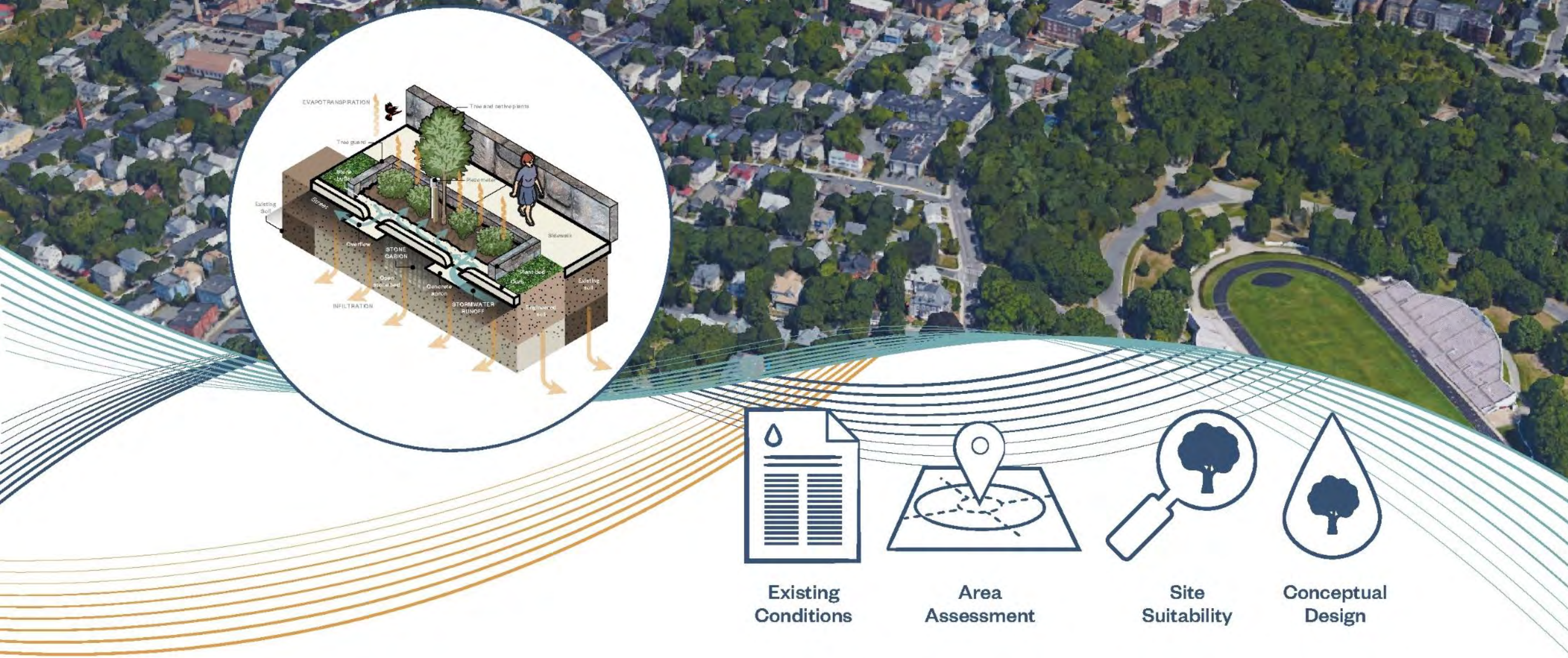

Prioritizing Green Infrastructure for Phosphorus Reduction within Boston's MS4

Hazen

NEW ENGLAND WATER ENVIRONMENT ASSOCIATION
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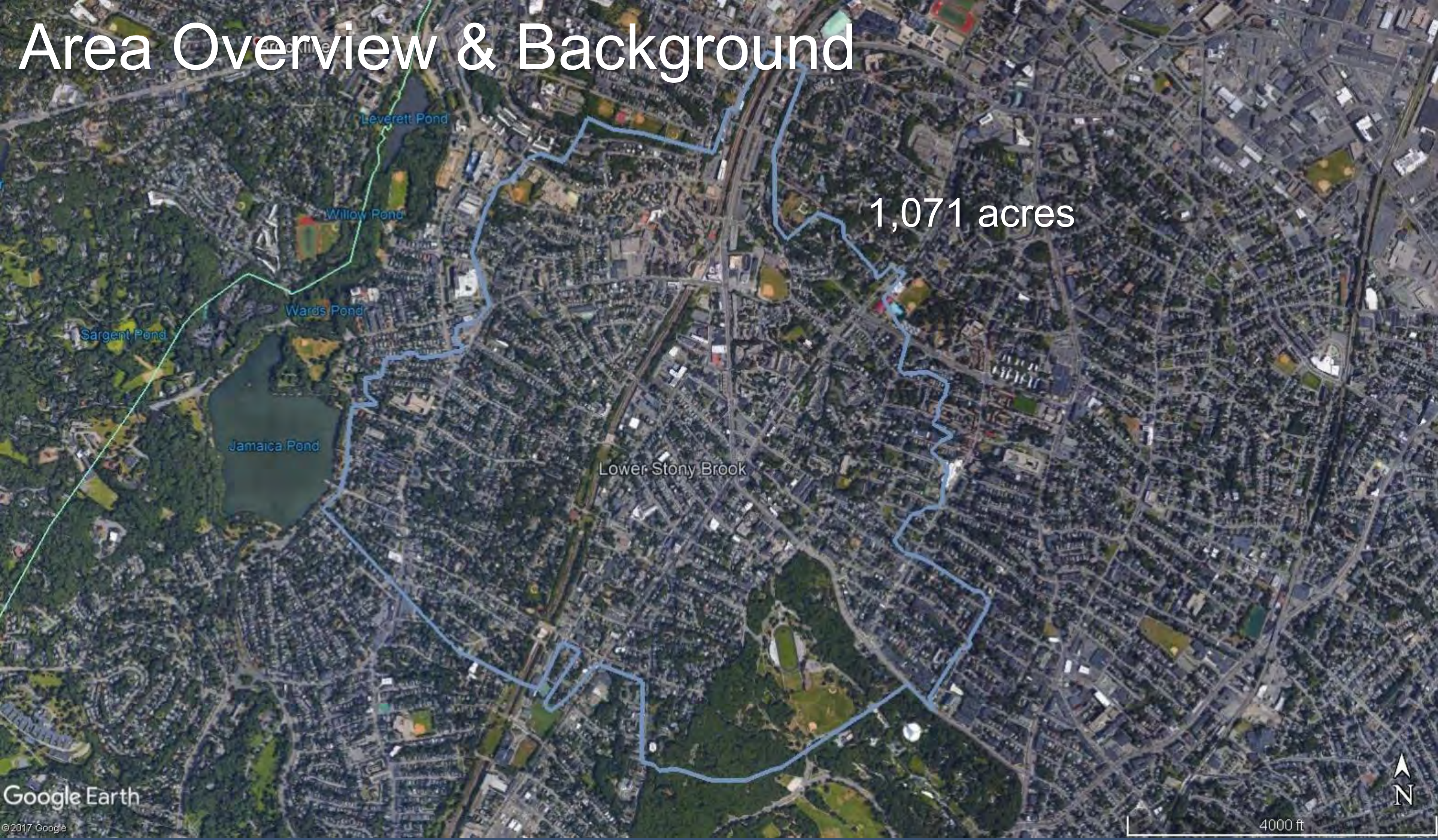
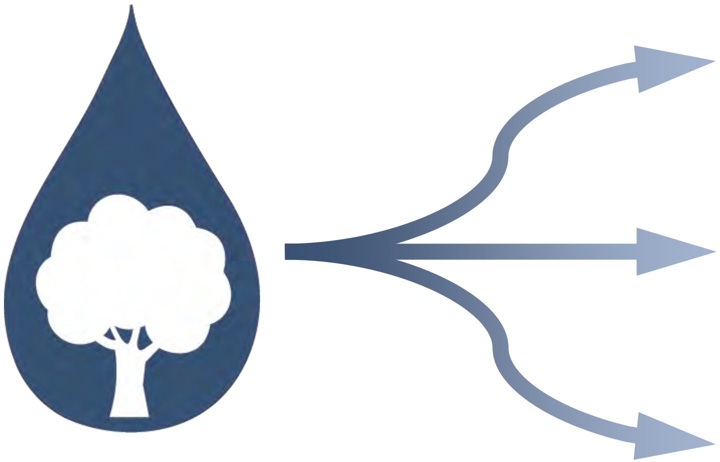
Boston Water and Sewer Commission

Area Overview & Background



Project Goals



- Develop a siting and design process
- Identify feasible GI opportunities
- Develop and evaluate conceptual designs

