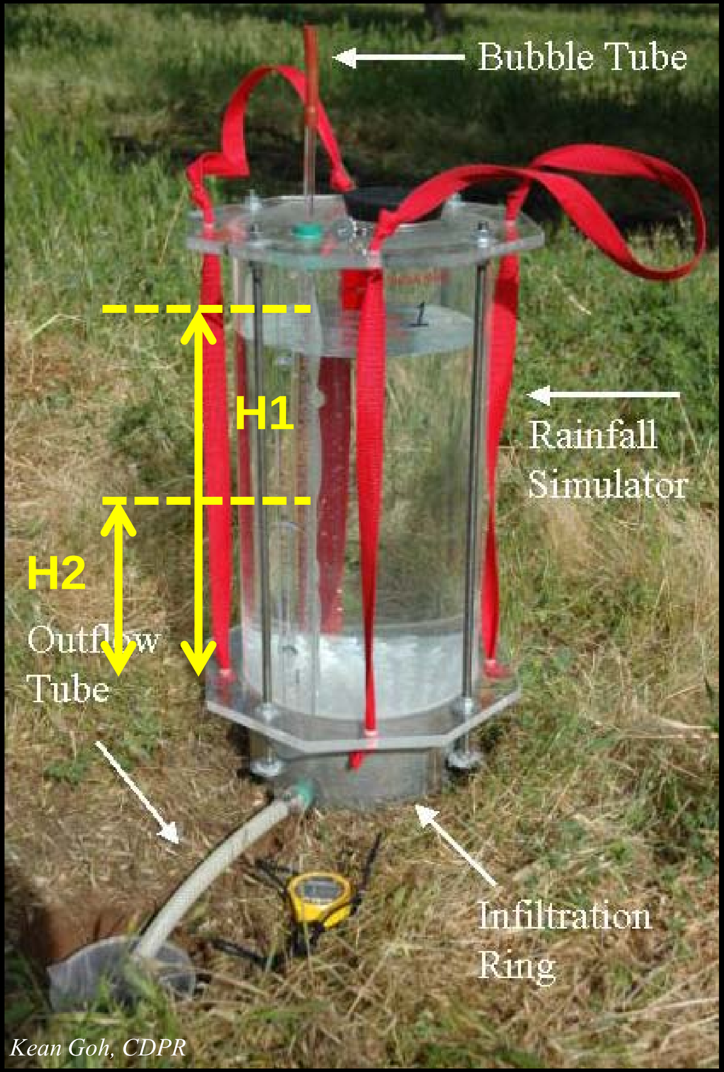
Are the type and scale of GI projects we are implementing *"restoring pre-development hydrology*"?

Are the ecological services derived from GI meaningful, in an infrastructure context?

Infiltration capacity of conventional and new engineered permeable urban spaces

Sites: New York City and Philadelphia

Method: Cornell Sprinkle Infiltrometer



Alizadehtazi et al (in revision)

Conventional Permeable Urban Spaces

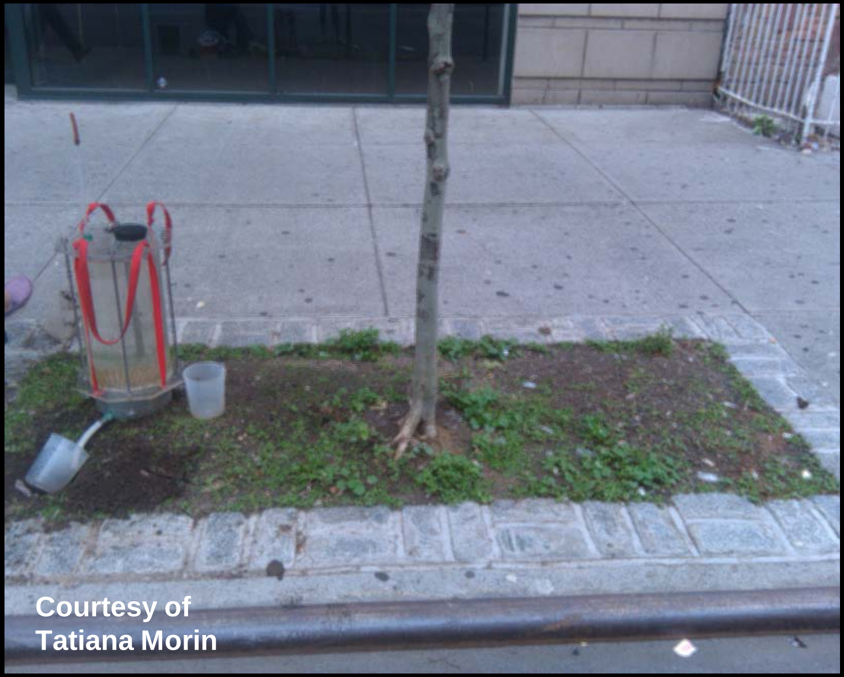
Vegetated Courtyard

Backyard

Urban Park

Conventional Permeable Urban Spaces

Tree Pits



Without guards

With guards

New Engineered Permeable Urban Spaces

Porous Pavers

Porous Rubberized Safety Materials

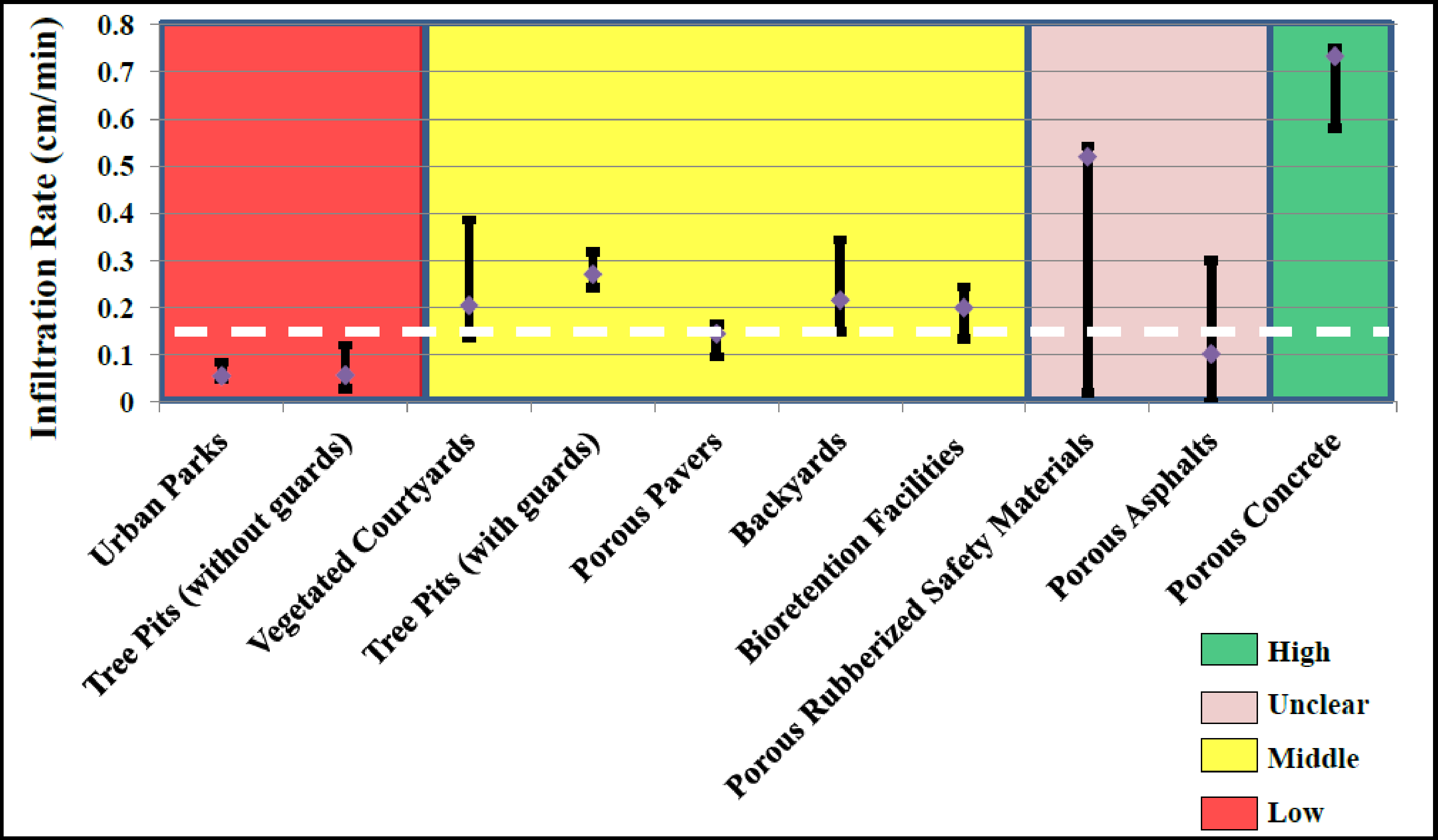
Porous Asphalt

Concrete

New Engineered Permeable Urban Spaces

Bioretention “Greenstreets”

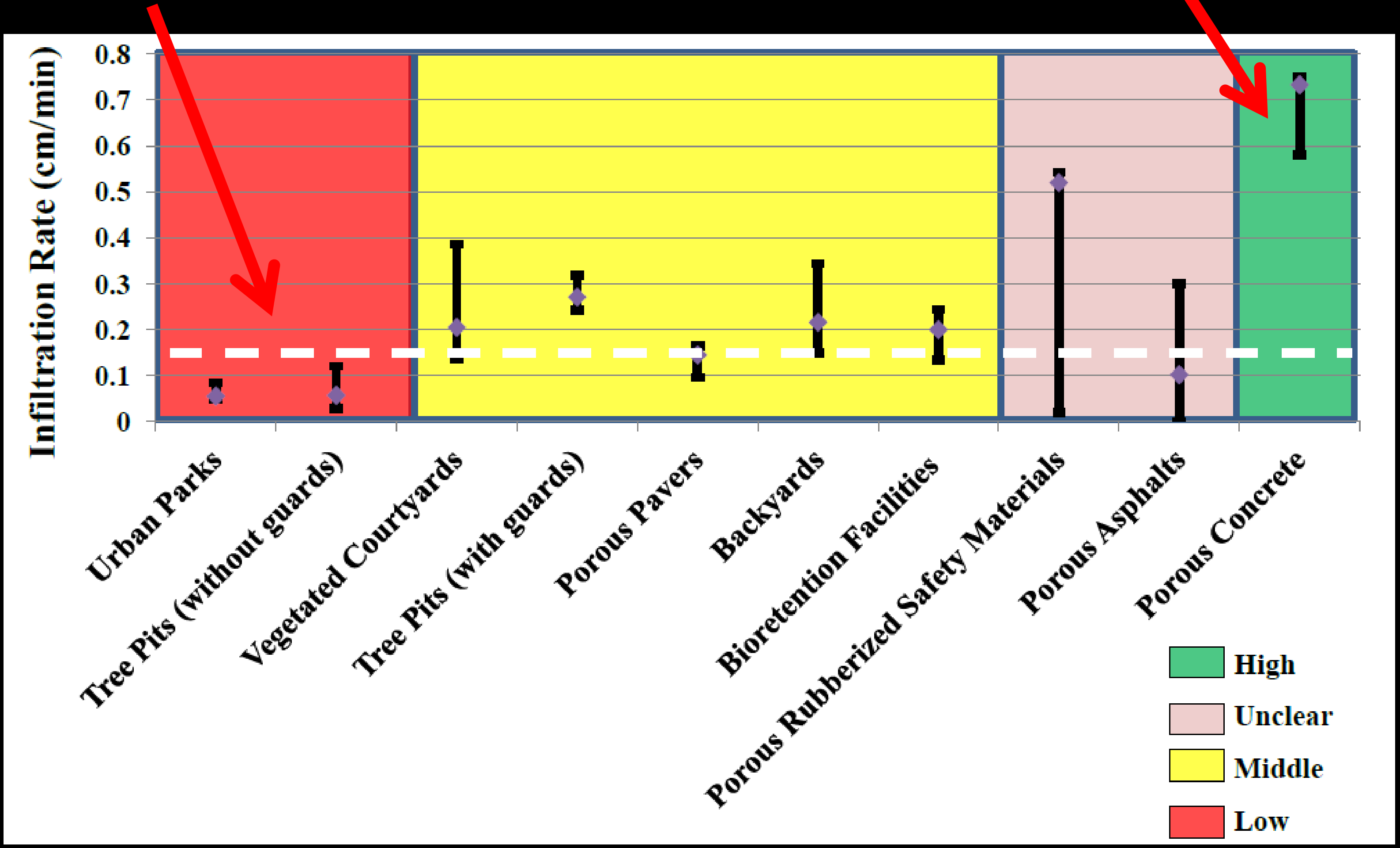
Results



Infiltration Rate (cm/min)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Urban Parks
Tree Pits (without guards)
Vegetated Courtyards
Tree Pits (with guards)
Porous Pavers
Backyards
Bioretention Facilities
Porous Rubberized Safety Materials
Porous Asphalts
Porous Concrete
High
Unclear
Middle
Low

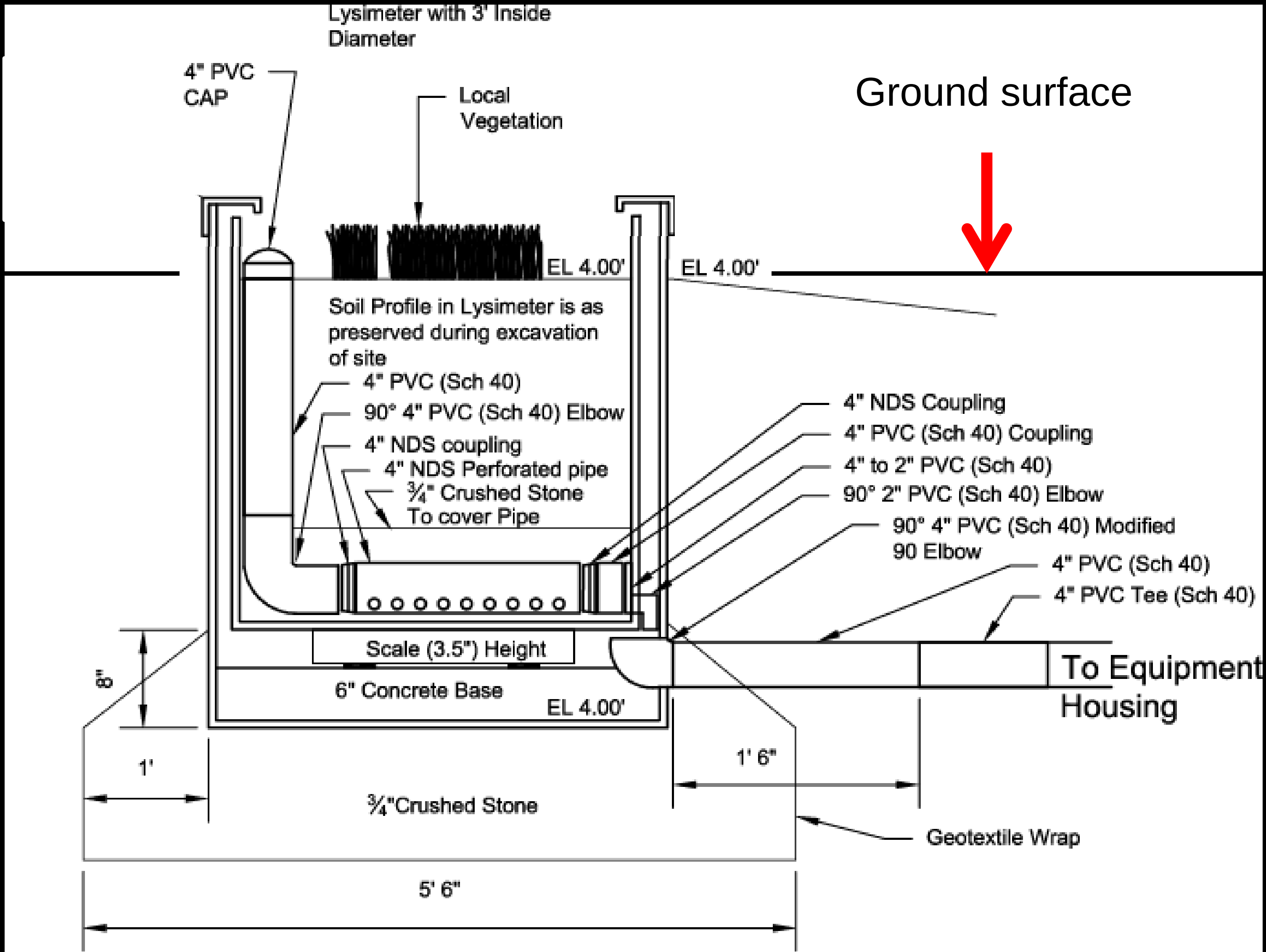
Conventional spaces (parks and tree pits without guards) were the sites with the lowest infiltration capacity

An engineered permeable space consistently presented the highest infiltration capacity



Take home message: we can engineer more permeability into our heavily developed landscapes

Can we accelerate urban evaporation (= mitigate the urban heat island) by directing stormwater to urban green spaces?