Project Elements

Existing Info Review

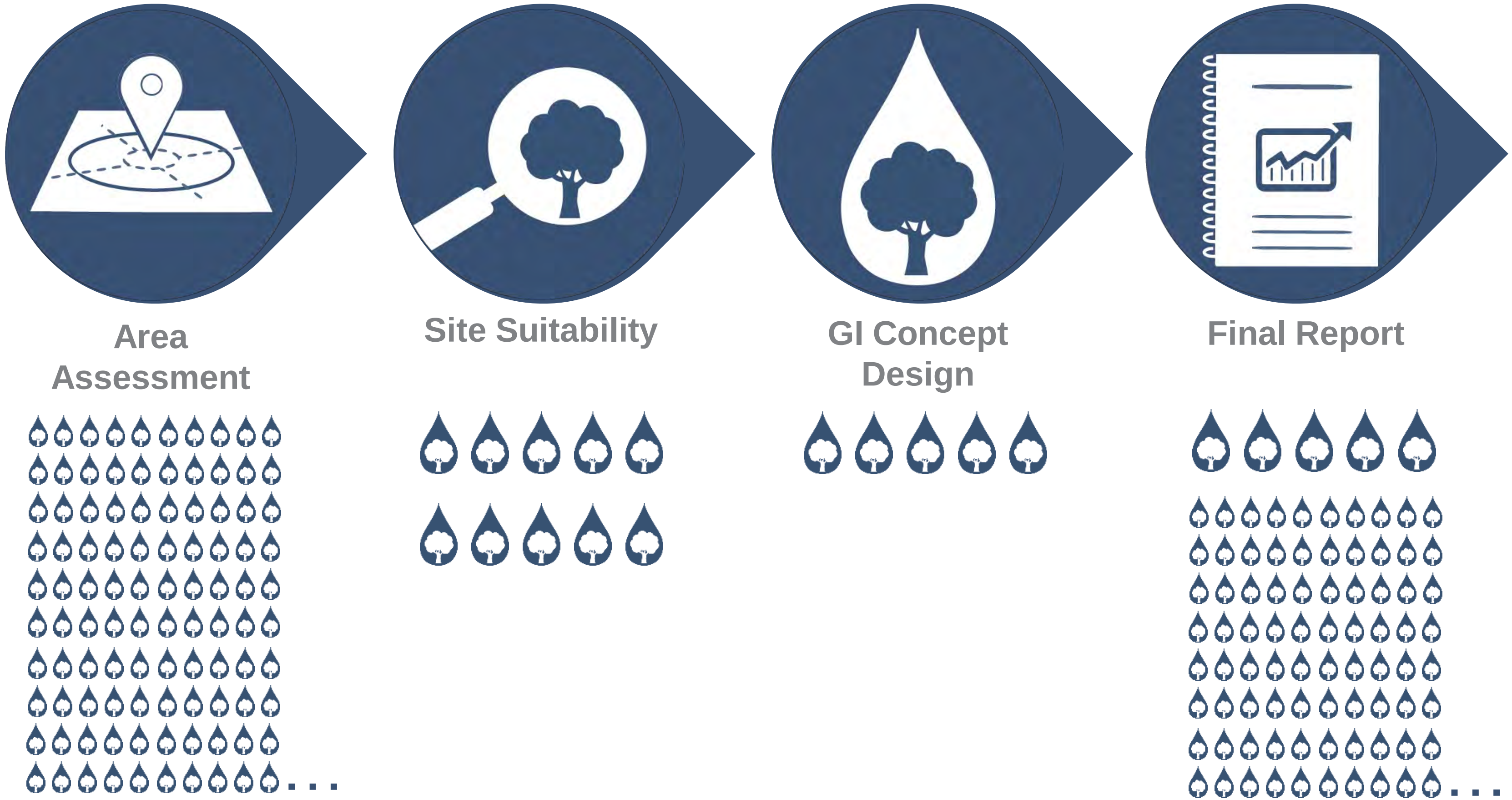
Area Assessment

Site Suitability

GI Concept Design

Final Report

Prioritization of Opportunities



Area Assessment

Objective

Identify and track feasible GI opportunities and constraints throughout the entire study area

Approach

Delineate drainage areas, conduct desktop analyses to rate implementation feasibility, and conduct site visits for 34 prioritized opportunities

Outcome

Opportunities and constraints recorded for more than 1,500 drainage areas, resulting in more than 400 GI opportunities

Drainage Area Analysis

Drainage areas characterized as:

- **High** – Minimal constraint impacts
- **Off-site High** – DA can be easily managed by an adjacent parcel
- **Medium** – Some constraints however drainage area could still be managed with additional coordination
- **Off-site Medium** – Drainage area may need to cross a street or need further investigation
- **Low** – Drainage area is not suitable for GI nor can it be managed by another location

Legend

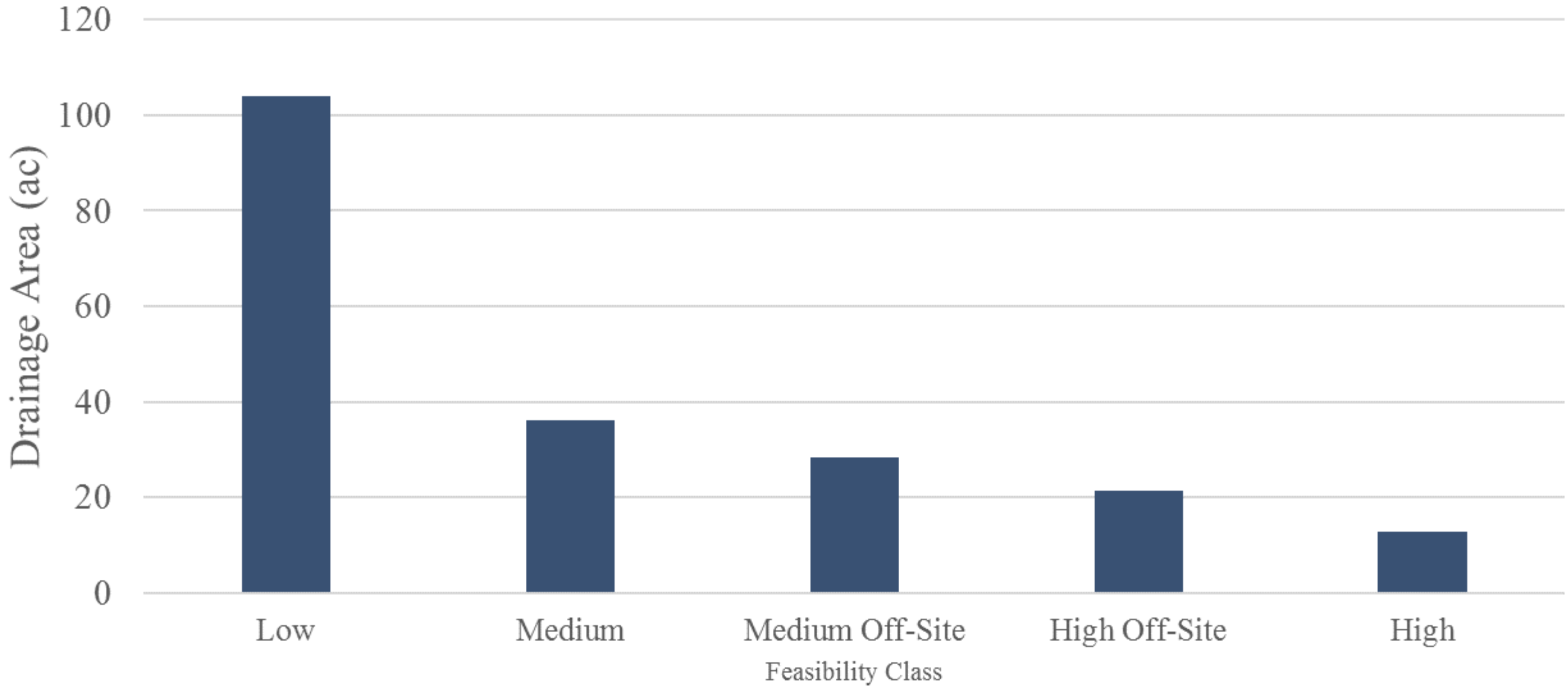
Drainage Area Feasibility

- **High Potential**
- **Low Potential**
- **Medium Potential**
- **Off-site High Potential**
- **Off-site Medium Potential**

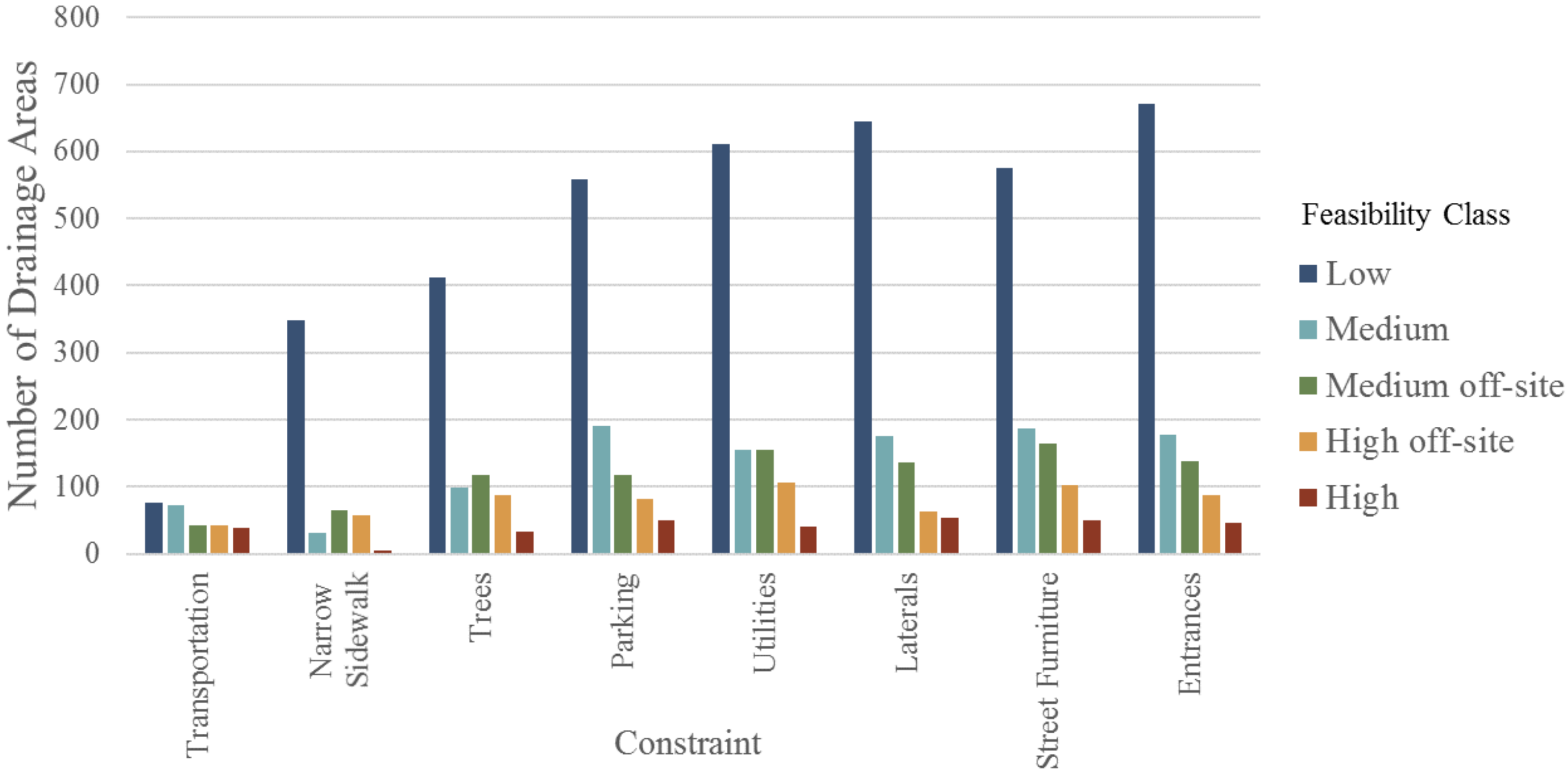
Drainage Area Tracking

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	Study Area	Drainage Area Identifier	On-site or RO	Nearest Inlet Facility I	Nearest Inlet Feature	Street Feature	Secondary Street Feature	Drainage Area Feasibility	Drainage Area (SF)	Constraints	Opportunities	Green Infrastructure Type	Alternative Green Infrastucture	GI ID	GI Footprint (SF)	GI Lo
2	Lower Stony Brook	1000	ROW	18GCB24	1807910009	1707210016	1707210016	Medium Potential	10,627	Trees, Street Parking, Possible Laterals, Street Furniture	Wide Sidewalk, Grass Strips, Additional Drainage, Degraded Sidewalk	Porous Pavement	Subsurface System	-	-	Roa
3	Lower Stony Brook	1001	ROW	17GCB93	1707910004	1707210016	-	Medium Potential	3,124	Trees, Street Parking, Possible Laterals, Street Furniture	Wide Sidewalk, Grass Strips, Additional Drainage	Bioretention	Subsurface System	-	-	Roa
4	Lower Stony Brook	1002	ROW	18GCB22	1807910026	1807210024	-	Off-site Medium Potential	809	Trees, Utilities, Street Parking, Possible Laterals, Street Furniture	Topography, Additional Drainage	Subsurface System	-	-	-	Off-
5	Lower Stony Brook	1003	ROW	18GCB26	1807910036	1807210024	-	Off-site Medium Potential	4,080	Utilities, Street Parking, Possible Laterals, Street Furniture, Entrances	Additional Drainage	Subsurface System	-	-	-	Off-
6	Lower Stony Brook	1004	ROW	18GCB21	1807910028	1807210024	-	Off-site Medium Potential	1,057	Narrow Sidewalk, Street Parking, Possible Laterals, Street Furniture	Grass Strips	Subsurface System	-	-	-	Off-
7	Lower Stony Brook	1005	ROW	18GCB104	1807910085	1807210024	-	Off-site High Potential	4,122	Street Parking, Possible Laterals, Street Furniture, Entrances	Wide Sidewalk, Additional Drainage, Ease of Drainage Area Diversion	Porous Pavement	Subsurface System	-	-	Off-
8	Lower Stony Brook	1006	ROW	18GCB58	1807910068	1807210035	-	Medium Potential	1,814	Street Parking, Possible Laterals, Street Furniture, Entrances	Wide Sidewalk, Additional Drainage	Porous Pavement	Subsurface System	-	-	Roa
9	Lower Stony Brook	1007	ROW	18GCB61	1807910066	1807210035	-	Low Potential	1,577	Street Parking, Possible Laterals, Street Furniture, Entrances	Wide Sidewalk	-	-	-	-	-
10	Lower Stony Brook	1008	ROW	18HCB1	1808910042	1808210041	-	Off-site High Potential	8,267	Trees, Narrow Sidewalk, Utilities, Street Furniture	Ease of Drainage Area Diversion	Bioretention	Subsurface System	-	-	Off-
11	Lower Stony Brook	1009	ROW	18HCB6	1808910210	1808210041	-	Low Potential	8,703	Street Parking, Possible Laterals, Street Furniture, Entrances, Topography	Additional Drainage	-	-	-	-	-
12	Lower Stony Brook	1011	ROW	18HCB25	1808910212	1808210076	-	Off-site High Potential	8,512	Narrow Sidewalk, Utilities, Possible Laterals, Street Furniture, Entrances	Grass Strips, Ease of Drainage Area Diversion	Bioretention	Subsurface System	-	-	Off-
13	Lower Stony Brook	1012	ROW	18HCB31	1808910198	1808210076	-	Low Potential	4,232	Street Parking, Possible Laterals, Street Furniture, Entrances, Topography	Additional Drainage	-	-	-	-	-
14	Lower Stony Brook	1013	ROW	18HCB28	1808910052	1808210076	-	Low Potential	5,212	Utilities, Street Parking, Possible Laterals, Street Furniture, Entrances, Topography	Wide Sidewalk, Additional Drainage	-	-	-	-	-
15	Lower Stony Brook	1014	ROW	18HCB44	1808910086	1808210006	-	Medium Potential	4,051	Street Parking, Possible Laterals, Entrances	Wide Sidewalk, Additional Drainage	Porous Pavement	Subsurface System	-	-	Roa

Drainage Area Feasibility

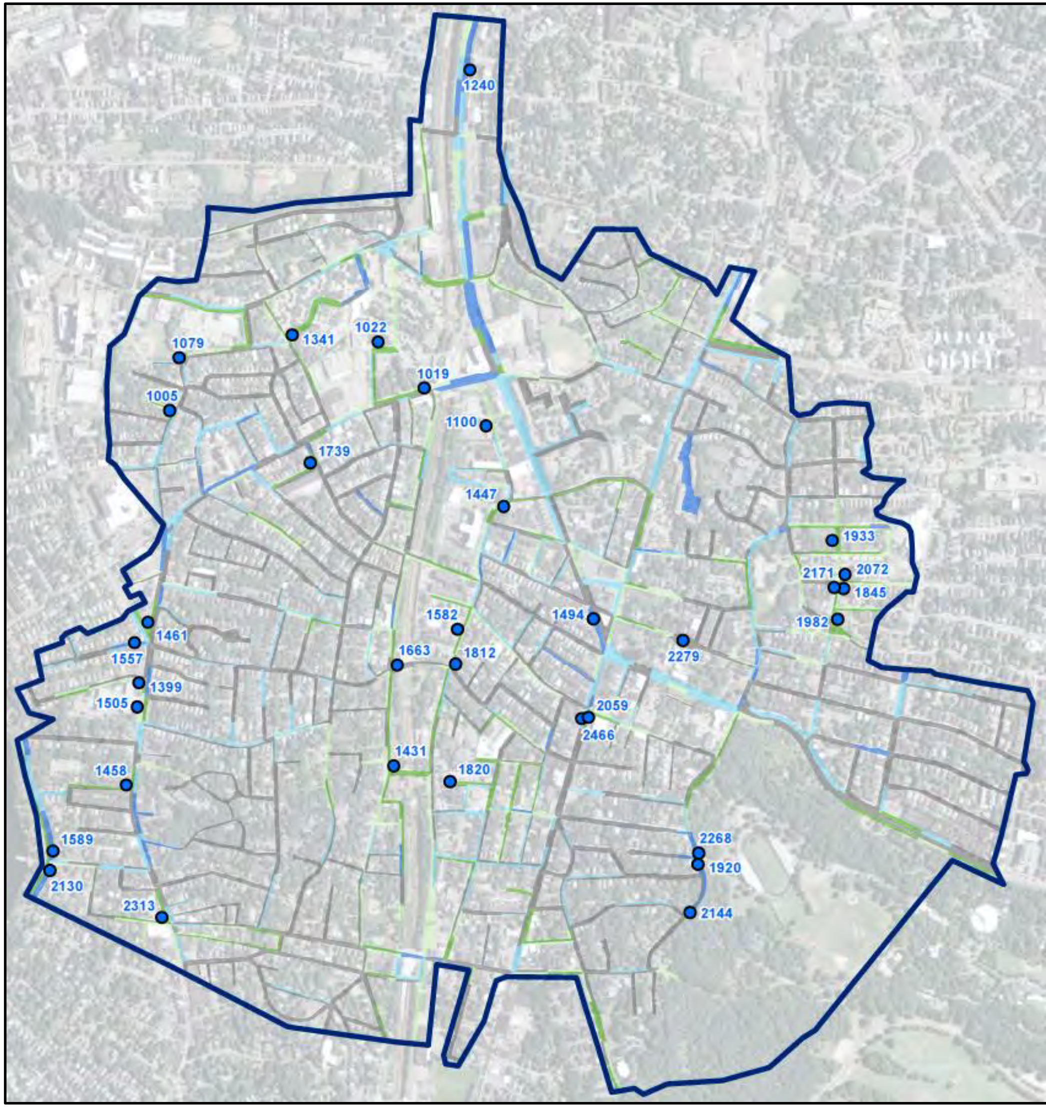


Constraints Encountered

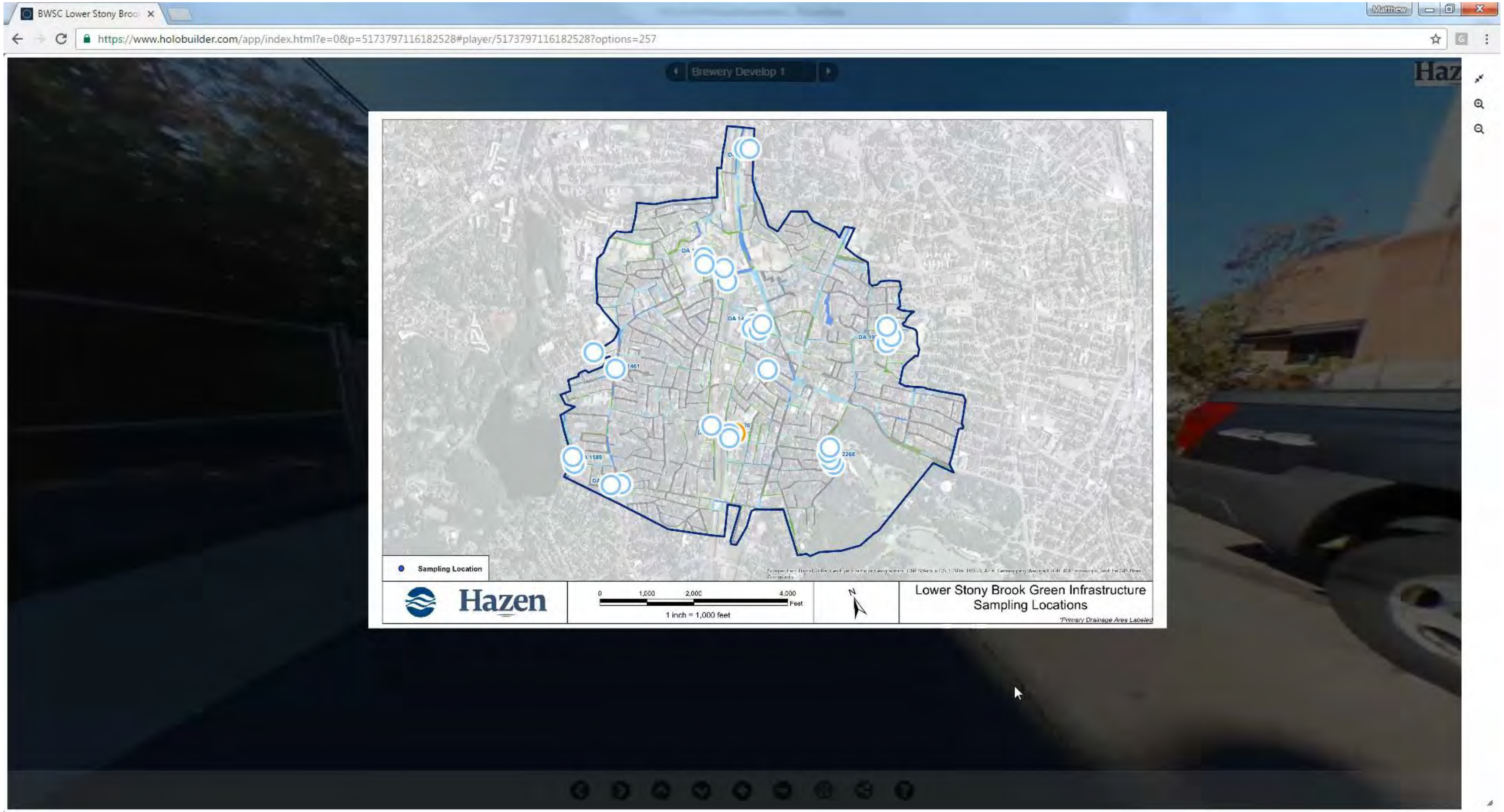


Site Visits

- 34 Site Visited
- 3 sites eliminated concluding site visits due to constraints
  - Poor topography
  - Numerous utilities
  - Transportation constraint
- Mix of ROW and Off-Site Opportunities
- 31 proposed locations