Weighing Lysimeter

Not To Scale

Sites

Ecological reference: Alley Pond Park (Queens, NY)

Summer

Winter

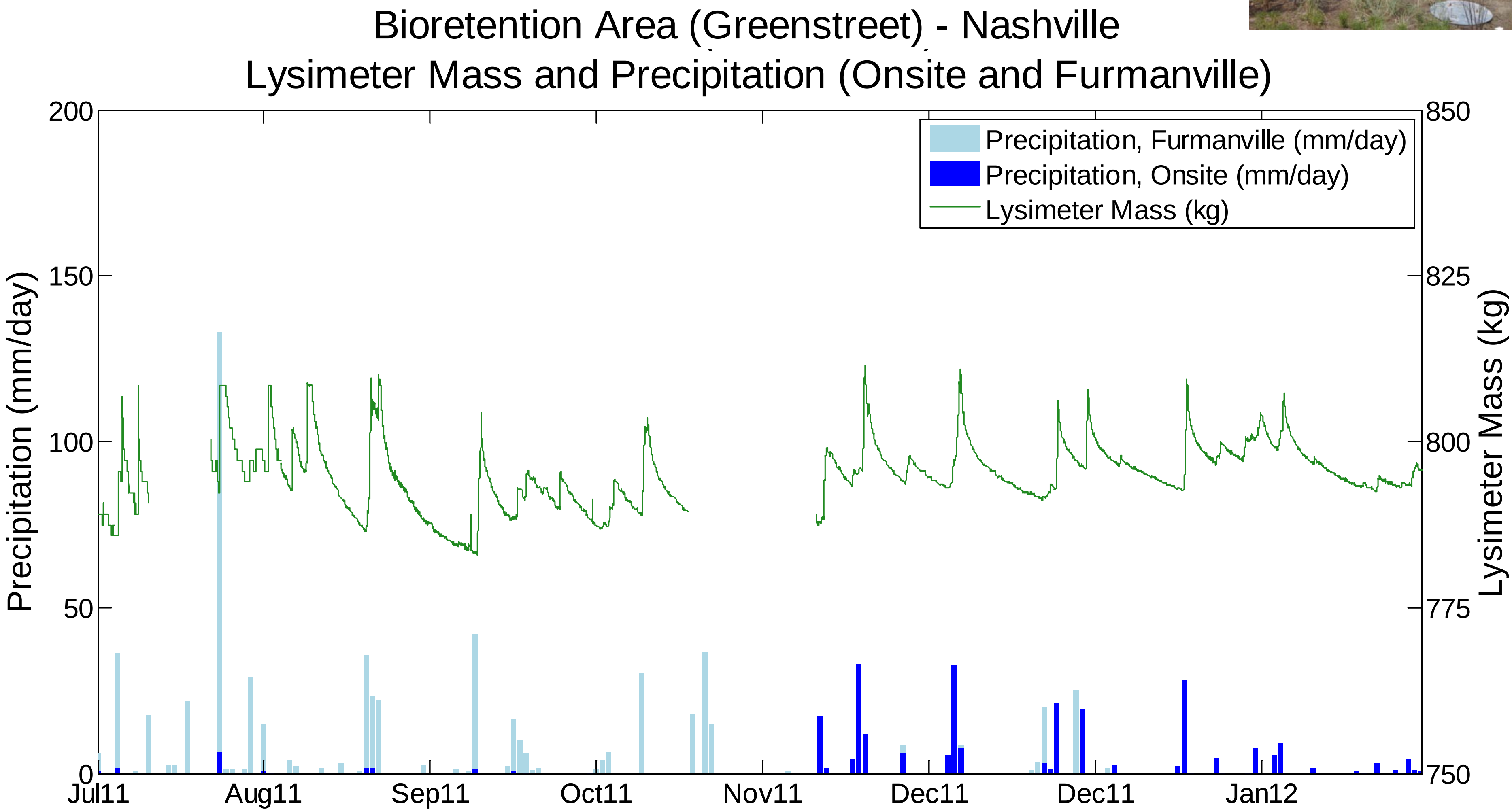
Sites

Two different bioretention "Greenstreets"

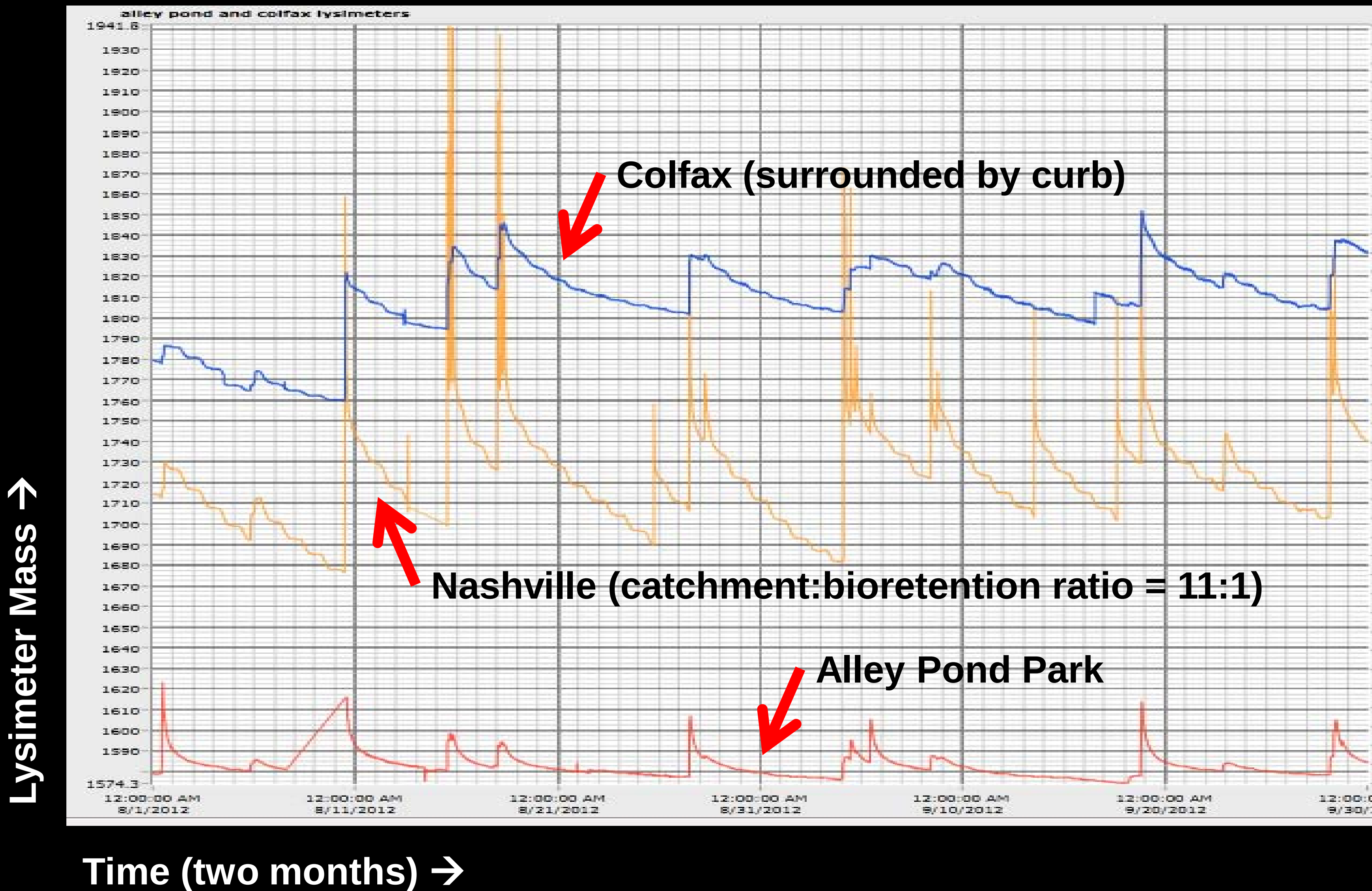
Colfax site: surrounded by curb

Nashville site: hydraulically connected to surrounding street and sidewalk catchments through curb cut (11:1)

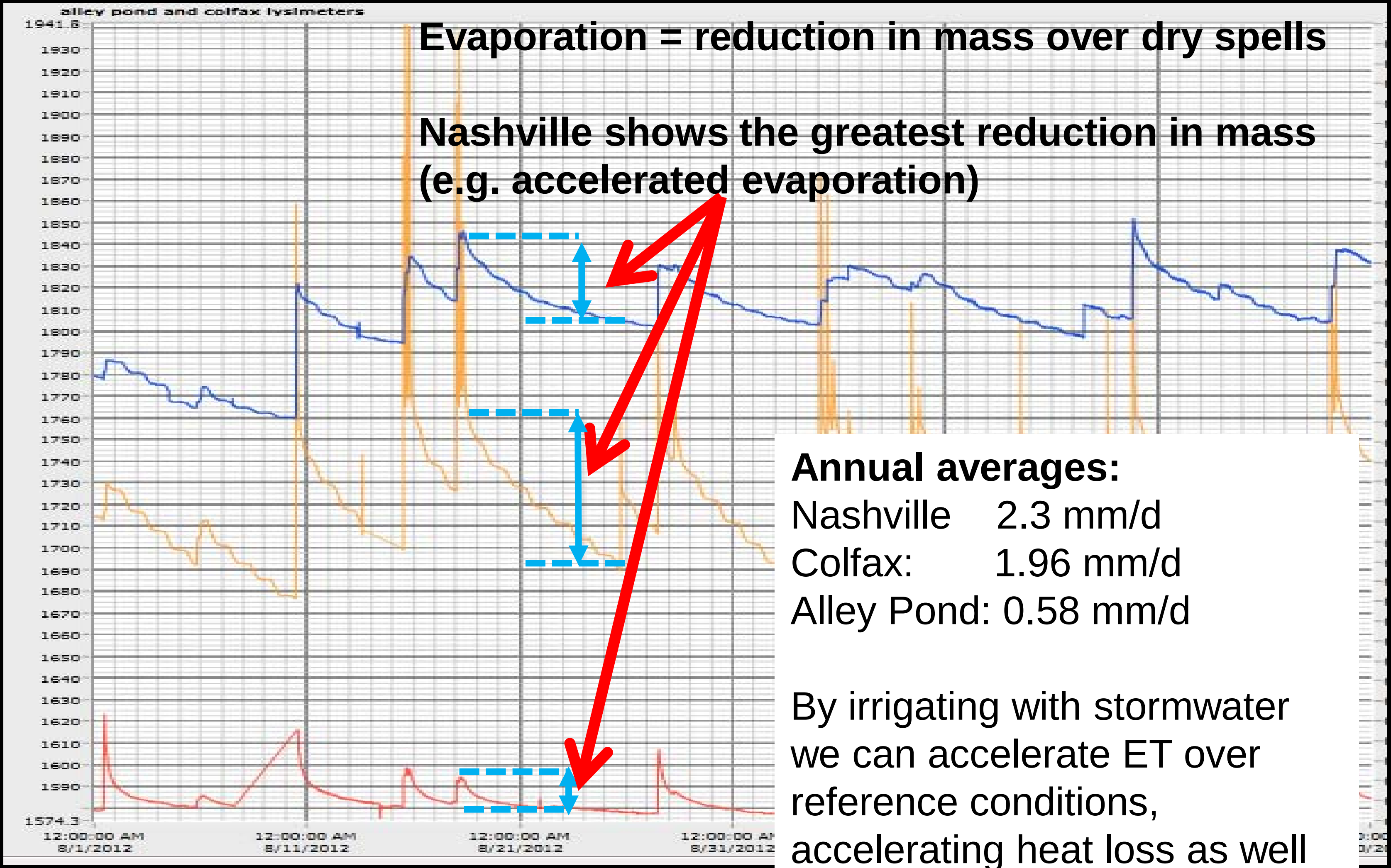
Sample Lysimeter data



Comparison of Results



Comparison of Results



Evaporation = reduction in mass over dry spells

Nashville shows the greatest reduction in mass (e.g. accelerated evaporation)

Annual averages:
Nashville 2.3 mm/d
Colfax: 1.96 mm/d
Alley Pond: 0.58 mm/d

By irrigating with stormwater we can accelerate ET over reference conditions, accelerating heat loss as well (1 gm = 595 calories)

Intercepting precipitation with new tree canopies

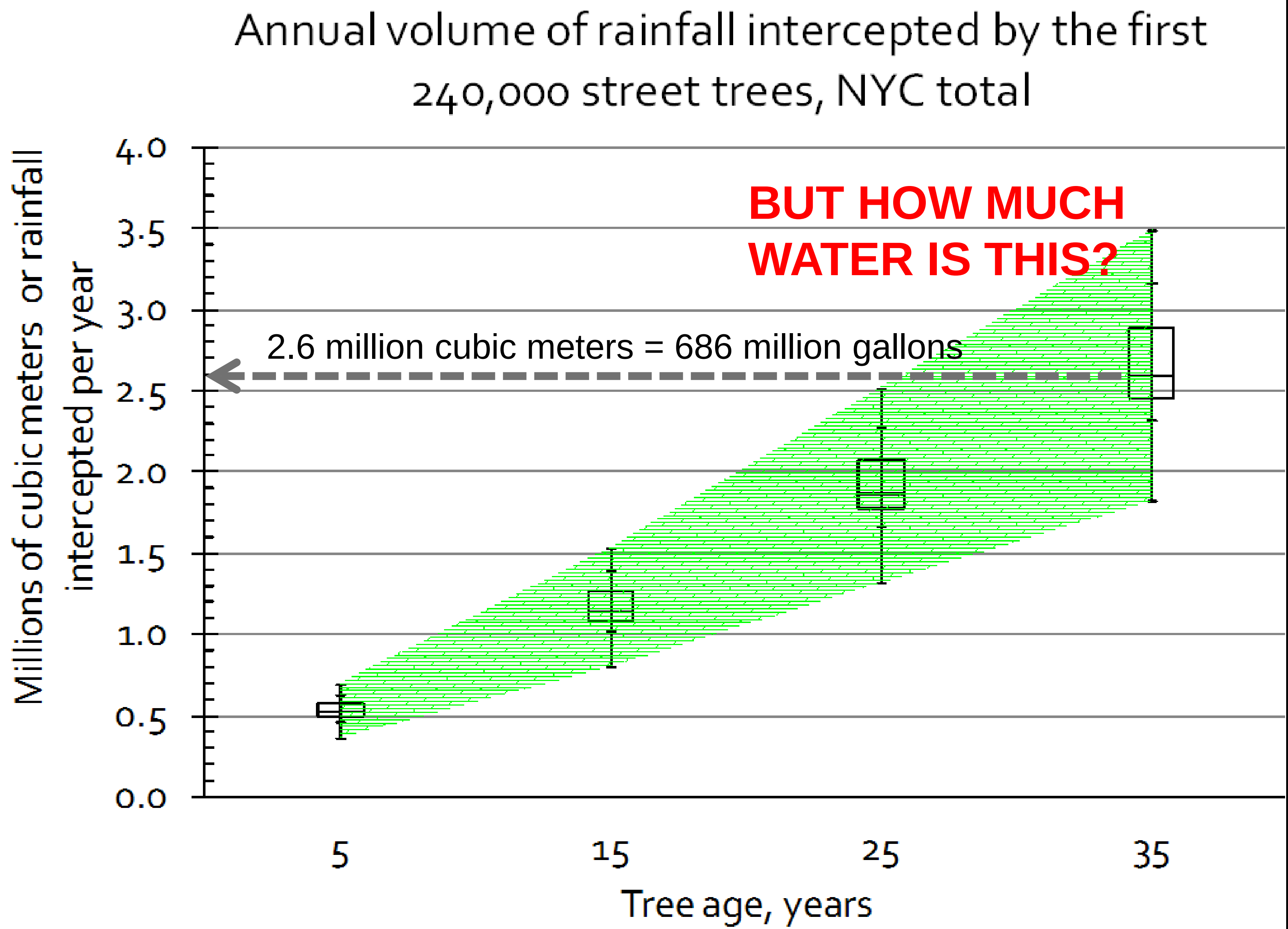
Why?