360º Site Visit Tour



Site Suitability

Objective

Further evaluate GI feasibility and inform potential water quality benefits

Approach

Conduct hand auger soil investigations and collect first flush stormwater samples at 10 prioritized sites

Outcome

Sites had varying degrees of infiltration and phosphorus reduction capacity, which informed further prioritization

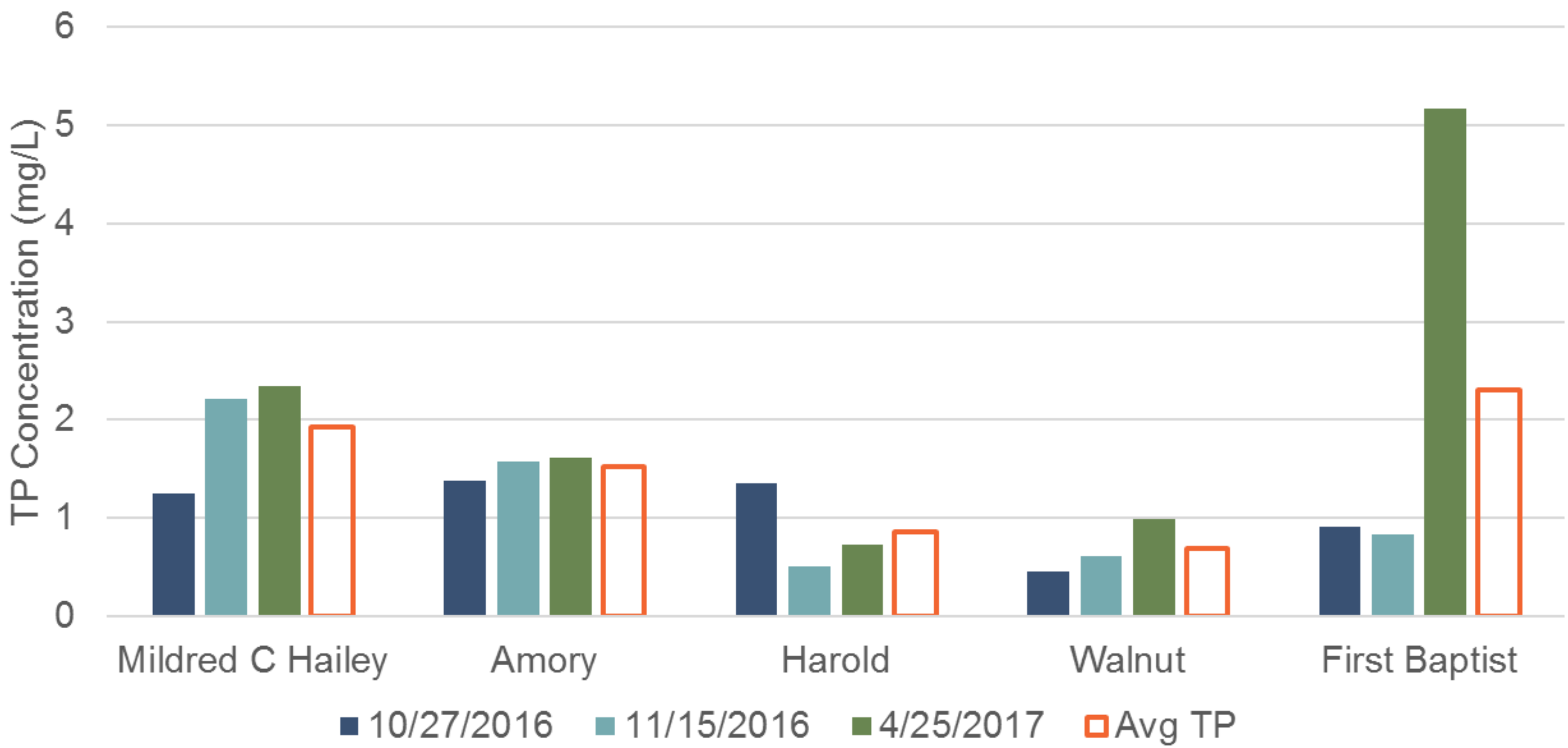
Hand Auger Characterization and Infiltration Testing

Soil Investigation Results

Site	Raw Drawdown (in/hr)	Design Infiltration Rate (in/hr)
1447	5	0.6
1431	11	1.2
1589	13	0.8
1933	9	2.0
2144	30	4.3
1240	6	1.7
1022	0	0
2313	7	1.0
1820	3.6	0.5