- Trees bring lots of benefits (e.g. shade, wind break, habitat, aesthetics)
- In forests, 10-40% of rainfall is intercepted (Zinke, 1967)

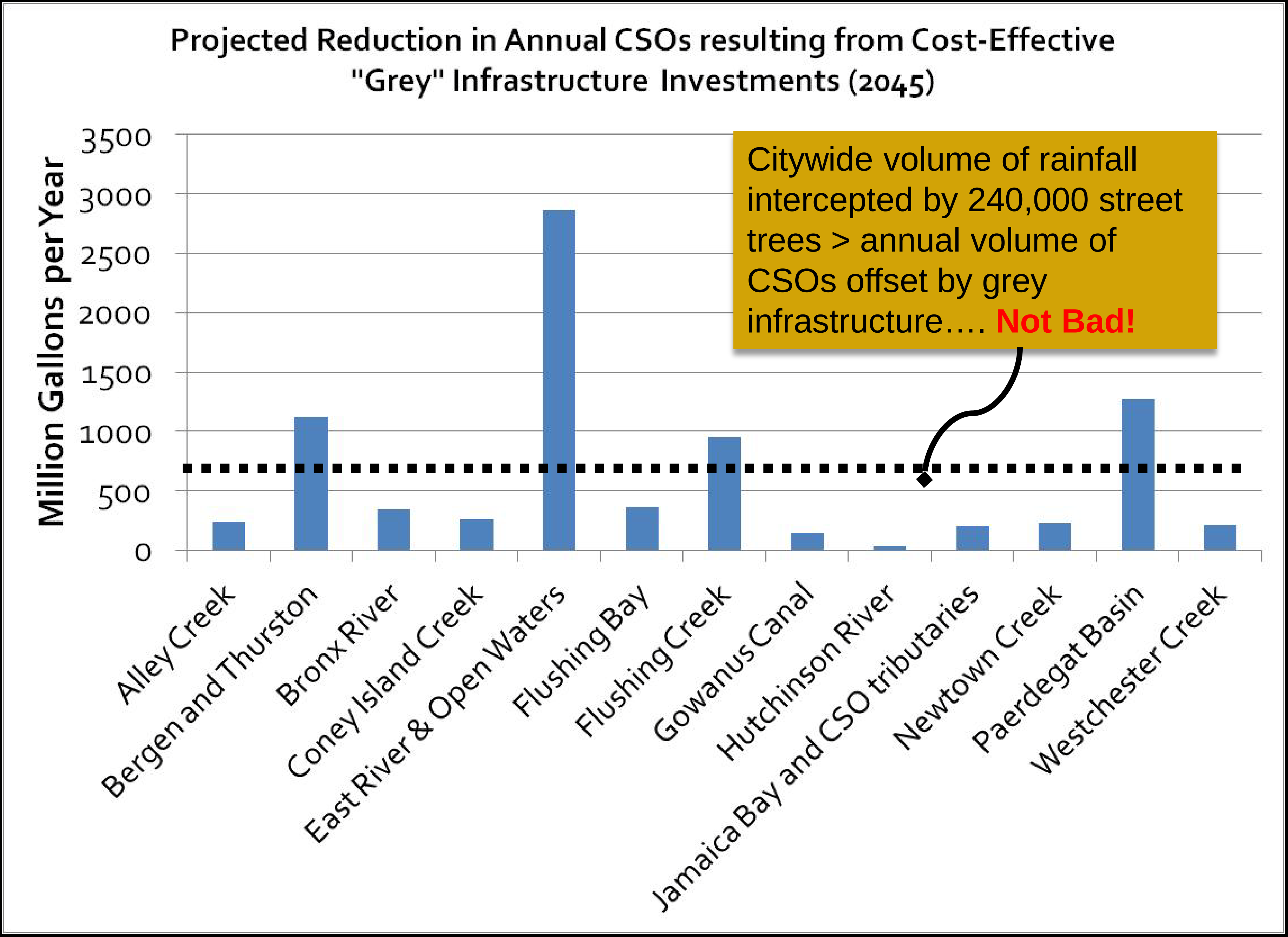
A preliminary assessment of the stormwater benefits of the Million Trees initiative at its half way point

milliontreesNYC

A PLANYC INITIATIVE WITH NYC PARKS AND NEW YORK RESTORATION PROJECT



Annual volume of rainfall intercepted by the first 240,000 street trees, NYC total
Millions of cubic meters or rainfall intercepted per year
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
BUT HOW MUCH WATER IS THIS?
2.6 million cubic meters = 686 million gallons
5
15
25
35
Tree age, years


Projected Reduction in Annual CSOs resulting from Cost-Effective "Grey" Infrastructure Investments (2045)
Million Gallons per Year
3500
3000
2500
2000
1500
1000
500
0
Alley Creek
Bergen and Thurston
Bronx River
Coney Island Creek
East River & Open Waters
Flushing Bay
Flushing Creek
Gowanus Canal
Hutchinson River
Jamaica Bay and CSO tributaries
Newtown Creek
Paerdegat Basin
Westchester Creek
Citywide volume of rainfall intercepted by 240,000 street trees > annual volume of CSOs offset by grey infrastructure…. Not Bad!

Triple (Quadruple?) Bottom Line

Economic scalability

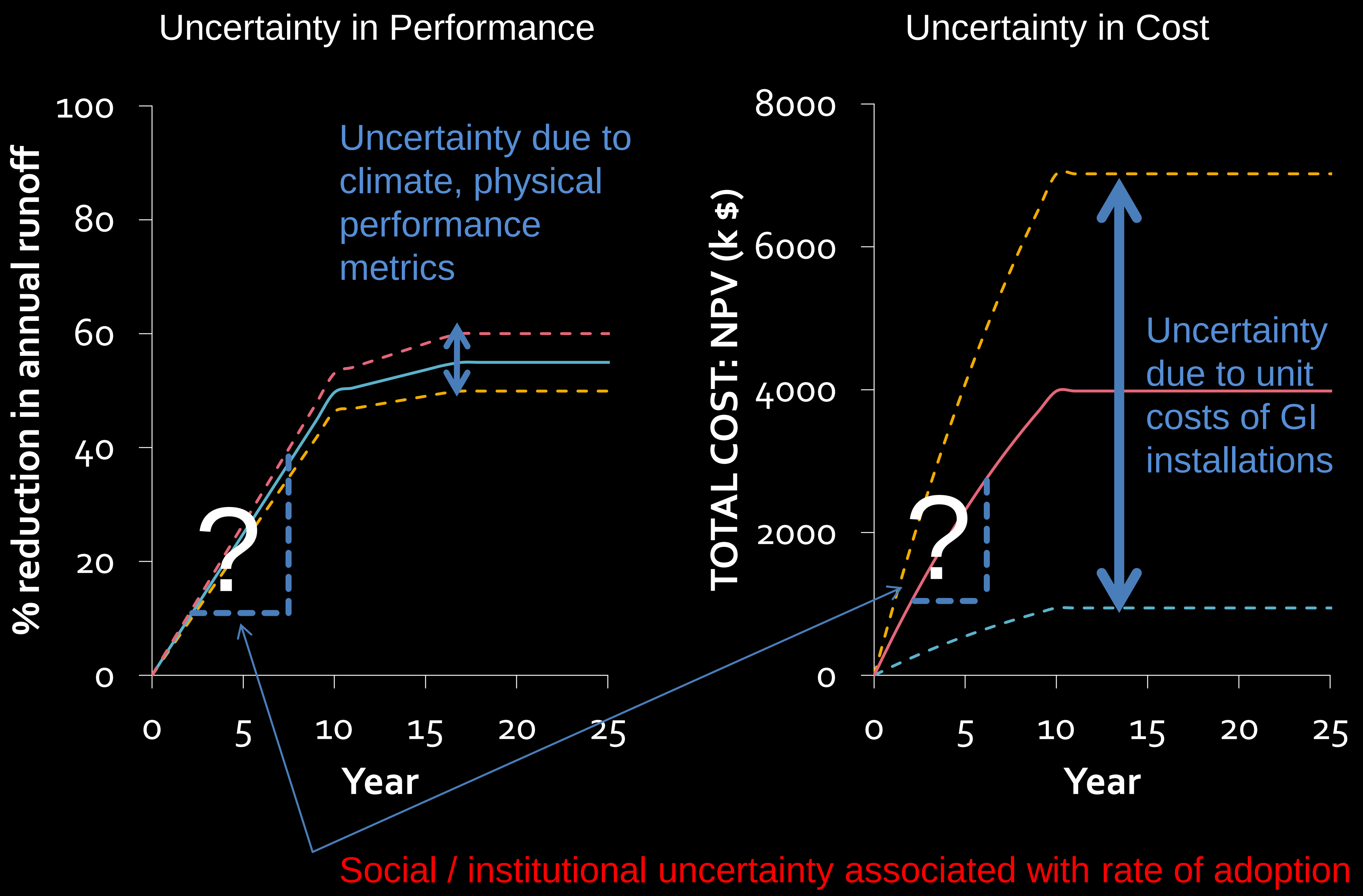
Ecological benefits

Social value

- New forms of partnerships?
- Neighborhood revitalization?

Climate change mitigation/adaptation value

Challenge of scaling up



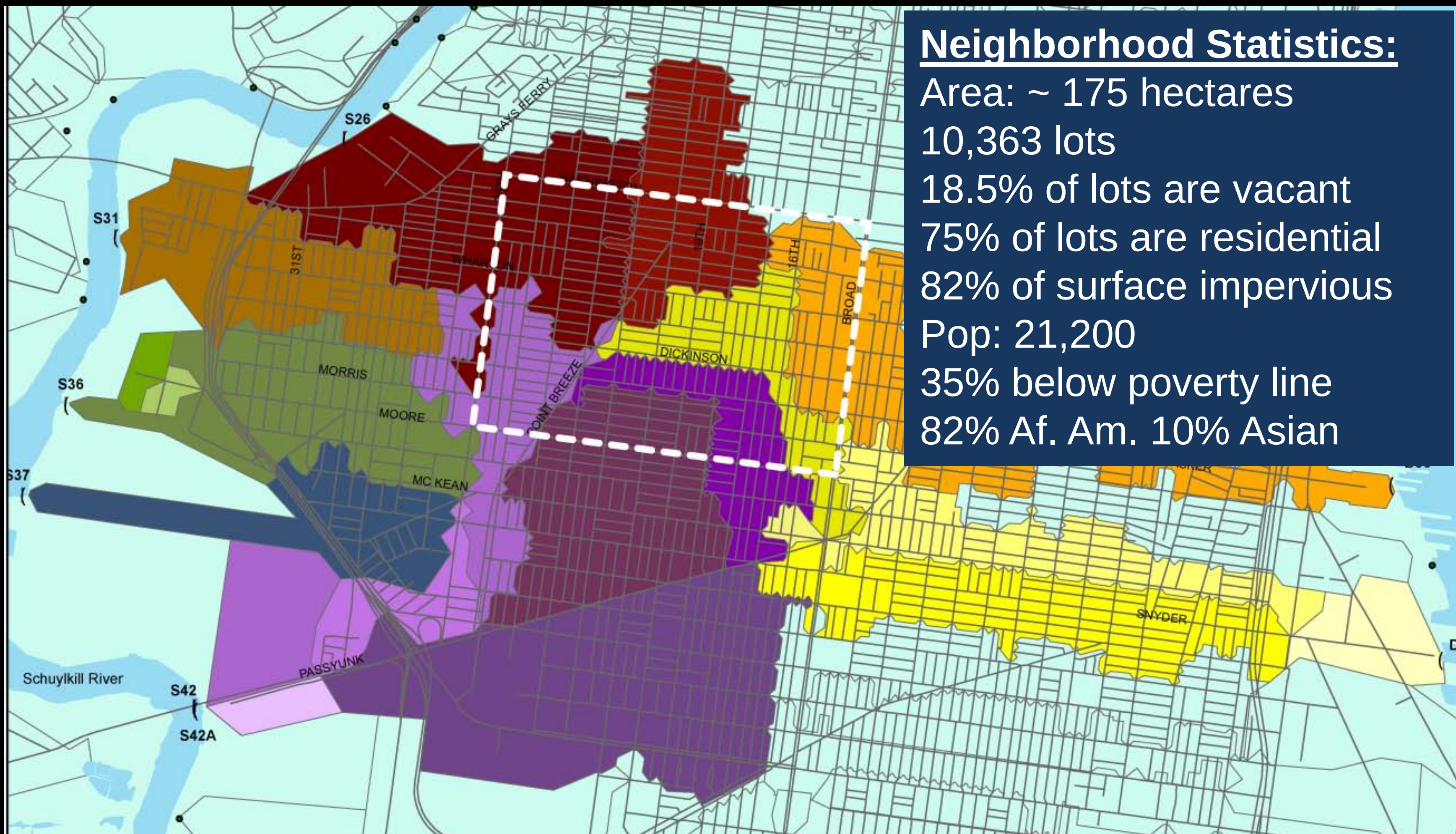
Project goals:

Disclaimer: results of this study do not represent any official position by PWD

- Answer a practical question:
  - Will PWD achieve its goal of promoting stormwater capture on 47% of the impervious surfaces in neighborhoods in combined sewer areas w/in 25 yrs?
- Develop a new modeling platform:
  - Simulation of spatiotemporal emergence of GSI in a sample Philadelphia neighborhood
  - Realistic depiction of interacting spatial, economic, legal, physical, and policy factors

Collaborators: Alex Waldman, Katy Travaline, Tim Bartrand, Juliet Geldi, Gavin Riggal, Chariss McAfee, Charles Loomis, Franco Montalto

Study Site: Point Breeze (Phila, PA)



Neighborhood Statistics:

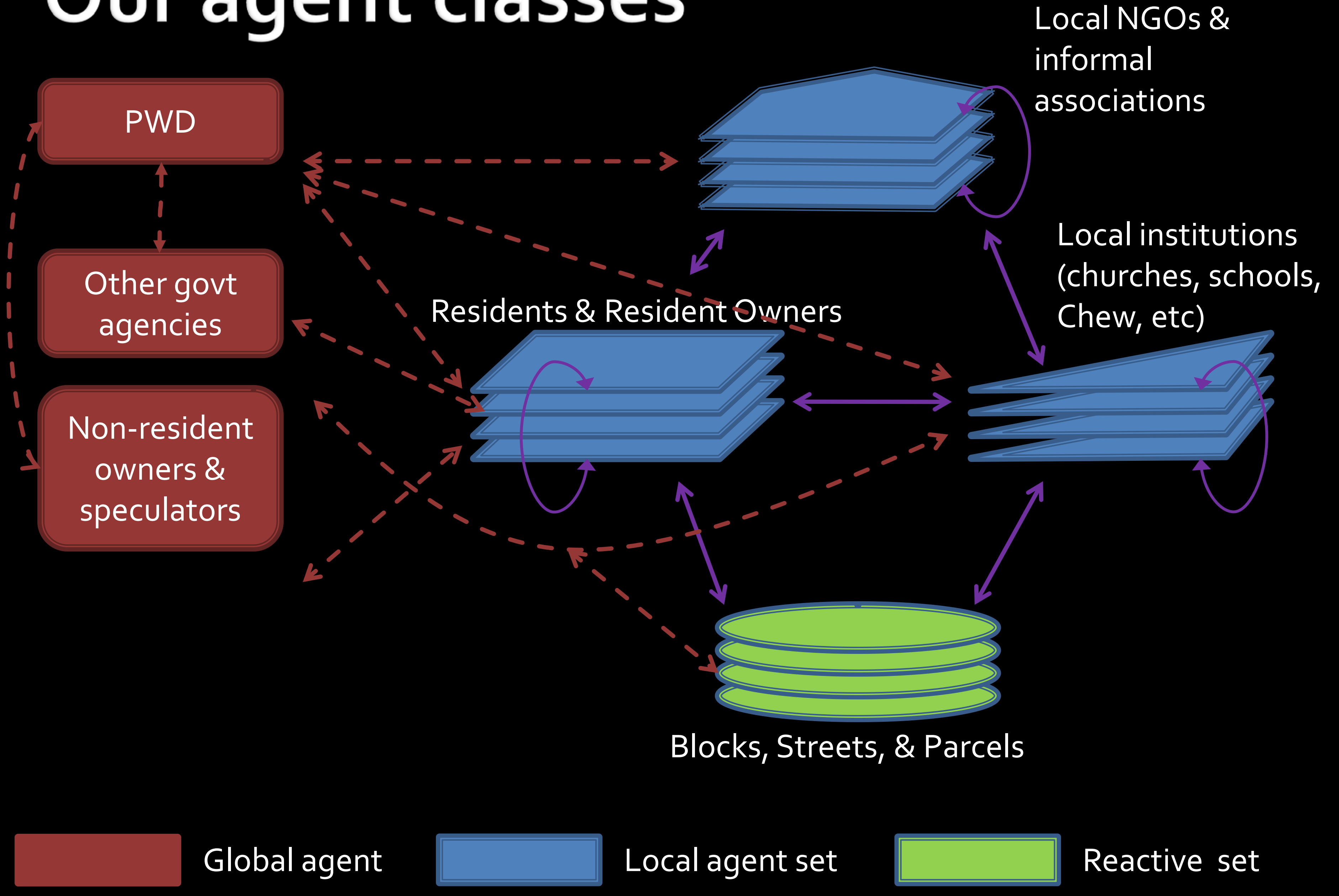
Area: ~ 175 hectares
10,363 lots
18.5% of lots are vacant
75% of lots are residential
82% of surface impervious
Pop: 21,200
35% below poverty line
82% Af. Am. 10% Asian

Methods: Agent-Based Models

- A family of computational models, typically custom built, that simulate the "bottom up" actions and interactions of autonomous "agents" in a network environment

- Can be used to develop insights into how agent behavior and multi-domain interactions affect system performance

Our agent classes



Initializing Agent Attributes through empirical methods

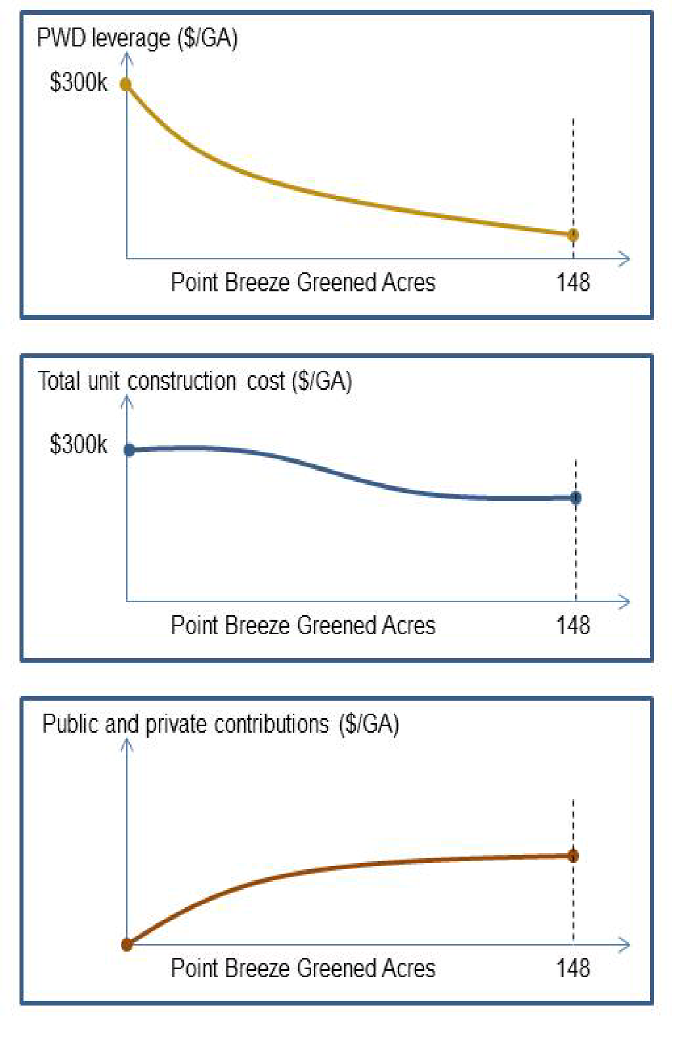
- PWD → Implementation & Adaptive Management Plan (PWD initiated, GSI following public works, private GSI)
- Property → Geospatial data sets; census and other aggregate data downscaled using stochastic methods
- Property owners, other city agencies, community organizations → Outreach activities
  - Participant-observation
  - Interviews
  - Community Street Fair
  - Questionnaires
  - Policy Official Outreach

Behavioral rules: PWD

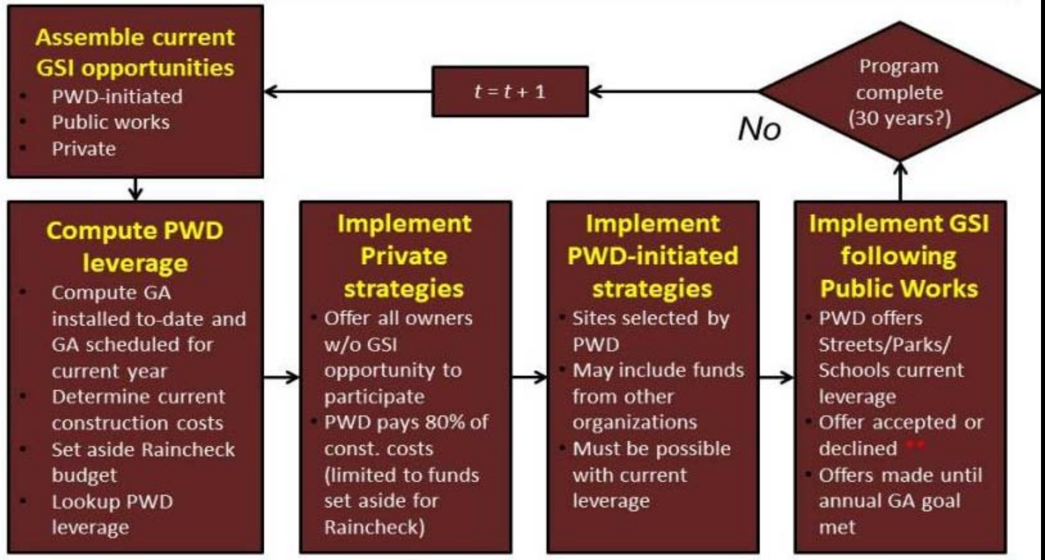
Cost scaling

Learning curve

Partnerships

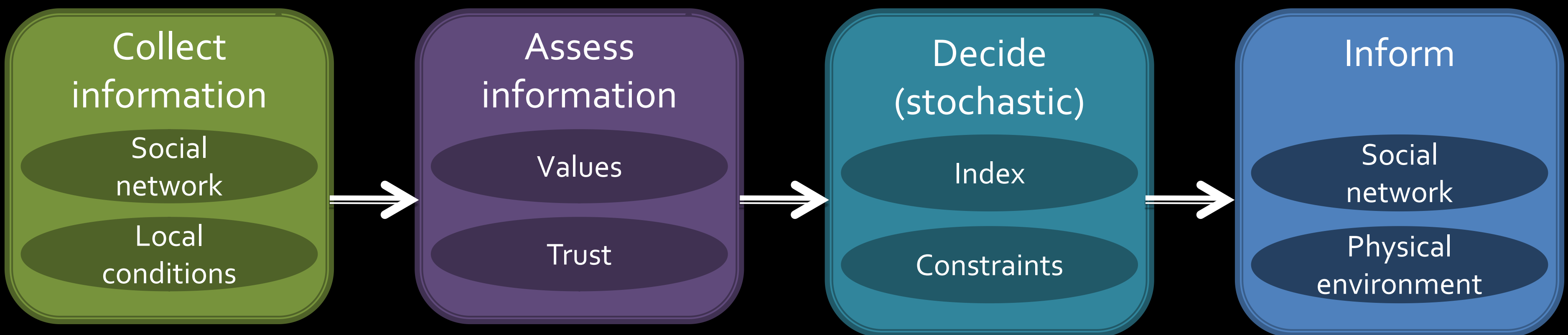


PWD decision sequencing (sample)

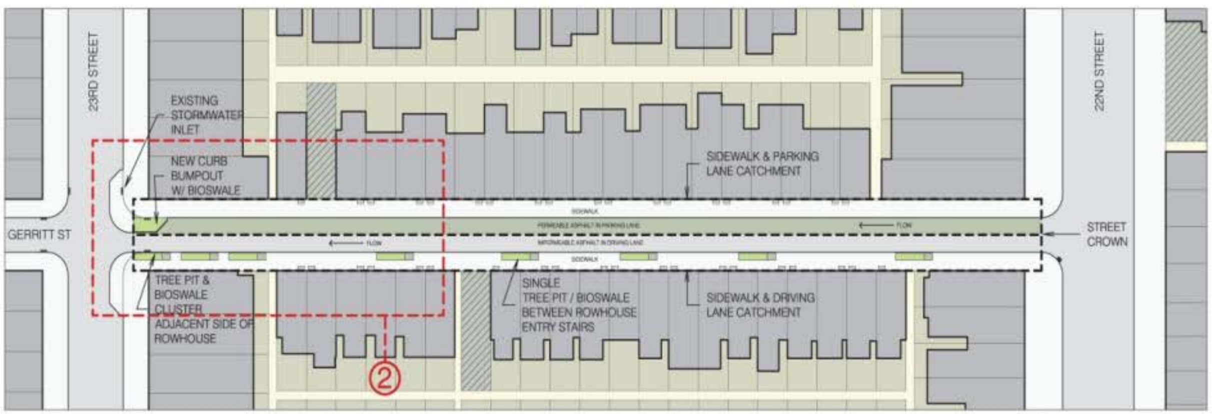


Behavioral rules: Property owners

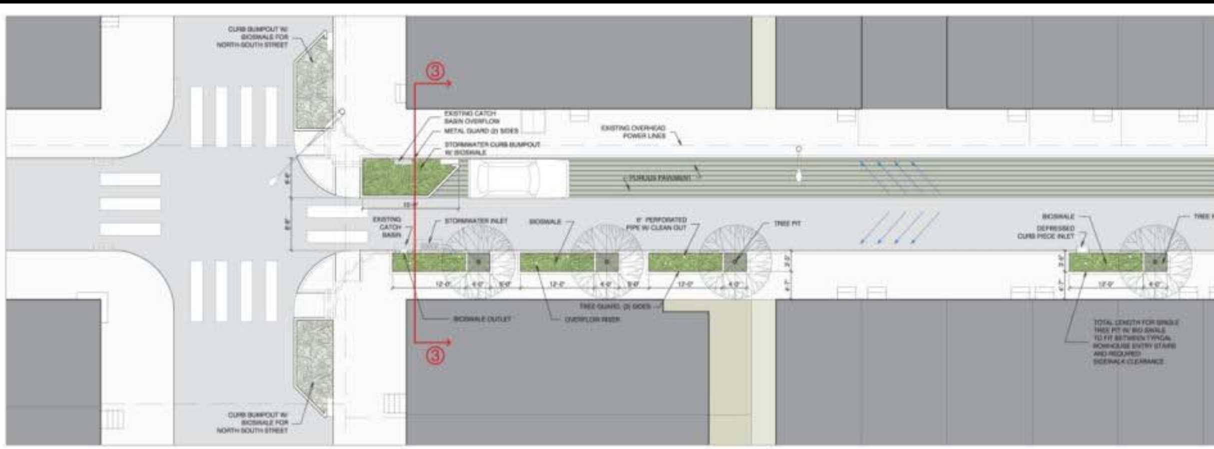
Property owner decision sequencing



Sample simulations:

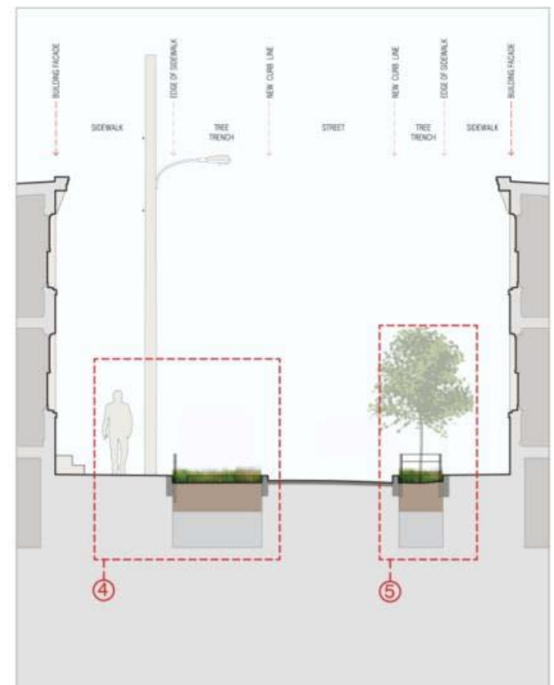


1 SITE PLAN - CATCHMENT & EXISTING CONDITIONS 1":40'



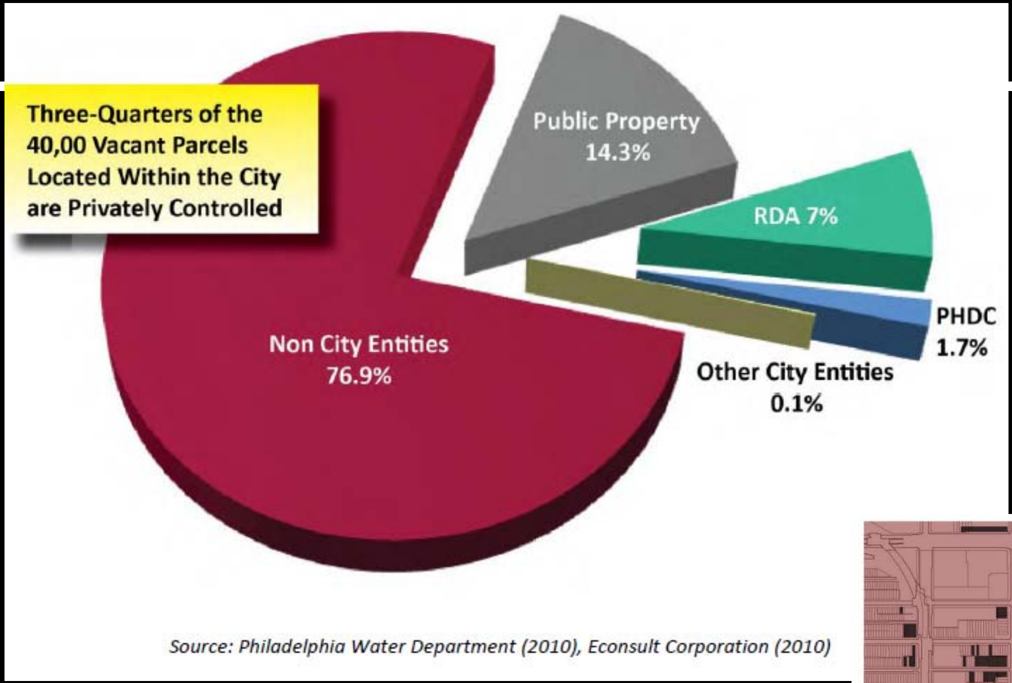
2 PLAN - PROPOSED 1/8"=1'

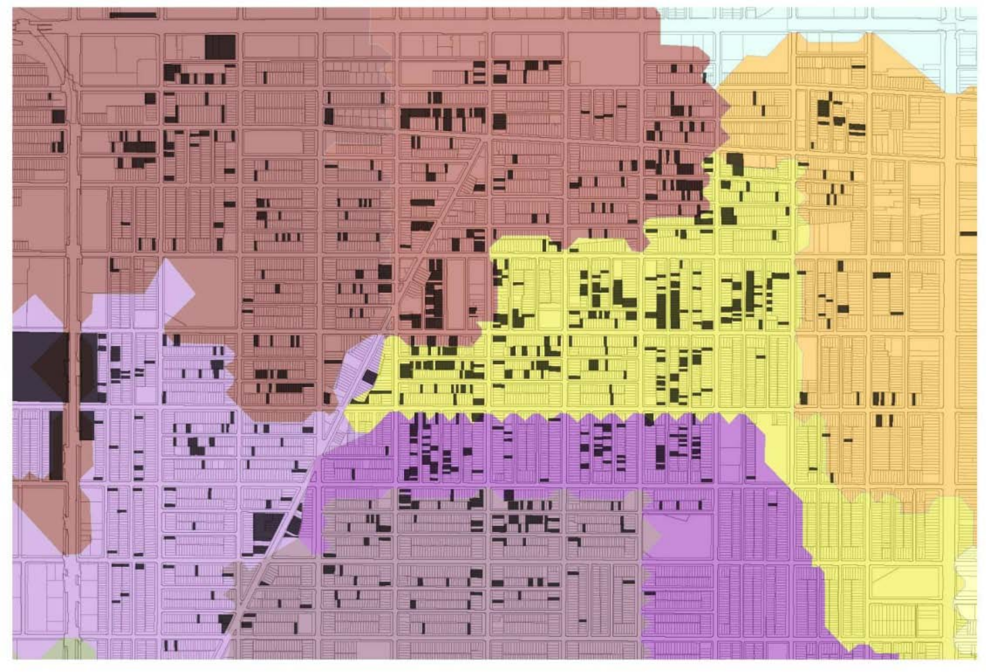
Model 1: Focus on managing runoff originating on public property on public land



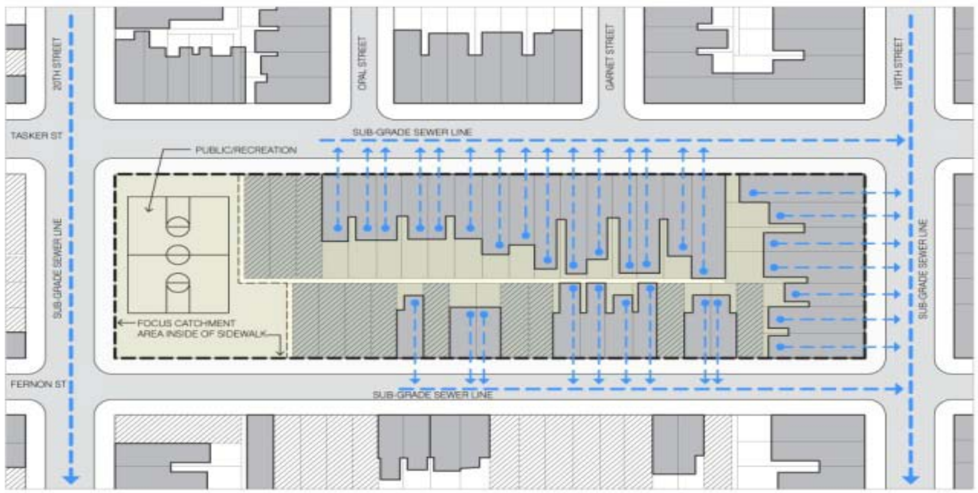
3 SECTION 1/4"=1'

Vacant Land in Philadelphia

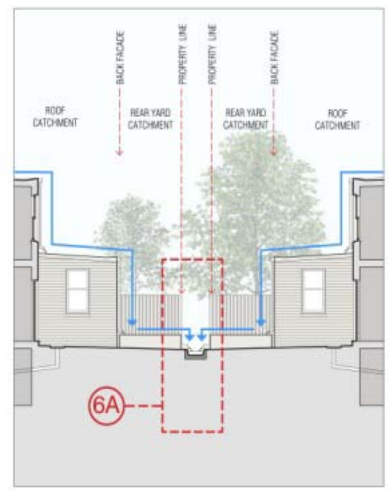




Sample simulations:



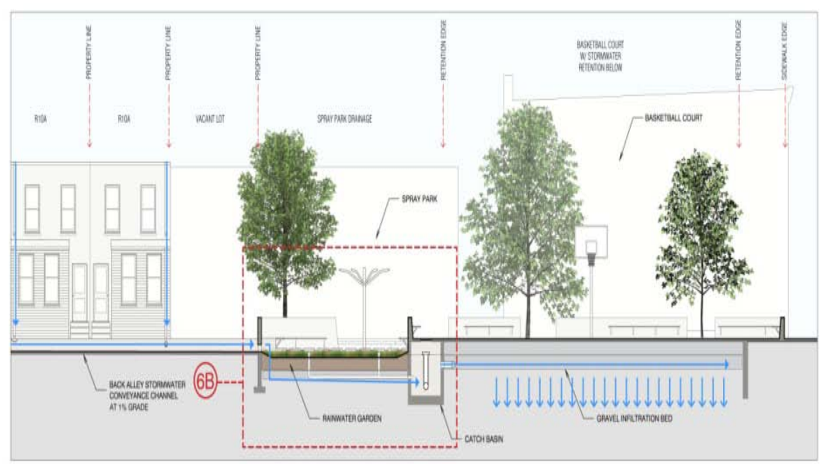
1 SITE PLAN - EXISTING DRAINAGE 1":40'