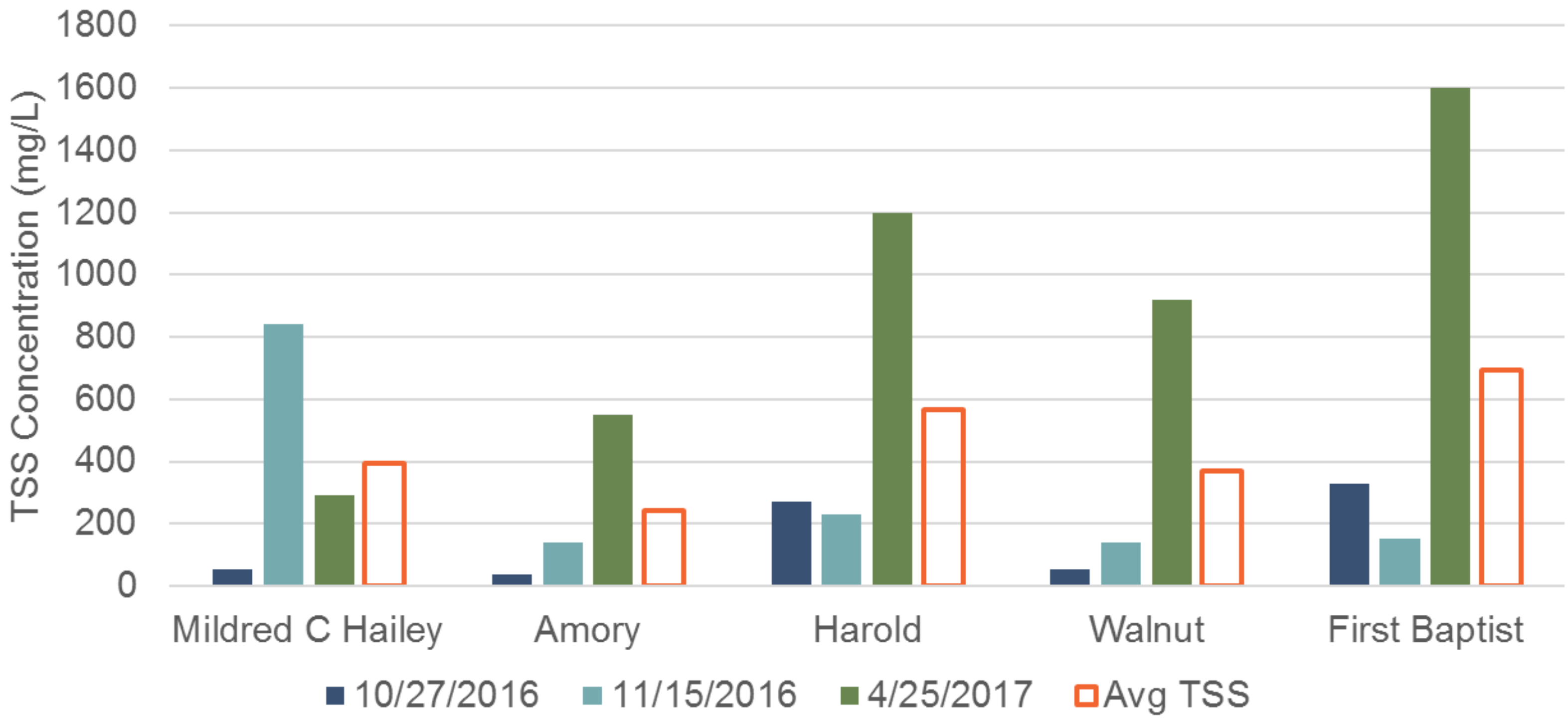
Storm Sampling Results

Total Phosphorus



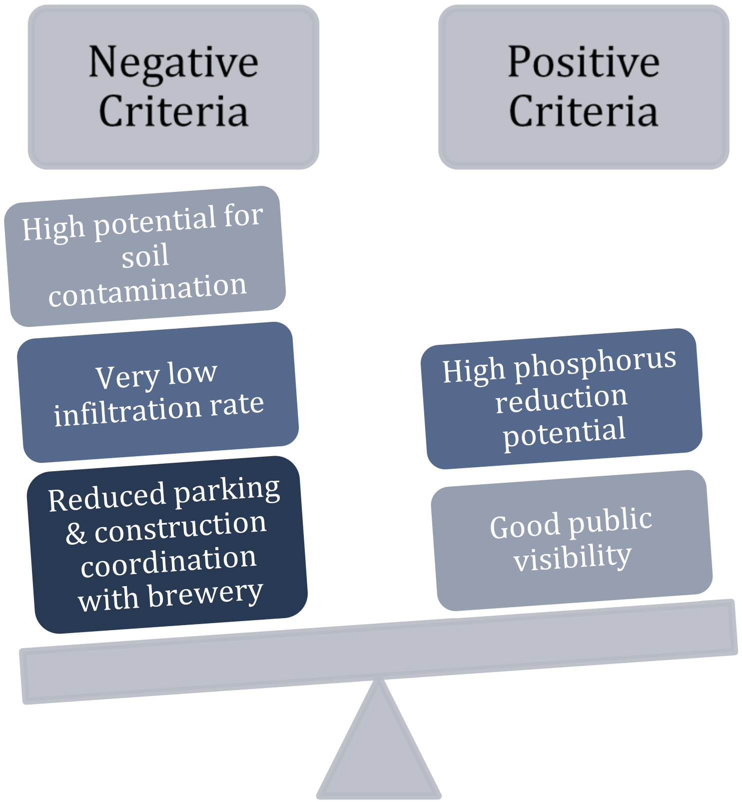
Storm Sampling Results

Total Suspended Solids

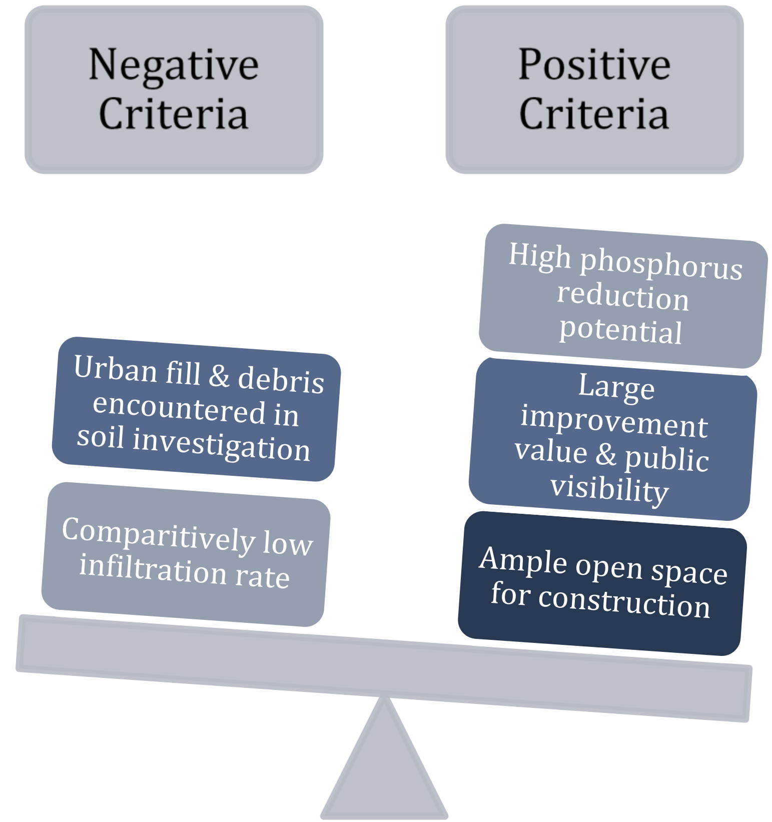


Site Suitability Prioritization

Selection Criteria for Site 1820



Selection Criteria for Site 1022



Green Infrastructure Design

Objective

Develop conceptual designs to present representative feasible opportunities and provide a basis for future design efforts

Approach

Prepare a concept sheet package for 5 sites summarizing the proposed design and key future considerations

Outcome

Multiple configurations of bioretention design within the ROW, public, and private properties

Types of Designs

Right-of-Way Bioretention

- Linear bioretention implemented within the ROW
- Treatment of adjacent ROW runoff through curb cuts and other diversions

Example: Walnut Ave.

Types of Designs

Small Catchment Bioretention

- Bioretention on a public or private property
- Treatment of adjacent areas < 1 ac
- Often sited in grassed areas, small parks, or other open spaces

Example: Amory St. & Dimock St.

Types of Designs

Large Catchment Bioretention

- Bioretention on a public or private property
- Treatment of adjacent areas > 1 ac
- Multiple drainage diversions, disconnections, and street crossings typical
- Often sited in vacant lots or other large open spaces

Example: Harold St. & Hollander St.

Design Considerations

Design Consideration	Description
Deteriorating Site	Broken or overgrown sidewalk, abandoned lot, or area needing maintenance
Drainage Diversion	Routing drainage from roof to ground level BMP or street drainage to parcel
Programmatic	Active construction or existing use requiring consideration
Transportation	Parking, bus lane, bike lane, driveways, loading zones, state route, or MBTA infrastructure
Subsurface Utilities	Subsurface utilities within site, intersecting drainage crossing, or within close proximity
Landscaping	Existing trees, bushes, or planters
Surface Structures	Utility poles, enclosures, sidewalk furniture, etc.
Topography	Steep grades, significant elevation drop/increase

First Baptist Church Bioretention

Design Calculations

- **Estimate bioretention footprint**
  - 5-7% of tributary area (43,560 ft^2) = 2,178 – 3,049 ft^2

- **Calculate water quality volume**

$$WQv = \frac{WQ_{Depth}}{12} * Area_{Impervious}$$

  - WQ_{Depth} = 1-inch
  - $Area_{Impervious}$ = 43,560 ft^2
  - WQv= 3,650 ft^3

- **Calculate drawdown time**

$$Time_{drawdown} = \frac{WQv}{K * Bottom\ Area}$$

  - WQv = 3,650 ft^3
  - K = 7.3 in/hr (assumed from field investigations)
  - Bottom Area = 3,073 ft^2
  - Drawdown Time = 1.95 hours
  - Stormwater Handbook guidelines < 24-hours

- **Calculate storage volume**

$$Storage = Area * (D_{Surface} + D_{Soil} * Porosity_{Soil} + D_{Stone} * Porosity_{Stone})$$

  - $D_{surface}$ = 9-inches
  - D_{soil} = 3-feet
  - D_{stone} = 1-foot
  - $Porosity_{Soil}$ = 0.3
  - $Porosity_{Stone}$ = 0.4
  - Storage Volume = 6,300 ft^3 > WQv

- **Estimate phosphorus load reduction**
  - Calculate annual volume

$$Vol = Rv * A * (\frac{P}{12}) \quad Rv = 0.05 * (0.009 * \%Imp)$$

    - *% Impervious = 90%*
    - *Catchment Area = 43,560 ft^2*
    - *Annual Rainfall = 44 in*
    - *Annual Runoff Volume = 137,359 ft^3*
  - Calculate annual TP load

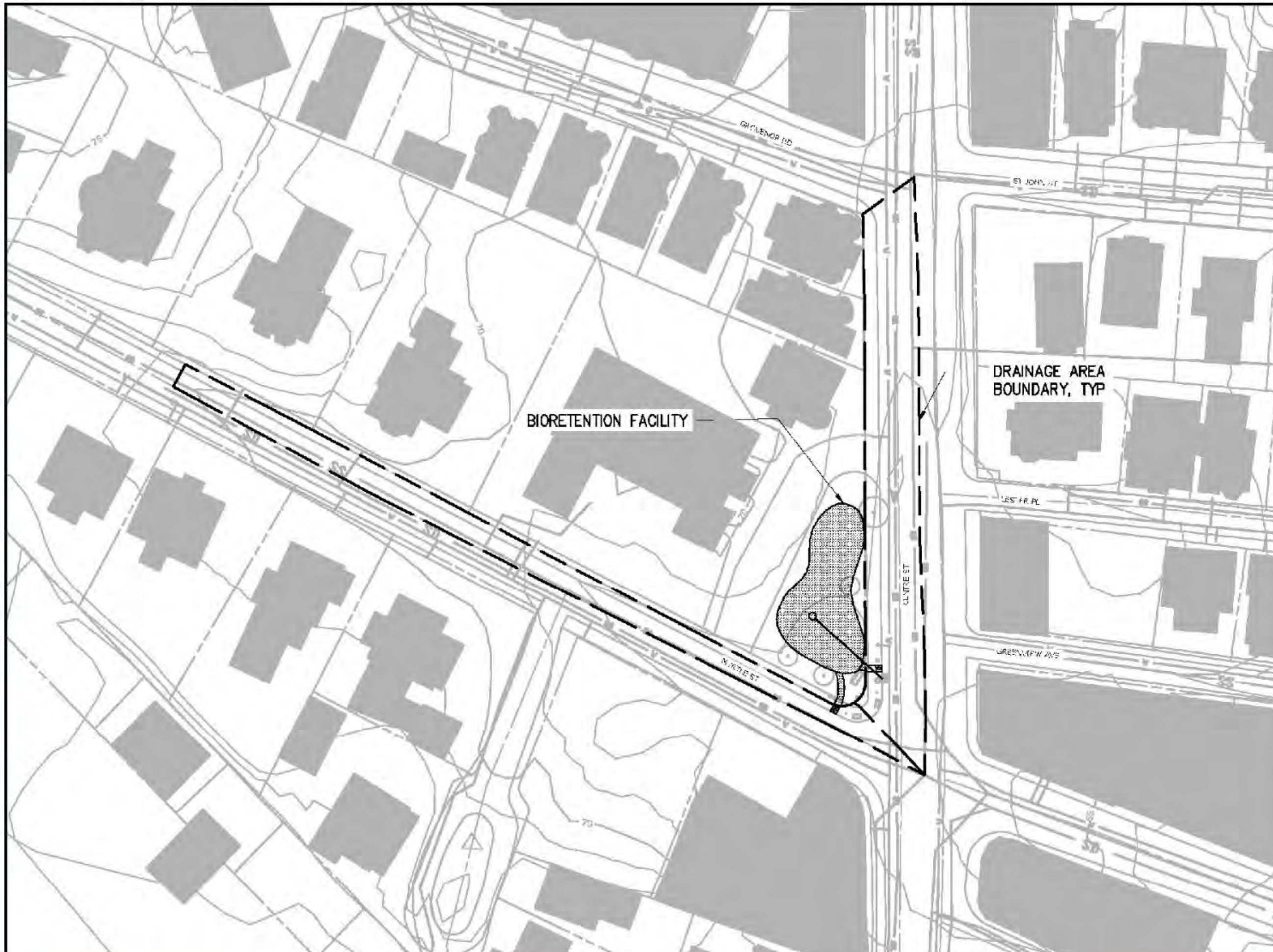
$$TP\ Load = Vol * \frac{EMC}{16018}$$

    - Influent EMC = 1.74 mg/l
    - Effluent EMC = 0.12 mg/l

Component	Ratio	Volume	Load
Inflow	100%	137,359 ft^3	14.9 lb/yr
Overflow	10%	13,736 ft^3	1.49 lb/yr
Outflow	10%	13,736 ft^3	0.10 lb/yr
Infiltration Loss	80%	109,887 ft^3	0.82 lb/yr
Total Discharge	20%	27,472 ft^3	1.60 lb/yr
		Load Reduction	**13.3 lb/yr (89%)**

First Baptist Church Bioretention

Drainage Area Plan View



LEGEND:

- EX. ROAD CENTERLINE
- EX. SIDEWALK
- EX. PROPERTY LINE
- SD — EX. STORM SEWER PIPE
- SS — EX. SANITARY SEWER PIPE
- W — EX. WATER PIPE
- 72 — EX. MINOR CONTOUR
- 75 — EX. MAJOR CONTOUR
- X — EX. FENCE
- SD — PR. STORM SEWER PIPE
- DRAINAGE AREA BOUNDARY
- PR. STORM SEWER STRUCTURE
- BUILDING
- EX. GRASSED STRIP
- PR. BMP AREA
- EX. TREE

N

Note: Landscaping, utility structures, signs, and existing storm drainage structures locations approximated from aerial overlay

60 30 0 60'

1"=60'-0"