4 ALLEY SECTION 1/8"=1'

<u>Model 2:</u> Also allows PWD to manage residential stormwater on publically owned vacant parcels of land

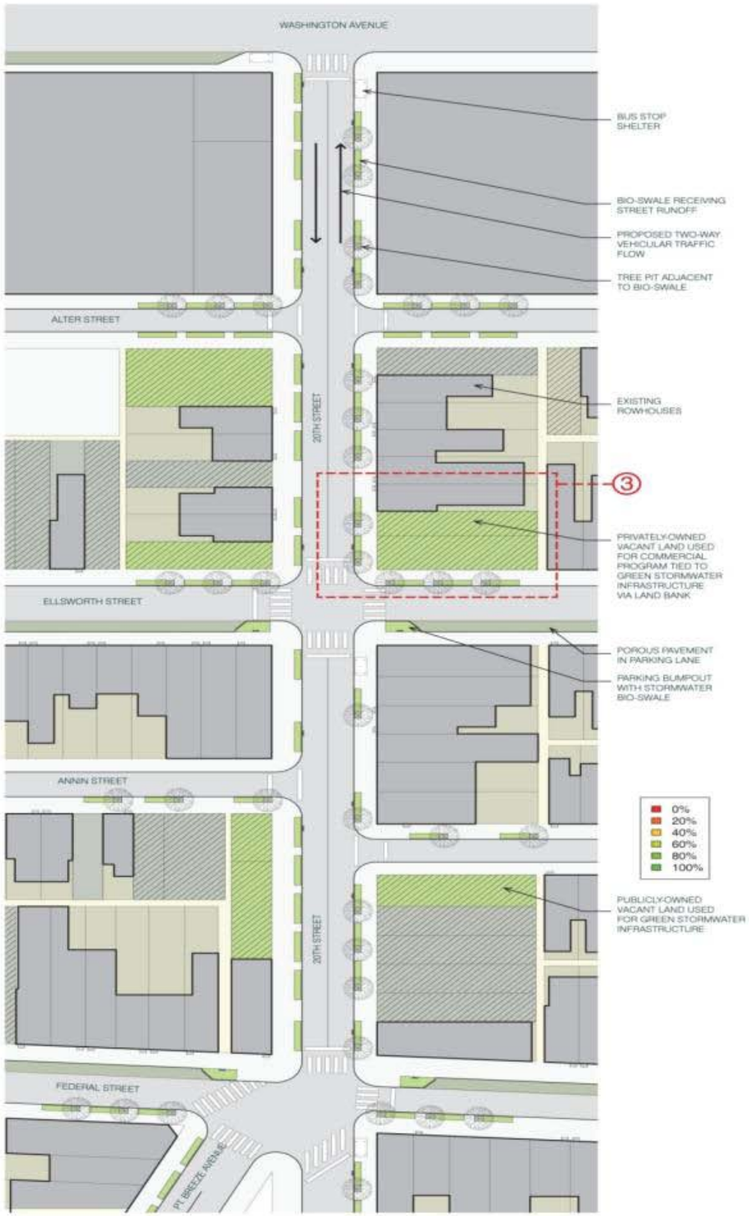
2 SITE PLAN - PROPOSED DRAINAGE 1"=40'



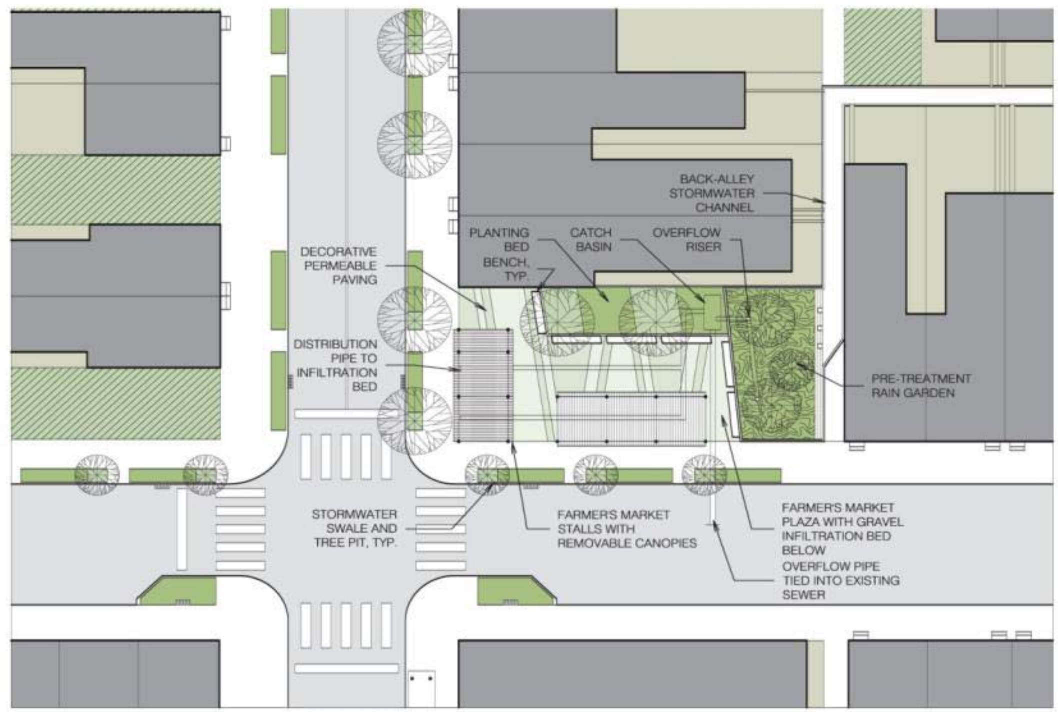
5 BLOCK SECTION 1/8"=1'

Sample simulations:

Model 3: Adds in a GSI banking program whereby a third party acquires privately owned vacant land and sells GSI credits to offset stormwater impacts of development elsewhere

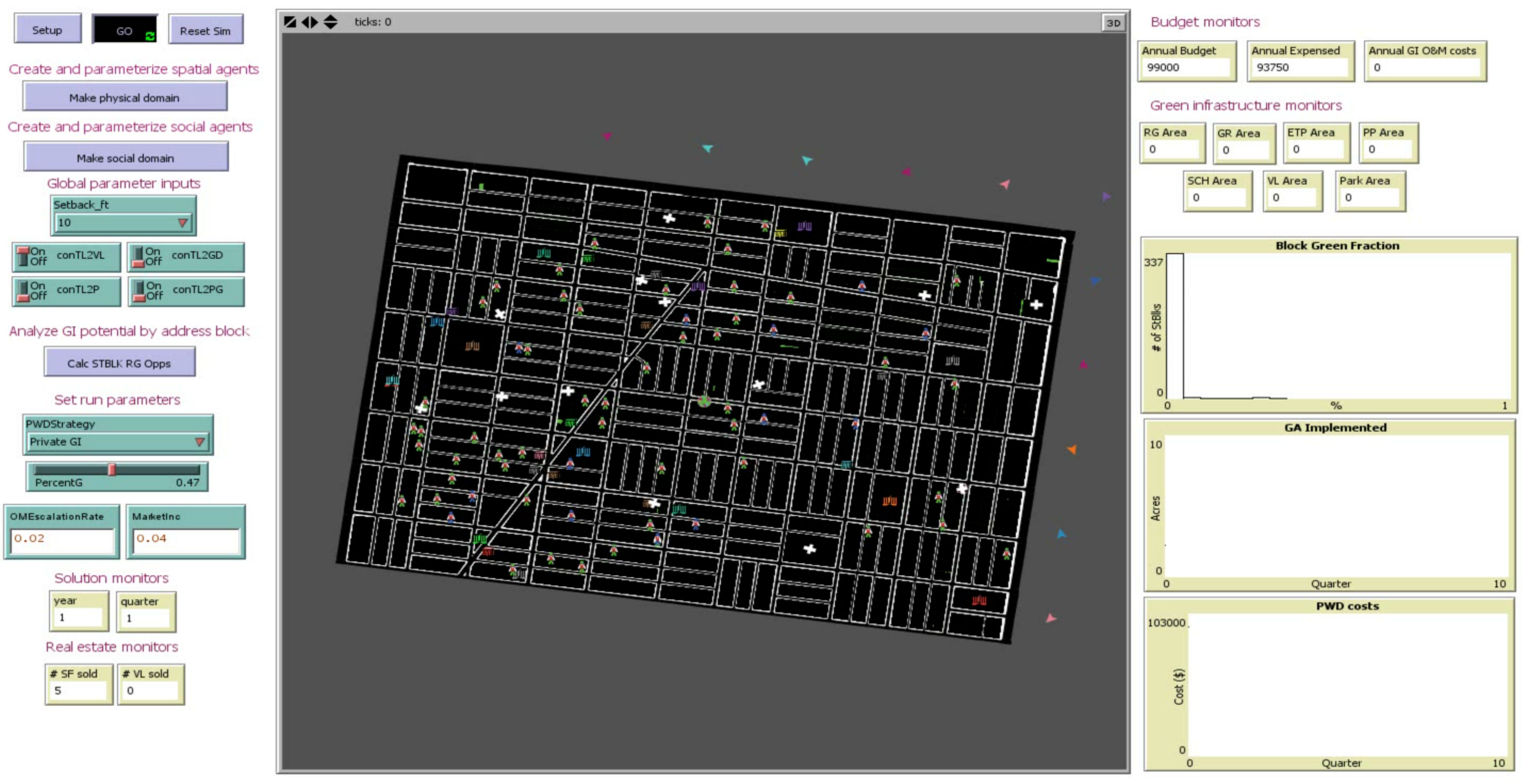


2 SITE PLAN -20th SREET GATEWAY 1"=40'

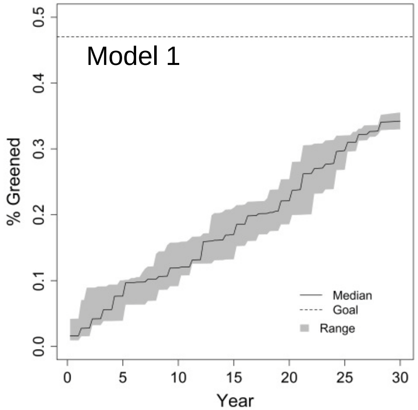


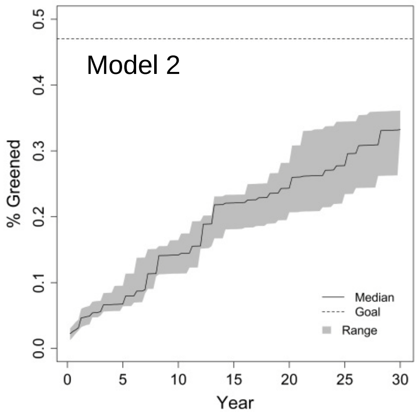
3 SYNERGY 1 - LAND BANK PARCEL + COMMERCIAL PROGRAM 1"=20'

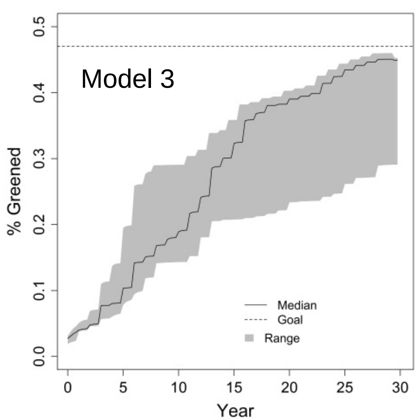
Visualization of Results (sample run)



Time Evolution of Community-Scale GSI in Point Breeze

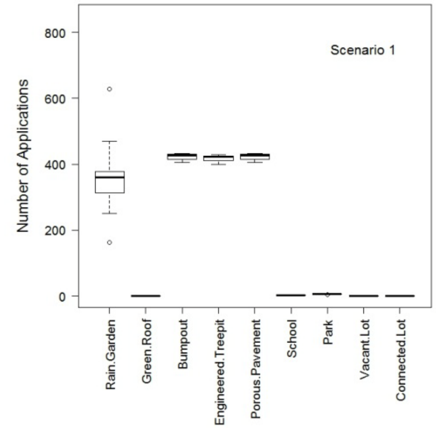




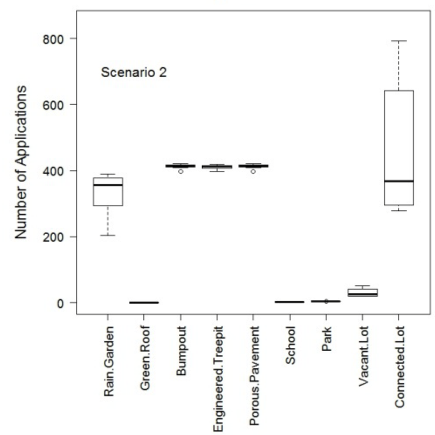


Frequency of Different GI Strategies After 30 Years

Model 1



Model 2

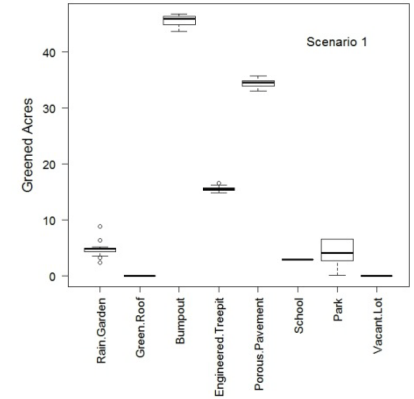


Model 3

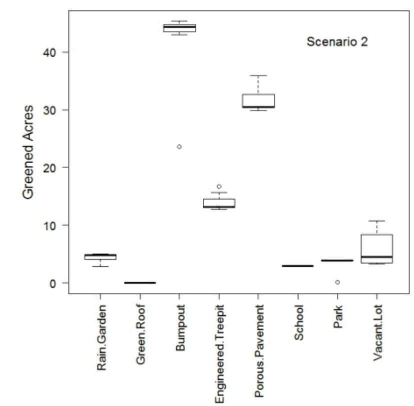
Not available

Net Greened Acres Associated with each GSI Strategy After 30 Years

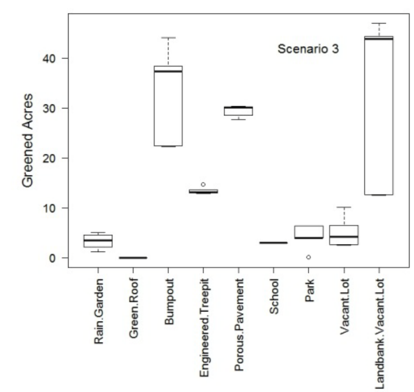
Model 1

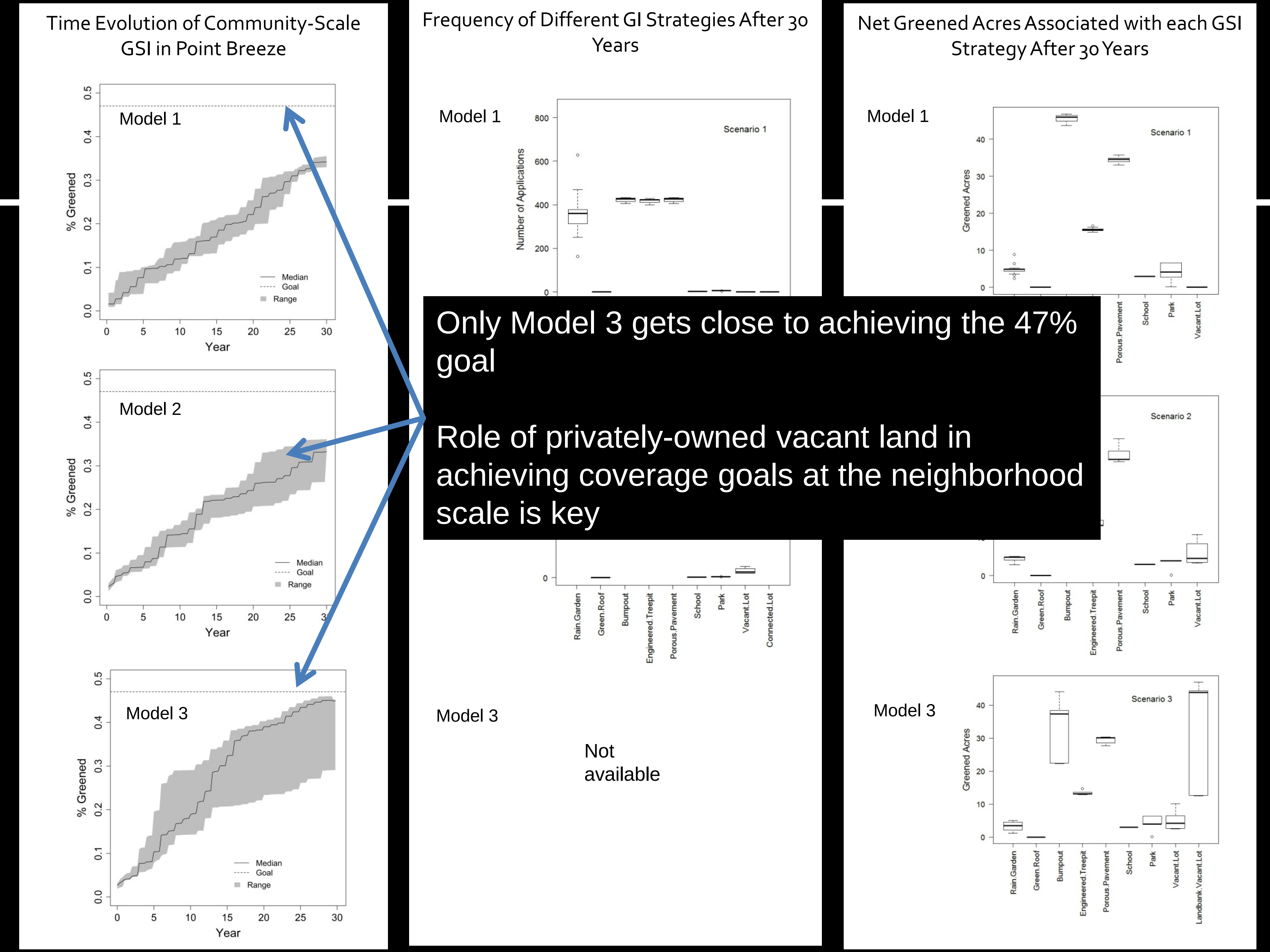


Model 2

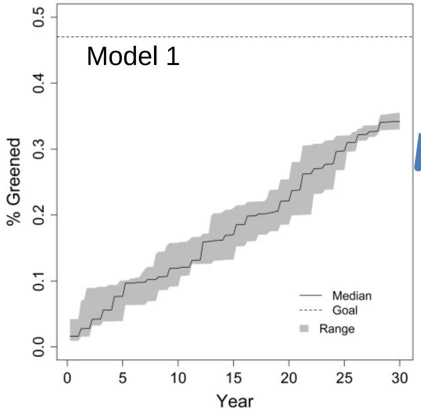


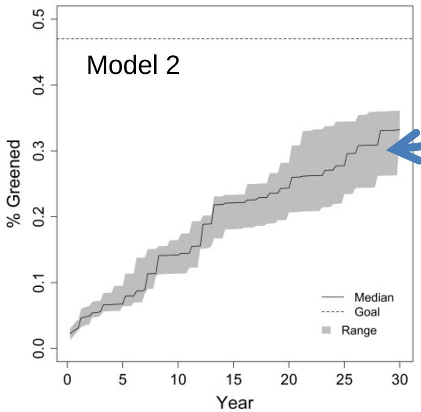
Model 3

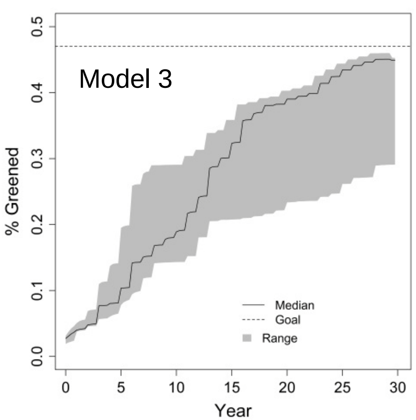



Time Evolution of Community-Scale GSI in Point Breeze
Frequency of Different GI Strategies After 30 Years
Net Greened Acres Associated with each GSI Strategy After 30 Years
Model 1
Model 2
Model 3
% Greened
Year
Median
Goal
Range
Number of Applications
Scenario 1
Scenario 2
Scenario 3
Greened Acres
Rain.Garden
Green.Roof
Bumpout
Engineered.Treepit
Porous.Pavement
School
Park
Vacant.Lot
Connected.Lot
Landbank.Vacant.Lot
Not available
Only Model 3 gets close to achieving the 47% goal
Role of privately-owned vacant land in achieving coverage goals at the neighborhood scale is key

Time Evolution of Community-Scale GSI in Point Breeze

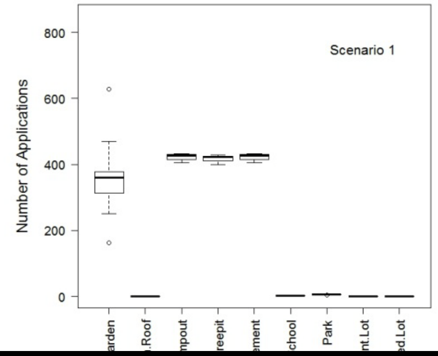


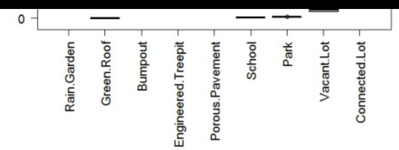




Frequency of Different GI Strategies After 30 Years

Model 1



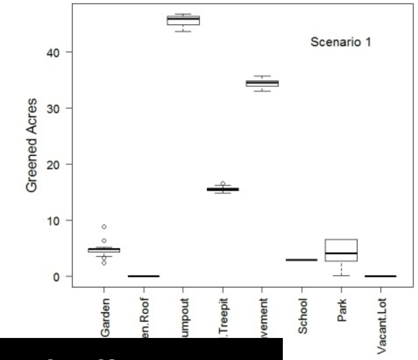


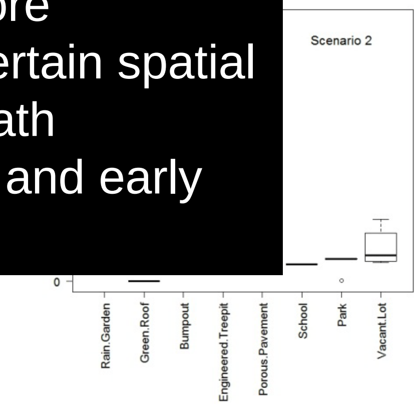
Model 3

Not available

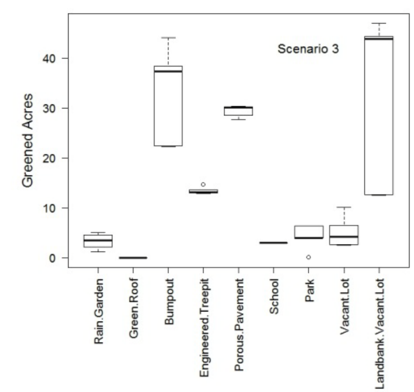
Net Greened Acres Associated with each GSI Strategy After 30 Years

Model 1

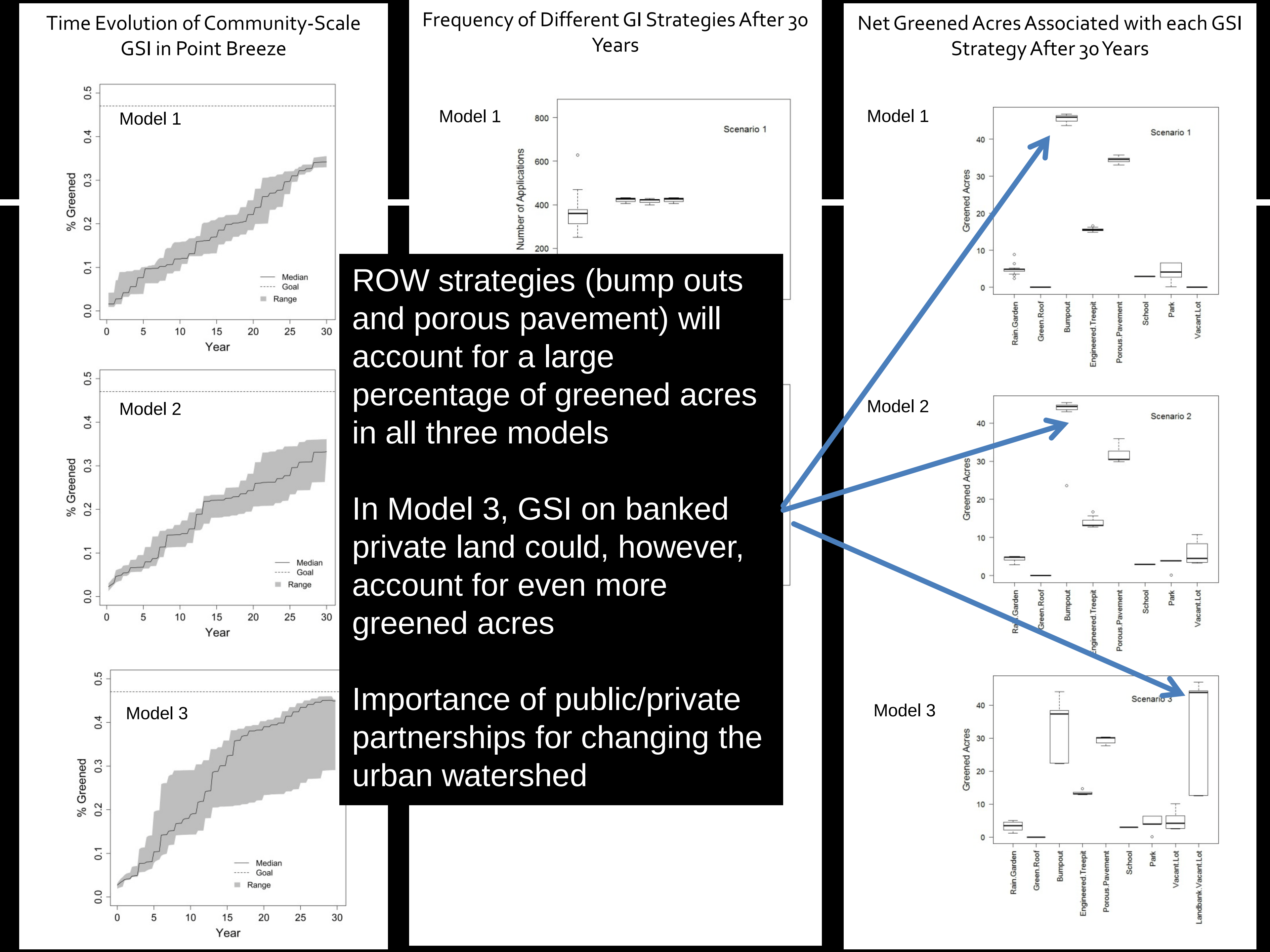




Model 3



Though models 1 and 2 arrive at a similar overall mean % green, there is more uncertainty in Model 2 due to uncertain spatial placement of early installations (path dependency of budget allocations and early GI placement decisions)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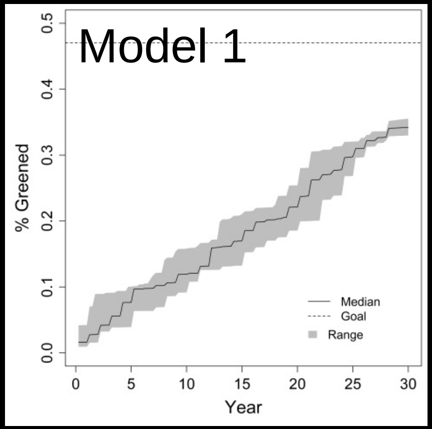
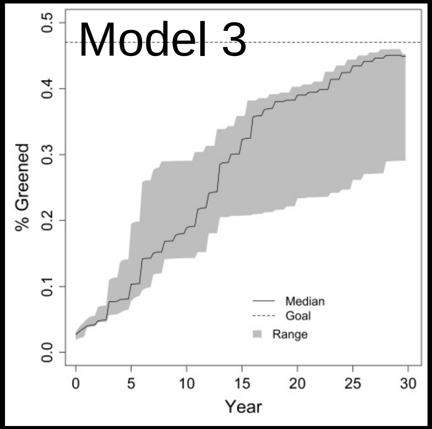
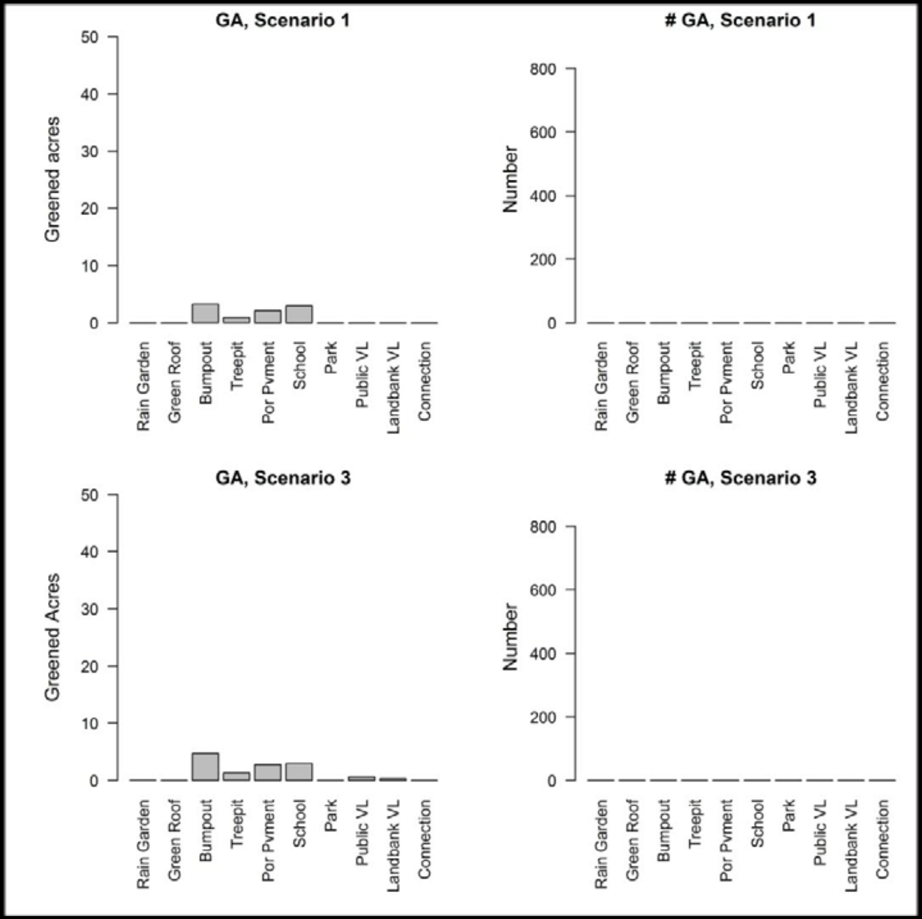
Greened Acres
Rain.Garden
Green.Roof
Bumpout
Engineered.Treepit
Porous.Pavement
School
Park
Vacant.Lot
Landbank.Vacant.Lot
ROW strategies (bump outs and porous pavement) will account for a large percentage of greened acres in all three models
In Model 3, GSI on banked private land could, however, account for even more greened acres
Importance of public/private partnerships for changing the urban watershed

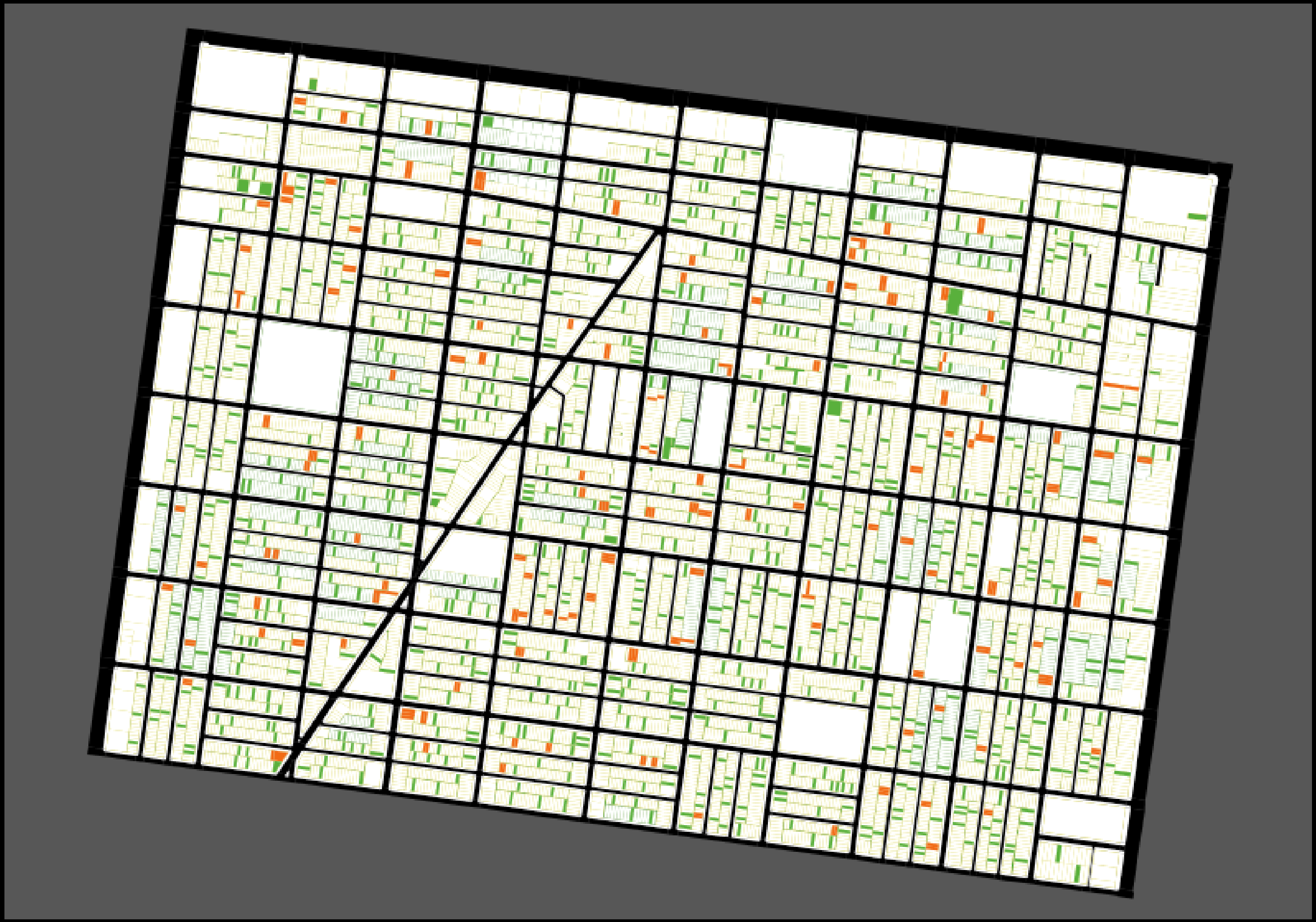
Animated results







How would the results differ in a neighborhood with a different spatial distribution of vacant land?