Lower Stony Brook Green Infrastructure
First Baptist Church Bioretention

Boston Water and Sewer Commission

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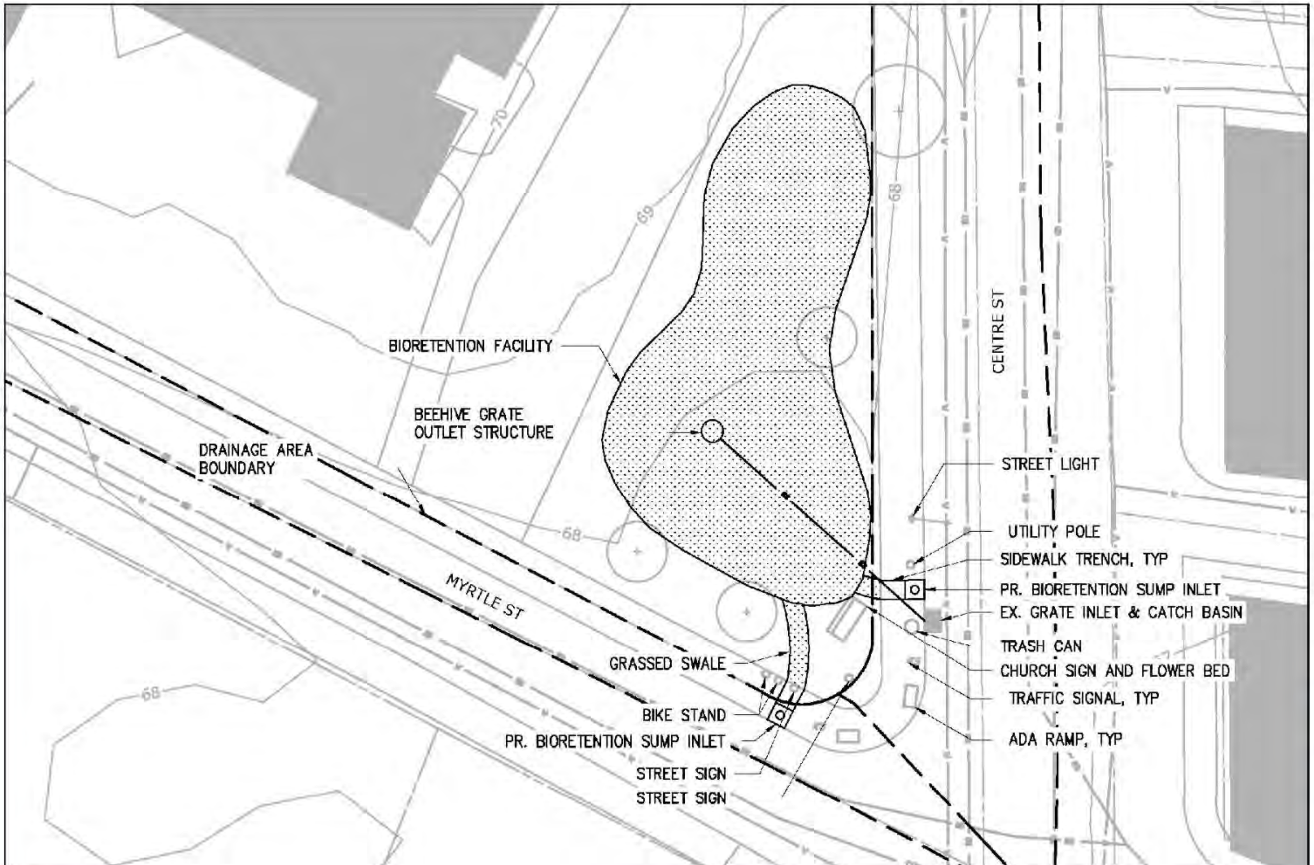
Sheet 3 of 12	08/25/17

Conceptual Design – Not for Construction

First Baptist Church Bioretention

Site Plan View



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- PR. STORM SEWER STRUCTURE
- BUILDING
- EX. GRASSED STRIP
- PR. BMP AREA
- EX. TREE

Note: Landscaping, utility structures, signs, and existing storm drainage structures locations approximated from aerial overlay

20 10 0 20'

1"=20'-0"

Lower Stony Brook Green Infrastructure
First Baptist Church Bioretention

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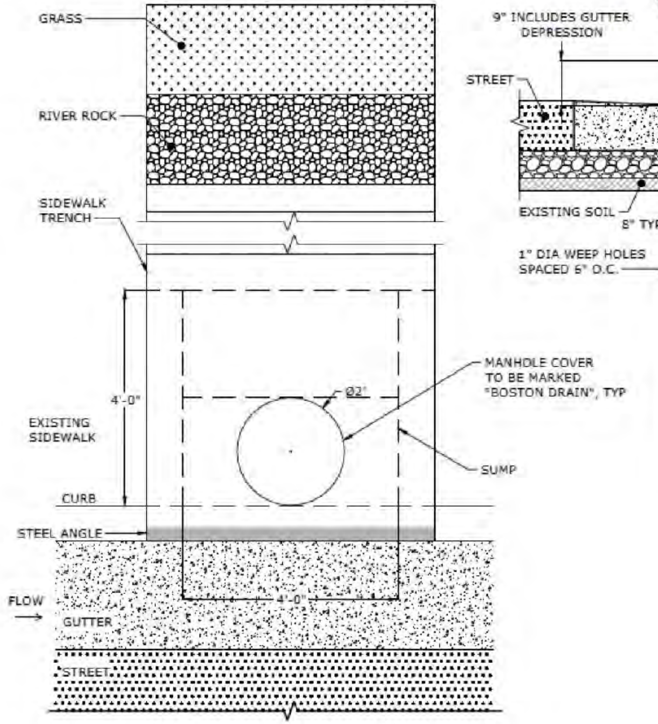
08/25/17

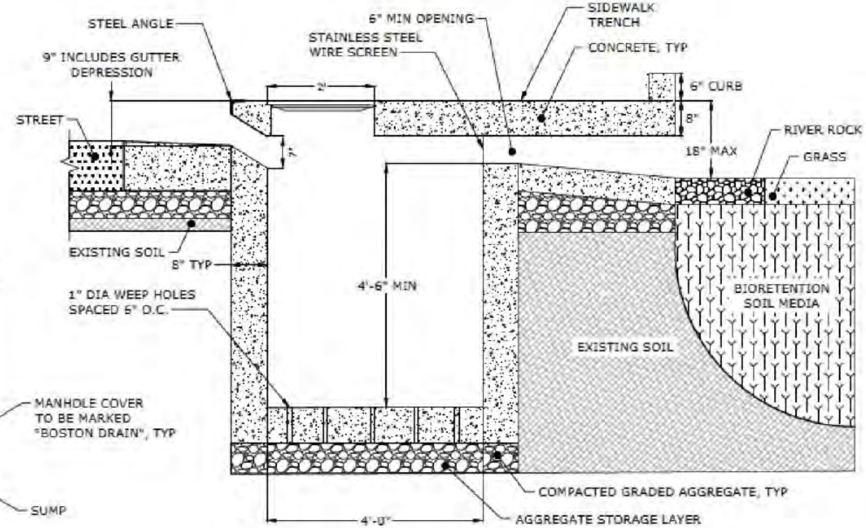
Conceptual Design – Not for Construction

First Baptist Church Bioretention

Inlet Details



Bioretention Sump Inlet
Plan View



Bioretention Sump Inlet
Section View

Lower Stony Brook Green Infrastructure
First Baptist Church Bioretention

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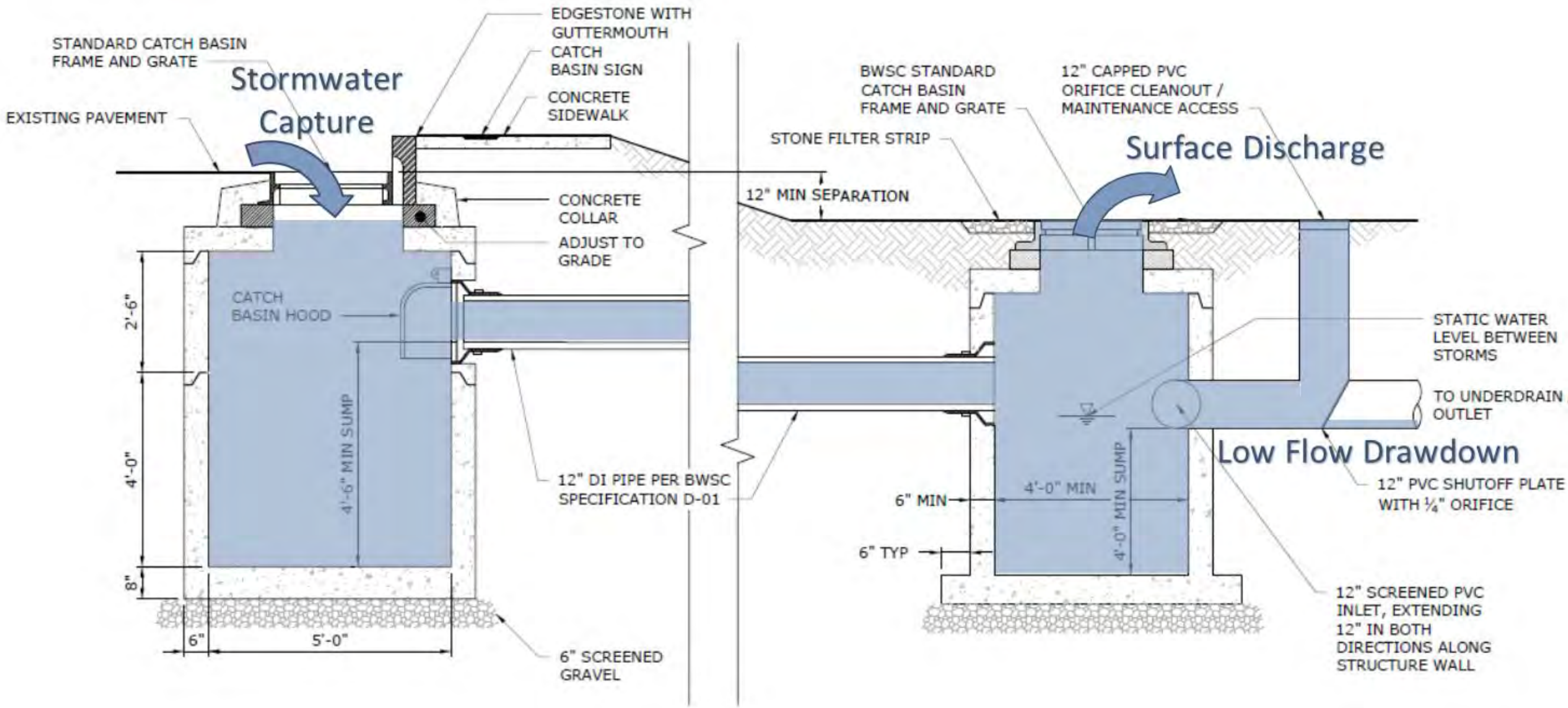
08/25/17

Conceptual Design – Not for Construction

Stormwater Diversion Design

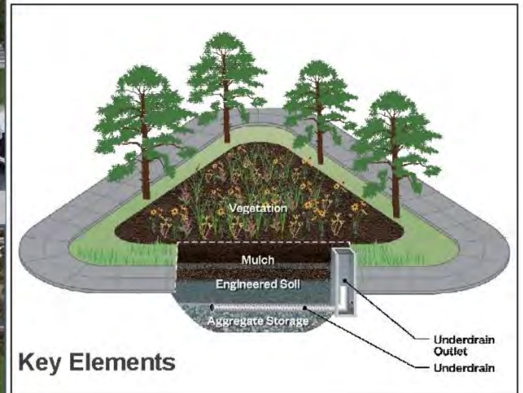


First Baptist Church Bioretention

Concept Overview

Proposed Location: View from Myrtle St.