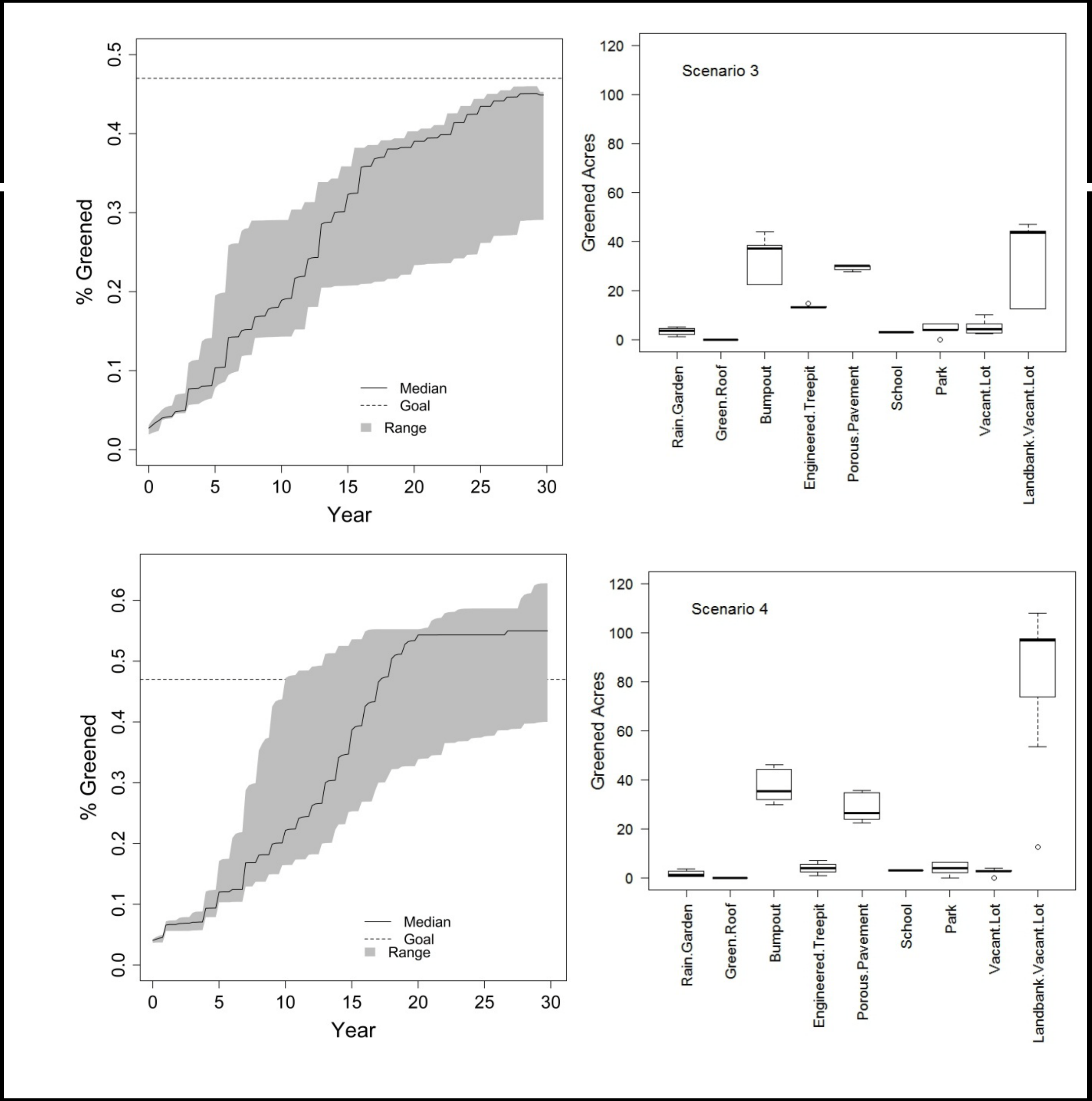


Results

Uniform distribution leads to greater neighborhood greening

Could indicate that dedicating some vacant land to stormwater management could help the city achieve its greening goals….

Can these become new community open-space assets??



Triple (Quadruple?) Bottom Line

Economic scalability

Ecological benefits

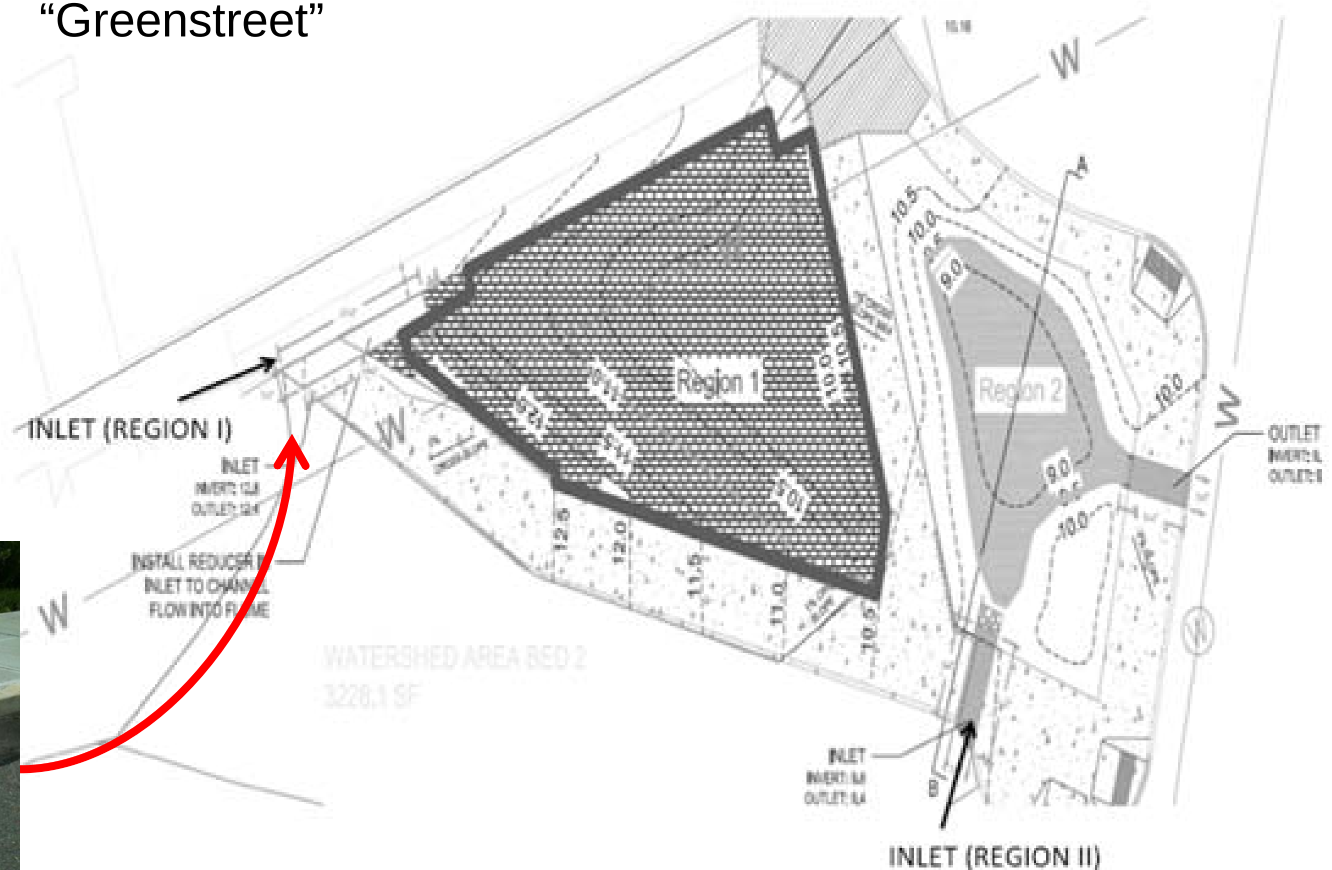
Social value

➔ Climate change mitigation/adaptation value

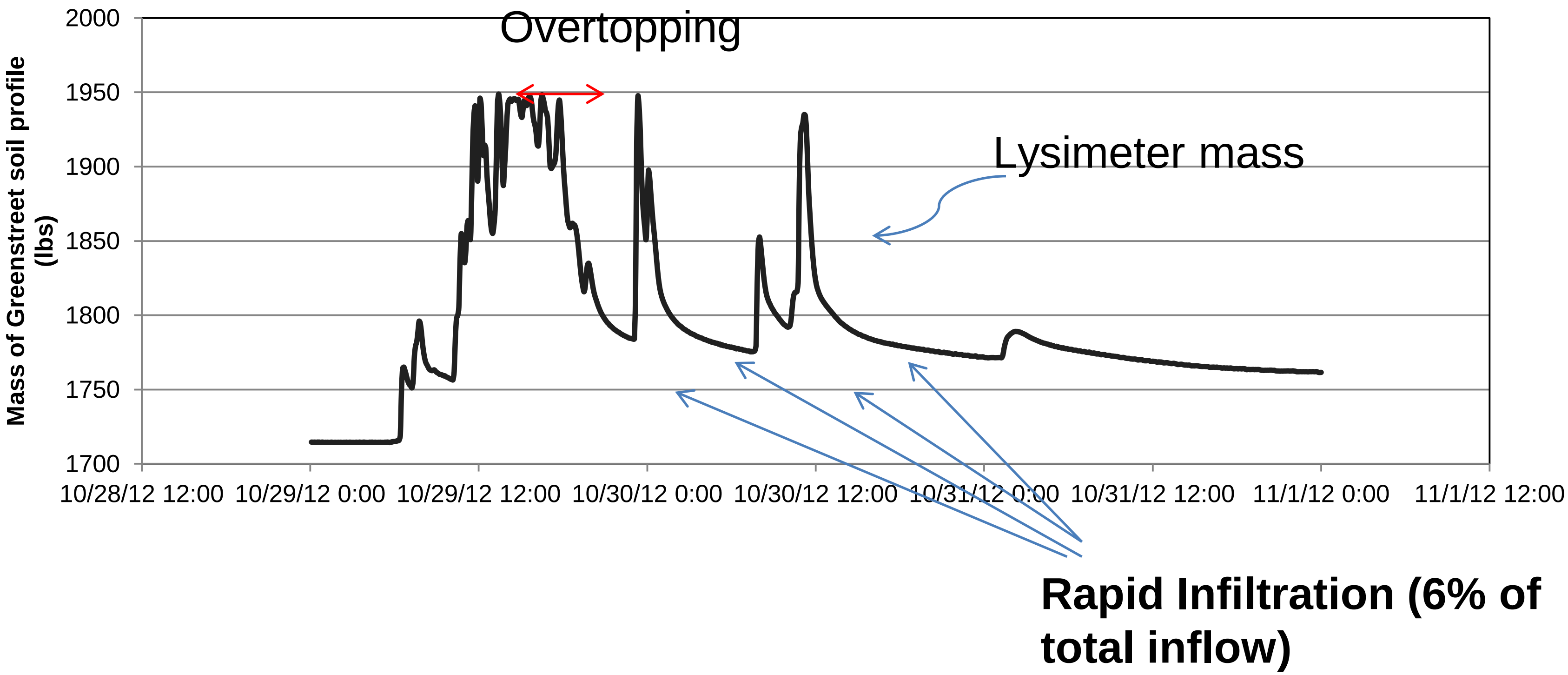
Adaptation Value

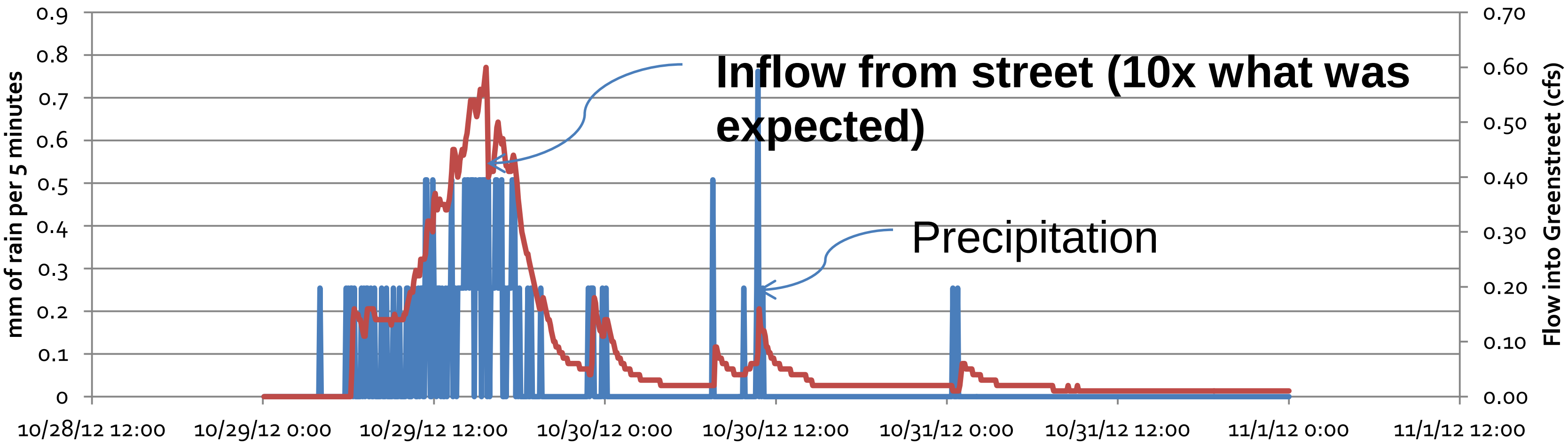
Response of Nashville Greenstreet to Hurricane Sandy

Nashville Bioretention "Greenstreet"



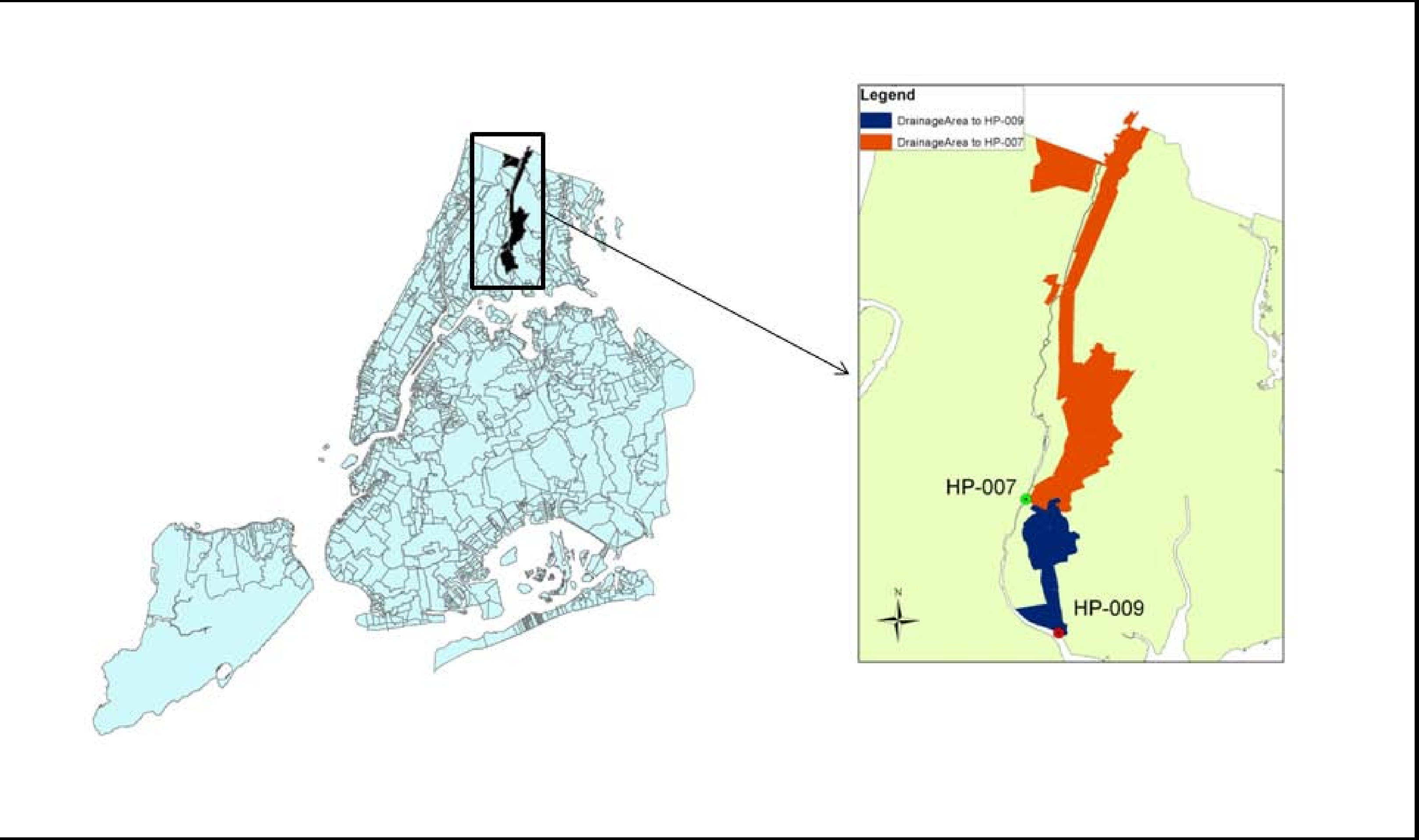

Curbcut inlet


Overtopping
Lysimeter mass
Rapid Infiltration (6% of total inflow)
Mass of Greenstreet soil profile (lbs)
2000
1950
1900
1850
1800
1750
1700
10/28/12 12:00
10/29/12 0:00
10/29/12 12:00
10/30/12 0:00
10/30/12 12:00
10/31/12 0:00
10/31/12 12:00
11/1/12 0:00
11/1/12 12:00