Proposed Location: View from Centre St.



Key Elements

Design Considerations

Landscaping

Existing trees need to be identified in order to determine root zone. A sign is located in the area as well.

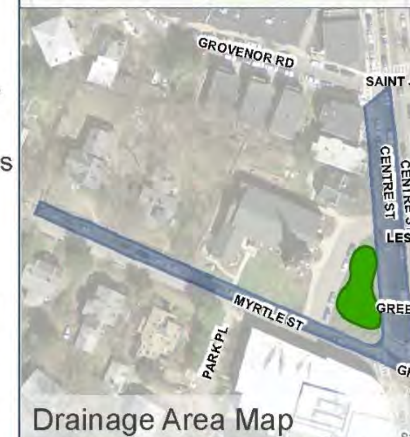
Drainage Diversion

Drainage from surrounding roads to be diverted to bioretention practice.

Subsurface Utilities

Utility markouts observed during field visits to site.

QR Code Link to 360° Tour



Drainage Area Map

Lower Stony Brook Green Infrastructure
First Baptist Church Bioretention

Existing Conditions

The proposed site currently is a large grassed area located adjacent to, and owned by, the First Baptist Church. The proposed bioretention practice footprint was sited to avoid impacting several trees and a church entrance sign which are located around the perimeter.

Proposed Green Infrastructure

A bioretention practice could be constructed in the grassed area adjacent to the church and the intersection of Centre St. and Myrtle St. Inlet routing may impact utilities within the sidewalk and may require utility relocation. This area could be a centerpiece of public demonstration due to its location next to a major thoroughfare (Centre St.), an adjacent bus stop, and bicycle lane.

Type: Bioretention
Address: Centre St. & Myrtle St.
Area Managed: 1.0 acres

Est. Construction Cost: $212,000
Est. TP Load Reduction: 13.3 lb/yr
Est. TP Reduction Cost: $16,000/lb/yr
Est. Cost/Acre: $212,000/ac

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Sheet 1 of 12 | 08/25/17

Conceptual Design – Not for Construction

First Baptist Church Bioretention

Planting Plan

	Genus and Species	Common Name
Lowland Mix	*Andropogon gerardii* *Carex formosa* *Panicum virgatum* *Polygonum hydropiper*	Big Blue Stem Handsome Sedge Switchgrass Marsh Pepper Knotweed
Upland Mix	*Asclepias tuberosa* *Eupatorium fistulosum* *Hypericum ascyron* *Monarda fistulosa*	Butterfly Milkweed Joe Pye Weed Great St. John's-wort Wild Bergamot
Shrubs & Tree	*Actaea racemose* *Amelanchiar speicies* *Clethra alnifolia* *Sambucas nigra 'Eva ppaf'*	Bugbane Serviceberry Sweet Pepperbush Black lace Elderberry

Lower Stony Brook Green Infrastructure
First Baptist Church Bioretention

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Sheet 7 of 12 | 08/25/17

Conceptual Design – Not for Construction

First Baptist Church Bioretention

Construction and Material Specifications: Key Points

Materials

Aggregates
- Shall be double washed and free of fines and foreign material.
- Shall have no more than 0.5% wash loss per AASHTO T-11 wash loss test.
- Shall have a minimum installed porosity of 0.4.

Bioretention Soil Media
- Shall be a homogeneous mix consisting of:
  - Sand: 85-88%
  - Silt and Fines: 8-12%
  - Organic Content: 3-5%
  - Clay Fraction: <2%
- Shall have a phosphorus content (Mehlich-3) of 15 – 60 mg/kg P.
- Shall have a minimum installed infiltration rate of 2 in/hr.

Underdrains
- Shall be constructed of SDR 35 smooth wall PVC pipe.
- The minimum pipe diameter shall be 12 inches.
- A minimum of 4 rows of 3/8 inch diameter perforations shall be provided around the diameter of the underdrain pipe and the perforations shall be placed 6 inches on center.
- Filter socks or geotextile fabric shall not be used to wrap the underdrain pipes.
- Cleanouts shall be provided at the end of all underdrain lines.

Vegetation
- Plant size should be no less than 2.5" diameter at breast height (DBH) for trees, 3-gallon for shrubs, and 1-quart for herbaceous plants.

Mulch (if needed)
- Shall be placed in a uniform 3" layer above the bioretention soil media.
- Shall be triple shredded hardwood mulch, free of weed seeds, soil, roots, and other material that is not bole or branch wood or bark. No pine needles, pine bark, or wood chips shall be used.
- Shall be at least 6 months old.

River Rock
- Shall be double washed and free of fines and foreign material.
- Shall be 1-3 inches, a neutral shade of white or brown, and free from jagged edges.

Execution

- The Contractor shall protect bioretention surfaces, excavations, and materials storage areas from severe weather conditions and contamination by dust, dirt, mud, cement, or other fine-grained material or sediment.
- Bioretention areas shall not be used as sediment and erosion control facilities.
- The method of excavation shall minimize compaction and surface sealing of the bottom of the bioswale.
- Prior to installation of the stone base, the bottom of the excavation shall be scarified to a minimum depth of 6 inches to alleviate any compaction of the facility bottom. The soil shall not be saturated at the time of rototilling and the stone base shall be placed after the soil has been tilled and before rain is forecast.
- No equipment shall be used to compact any portion of the bioretention installation, except hand tools to encourage natural settling.
- No equipment shall be driven over/in the bioretention area.
- Soil analysis shall be submitted to the Engineer for approval prior to placement in the bioretention area.
- Soil media shall be installed in lifts of no more than 12 inches. Water lifts lightly with a supply of clean water to encourage natural settlement. The surface of each lift shall be scarified by raking immediately prior to placing the next lift.
- After installation, the soil media shall be tested with a double ring infiltrometer (ASTM D3385) or Engineer approved alternative testing methodology to determine an actual drainage rate. The permeability should fall between 2 and 6 inches per hour.
- No fertilizer shall be added unless directed by the Engineer.

See separate specification documents for additional details

First Baptist Church Bioretention

Maintenance Requirements

Litter and Debris

Issue: Litter and debris, such as fallen leaves or branches, may be dropped, blown, or carried by runoff into the bioretention area. Litter and debris are aesthetic nuisances and can affect plant growth and drainage performance; they also have potential to add phosphorus if not removed.
Task: All litter and debris should be removed from the inlets and bioretention by hand or with hand tools and disposed of off-site as trash or yard waste. Be careful not to trample bioretention plants during removal.

Blocked Inlet

Issue: Sediment, trash, or debris can collect within or immediately downstream of the inlet. Even a small sediment deposit can prevent runoff from entering the bioretention area.
Task: The inlets should be inspected monthly and after storm events with more than an inch of rainfall. Any sediment, litter, or debris collected at the inlet should be removed with a hand shovel and disposed of.

Erosion

Issue: The flow of water within the bioretention area could form small gullies or bare spots, especially around inlets and sloped areas.
Task: For small areas, less than 2" deep and 6" wide, use a rake to smooth the area and recover with mulch/river stone. For deeper or larger areas, add bioretention soil to make the surface even, smooth the area with a rake, and add mulch/river stone to the surface. If flow continues to cut into these areas, cover the surface of that area with 1" diameter stone.

Surface Clogging

Issue: Over time, the bioretention area may become clogged by sediment, leaf debris, and surface compaction, keeping standing water on the surface for too long. Standing water more than 48 hours after a storm suggests significant clogging.
Task: Using a hand rake, work around the plants to remove and dispose of the surface mulch/river stone and top 1-2" of soil below the mulch/river stone. Replace the removed soil with bioretention soil meeting construction specifications and cover with mulch/river stone. This maintenance task should be done annually in the fall or if the bioretention soil is draining poorly.

Snow Removal and Spring Restoration

Issue: Piling snow on the bioretention surface may concentrate salts, damage vegetation, and compact bioretention soils.
Task: Minimize snow stockpiles over bioretention areas where possible. Bioretention should be inspected and maintained after each snow melt. Required maintenance after snow melt is likely to include removal of litter and debris, and removal or pruning of severely damaged plants. In the spring, test the bioretention for surface clogging and plant health and perform corrective maintenance as needed.

Weed Growth

Issue: Weeds may grow within the bioretention area, impacting aesthetics and crowding desirable vegetation.
Task: Consult planting plan and remove plants by hand that don't appear within the plan. Dispose of plant material as yard waste. Fill any holes within the bioretention soil and cover exposed soil areas with mulch/river stone.

Vegetation Health

Issue: Bioretention plants may die or become damaged over time due to a variety of factors including foot traffic, constantly saturated soils, drought, snow, or contaminated stormwater. Healthy bioretention vegetation is important to maximize pollutant removal, infiltration rates, and aesthetics.
Task: Because the bioretention is a water quality feature, fertilizer and pesticides should not be used. Dead plants should be removed and replaced as soon as possible with a plant of the same species and similar size. When replacing plants, use bioretention soil meeting construction specifications to fill any holes. New plants may require watering during extended dry periods.

Document Inspection | Maintain for Performance | Maintain for Aesthetics

First Baptist Church Bioretention

Maintenance Checklist

Date: ____________ Site: ______________________________

Inspector: ____________________

24-hr Rainfall: _______ inches

Inspection

Inlet(s) clogged? ☐ Yes ☐ No

- If yes, specify which inlets are clogged: _________________

Surface Water? ☐ None ☐ Ponded (____ Inches)

- If surface is ponded, re-inspect 24-48 hours after rainfall

Outlet structure clogged? ☐ Yes ☐ No

Underdrain Riser Caps Missing? ☐ Yes ☐ No

Noticeable Erosion? ☐ Yes ☐ No

Noticeable Sediment Deposition/Surface Clogging? ☐ Yes ☐ No

Plant Death? ☐ Yes ☐ No

Plant Overgrowth? ☐ Yes ☐ No

Trash/Debris Present? ☐ Yes ☐ No

Weeds or invasive plants present? ☐ Yes ☐ No

Date: ____________ Site: ______________________________

Maintenance Coordinator: ____________________

Maintenance

Note: Only check the items where maintenance was necessary and was completed. If needed maintenance was not completed, indicate the expected completion date.