Inflow from street (10x what was expected)
Precipitation
mm of rain per 5 minutes
Flow into Greenstreet (cfs)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
10/28/12 12:00
10/29/12 0:00
10/29/12 12:00
10/30/12 0:00
10/30/12 12:00
10/31/12 0:00
10/31/12 12:00
11/1/12 0:00
11/1/12 12:00

Mitigation value

A Life Cycle Comparison of “grey” and “green” approaches to CSO reduction (Bronx, NY)

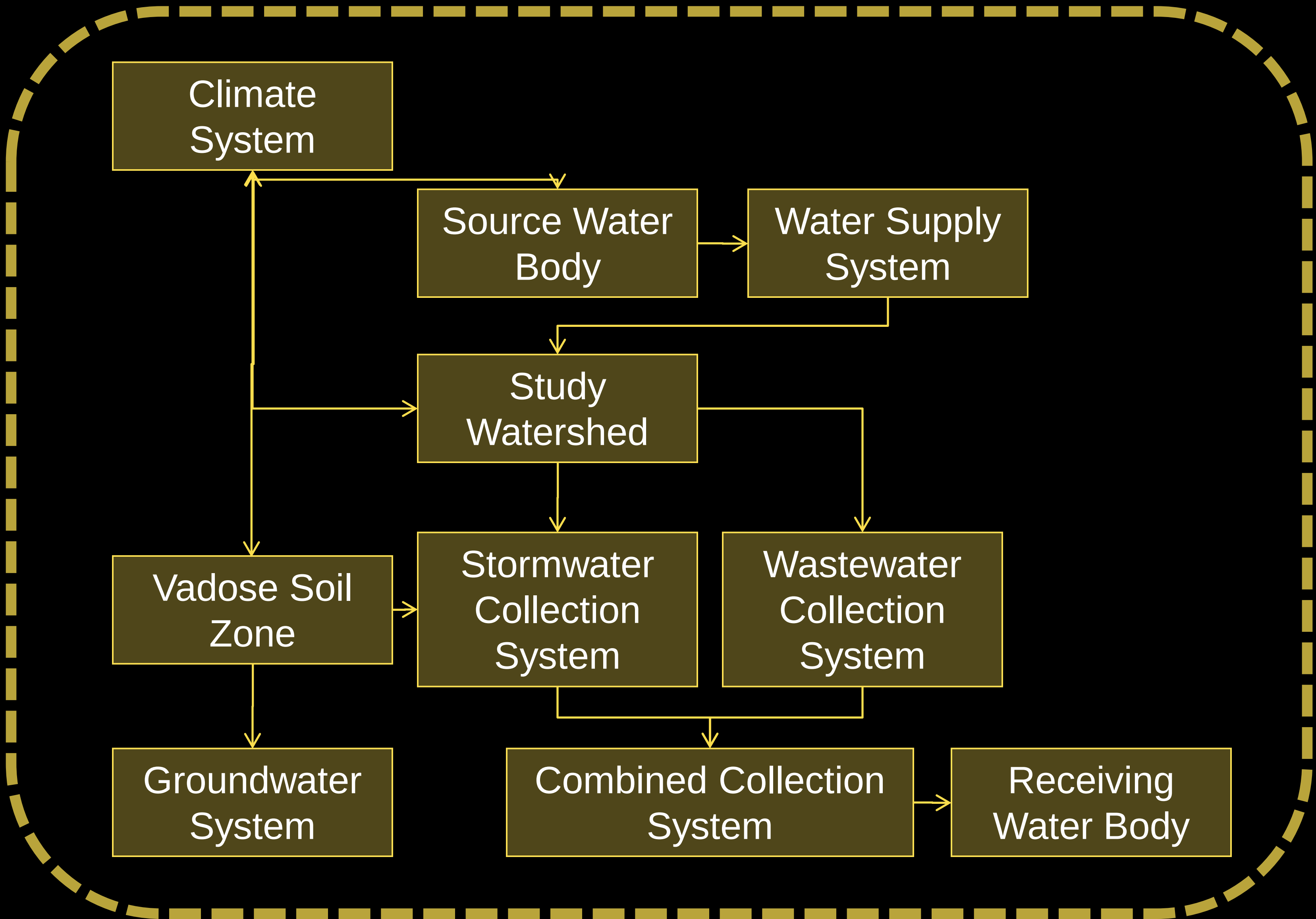


De Sousa et al 2013

Three strategies

- Distributed green approach
- Detention tank with pump
- Detention tank with treatment/discharge

Life Cycle Assessments



System Boundary

De Sousa et al 2013

Analysis considered

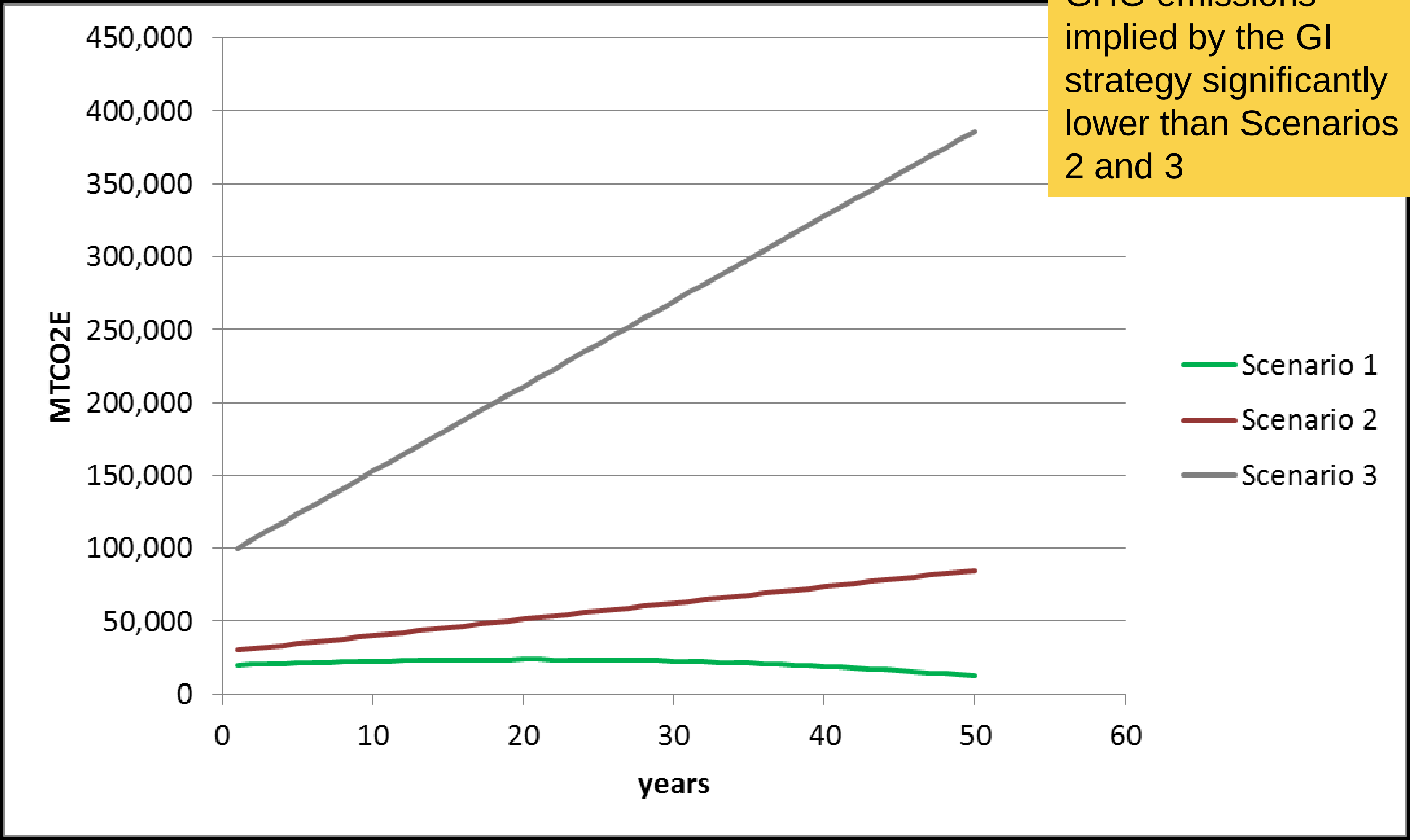
- **GHG released during**
  - Project installation
  - 50 yrs of operation and maintenance
  - At WWTP with the project in place
- **Also considers GHG associated with**
  - Shade provided by trees near residences
  - Wind blocked by trees near residences
  - Carbon permanently sequestered in trees

Watershed modeling

CSO reduction strategy	Change in volume of untreated sewer overflows per year over do-nothing case	Change in flow to the Hunts Point Wastewater treatment plant over do-nothing
1. Green	Down	Up
2. Grey- detention tank	Down	Up
3. Grey- treat and discharge	Down	No change

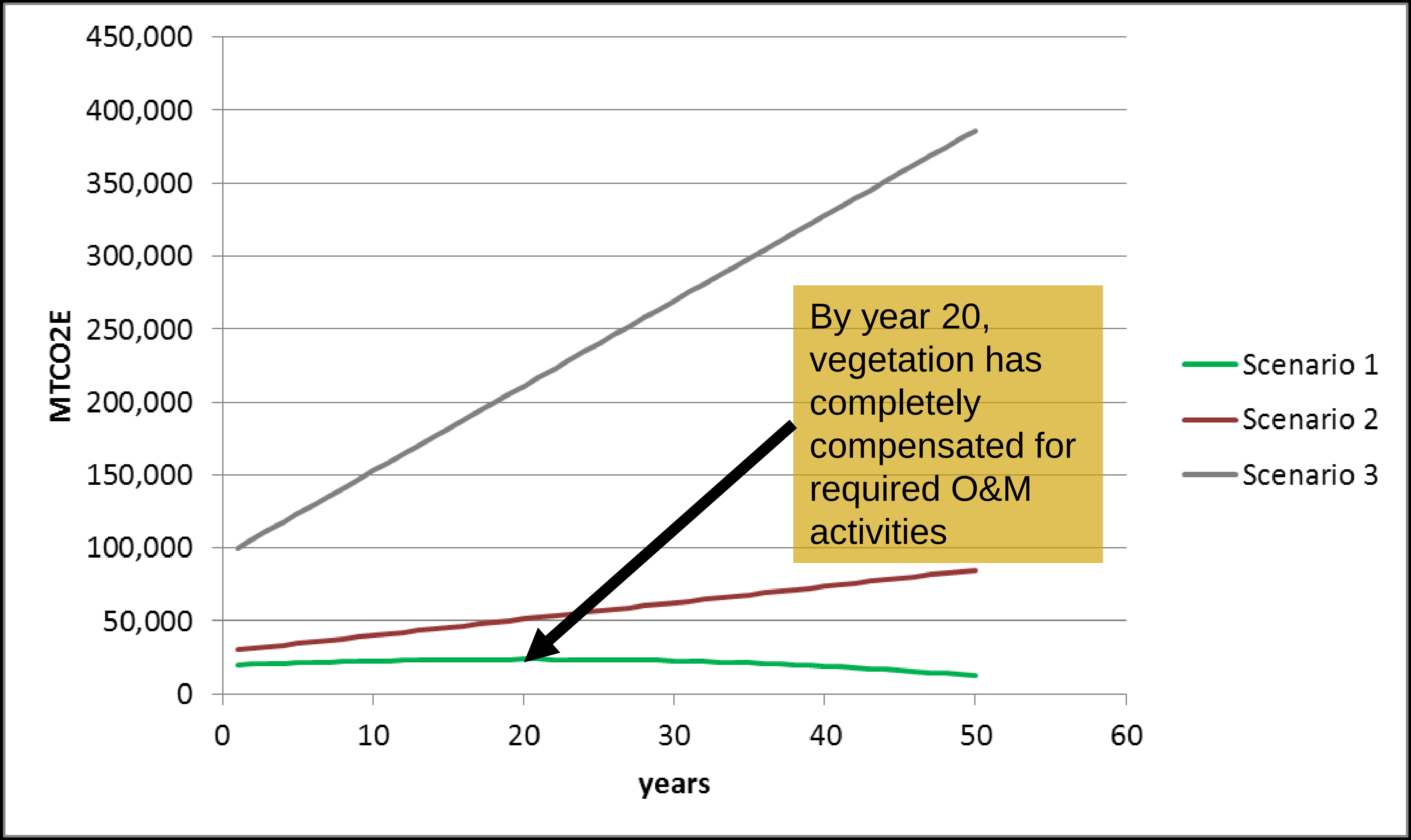
De Sousa et al 2013

LCA Comparison



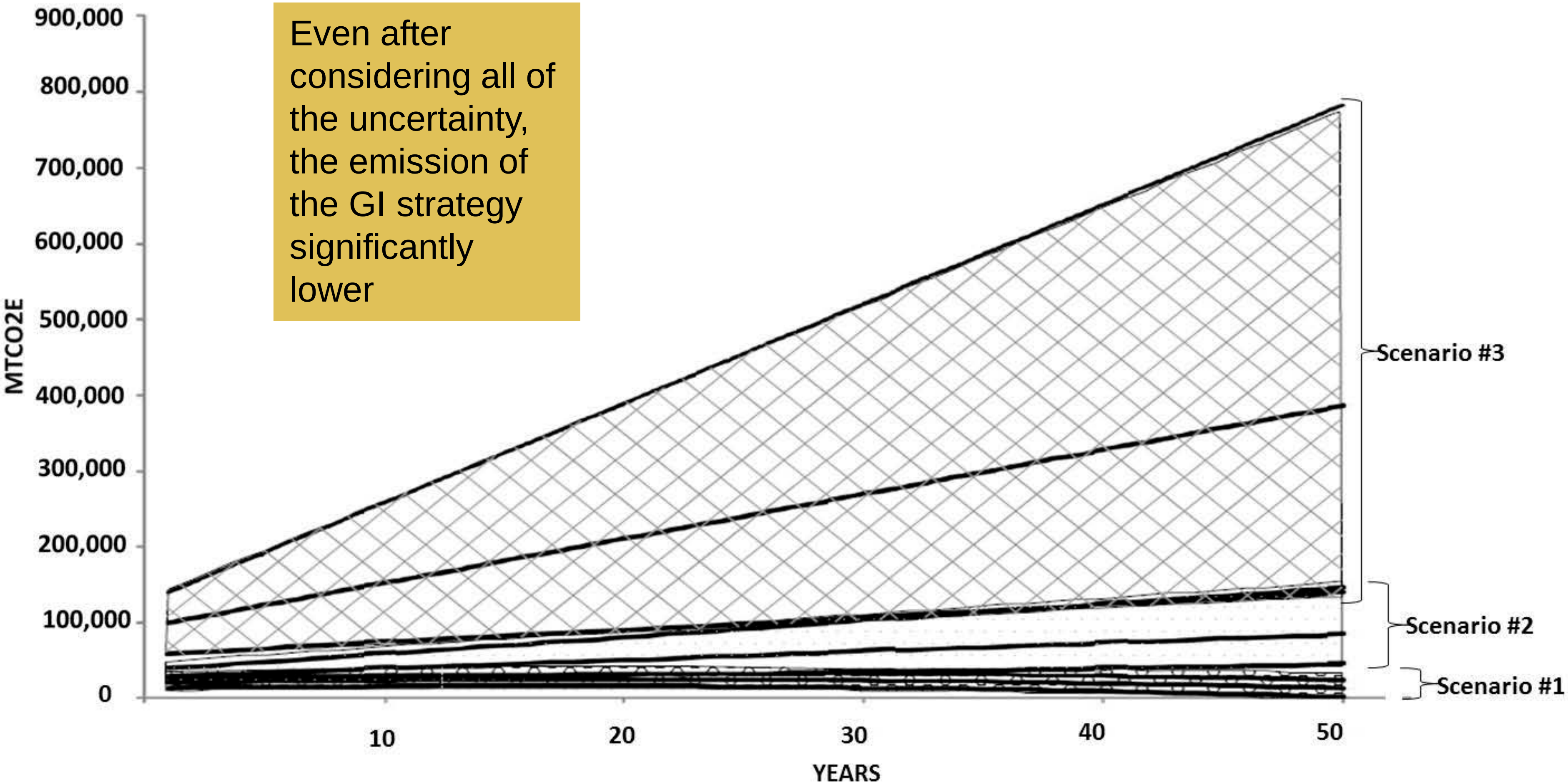
GHG emissions implied by the GI strategy significantly lower than Scenarios 2 and 3

LCA Comparison



Sensitivity Analysis

Even after considering all of the uncertainty, the emission of the GI strategy significantly lower



Concluding Remarks

- Quantification of actual TBL benefits of urban GI is still at the early stages
- At the site and watershed scale, the opportunity for making urban watersheds more functional is great.
- Cost-effectiveness, however, is contingent upon selection of the proper strategy for the site, and creating the right partnerships
- These partnerships are also an opportunity for a wide range of stakeholders to assist in, and benefit from this unprecedented phase of investment in cities

STUDENTS HAVE FUN OPERATING PLAY PUMP

Thanks!

eDesign Dynamics

Drexel UNIVERSITY

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