Weeds Removed: ☐

Dead Plants Replaced: ☐

Mulch Replaced: ☐

Plants Pruned: ☐

Trash Removed: ☐

Outlet Structure Cleared: ☐

Sump Inlet Structure Cleared: ☐

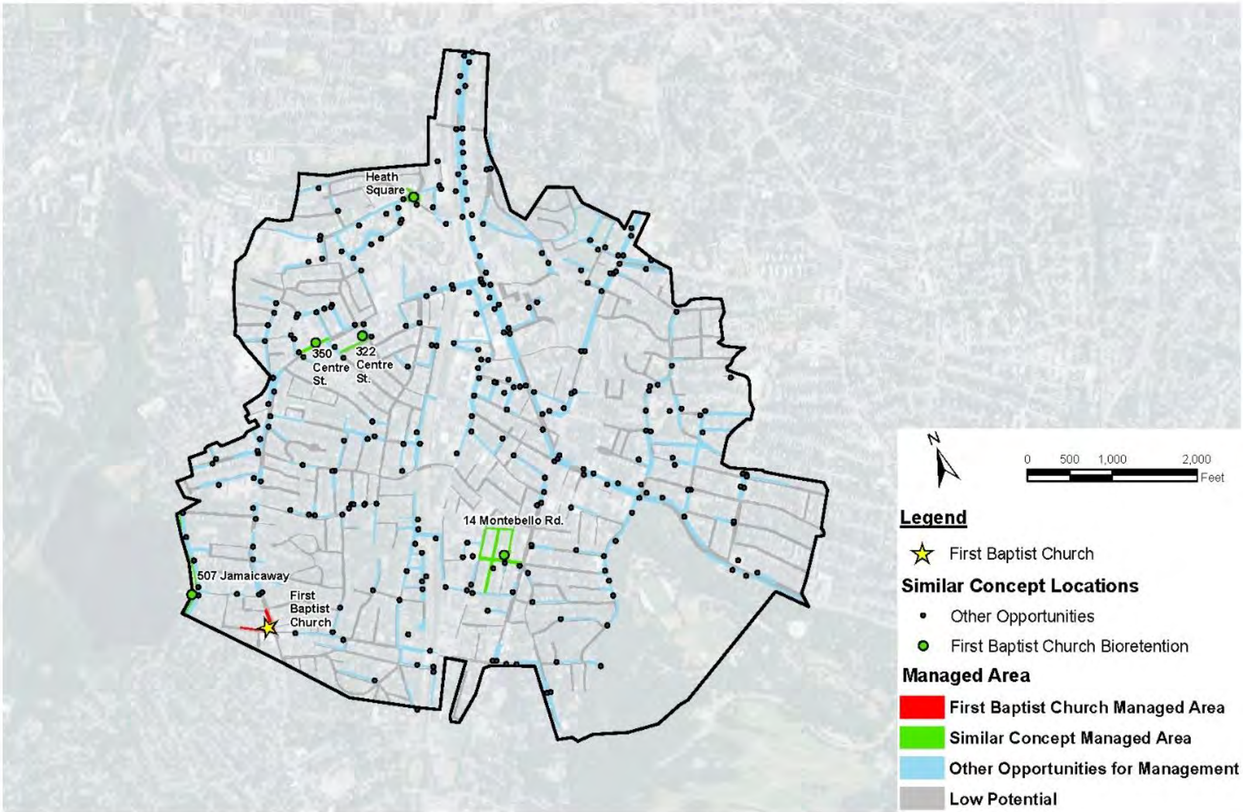
Soil Surface Replaced: ☐

Eroded Areas Repaired: ☐

Gravel Splash Pad Repaired: ☐

First Baptist Church Bioretention

Similar Concept Locations



Similar Concept Locations

5 other sites were identified with characteristics similar to the First Baptist Church Bioretention.

Summary of First Baptist Church Bioretention Similar Concepts

Number of Sites: 5

Area: 3.2 acres

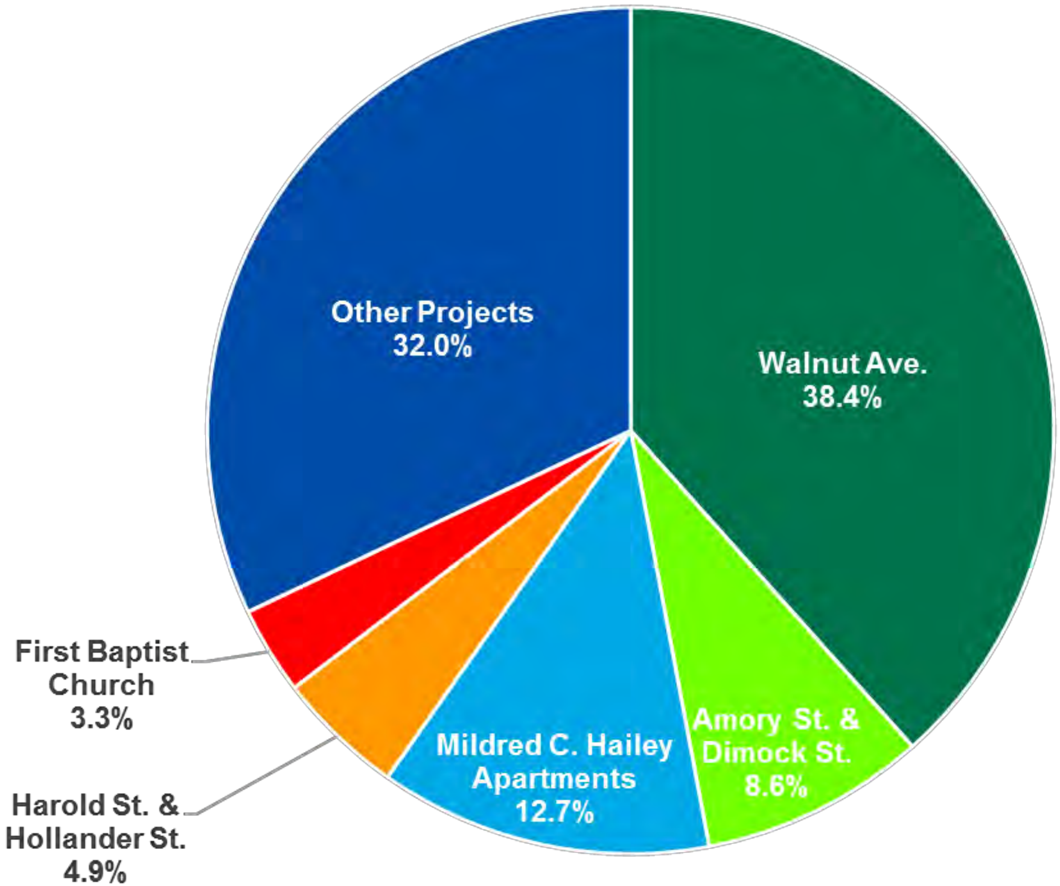
% of Remaining DA: 3.3%

Characteristics:

- High public visibility off-site locations including churches and active parks & schools

Similar Opportunities

Site Name	Number of Sites	Area (Acres)	% of Remaining DA
Amory St.	29	8.1	8.6%
Harold St.	9	4.6	4.9%
Walnut Ave.	205	36.3	38.4%
Mildred C. Hailey	41	12.0	12.7%
First Baptist	5	3.2	3.3%
Other Projects	143	30.2	32.0%

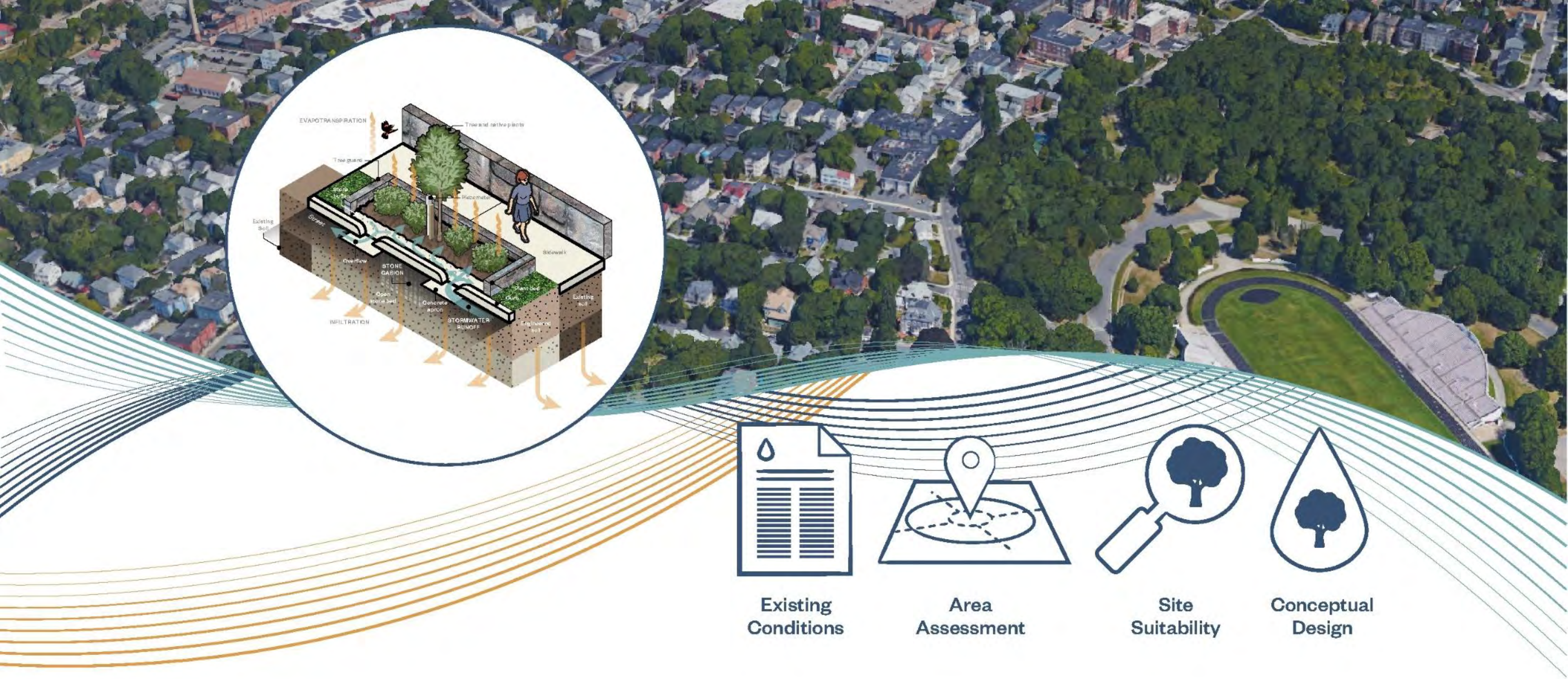


Conclusions

Value in area-wide approach

Simple, low-cost screening data

Mix of design configurations



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