

# Green Infrastructure and Flood Resiliency-Land Use Management as an Adaptation Strategy in the Built Environment: Exeter Resilience Project

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**WATERSTONE  
ENGINEERING**  
INNOVATIVE STORMWATER MANAGEMENT

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## OVERVIEW

- ✓ Innovative Communication Methods
- ✓ Climate Adaptation Policy
- ✓ Resilient Stormwater Management



# Green Infrastructure and Climate Adaptation

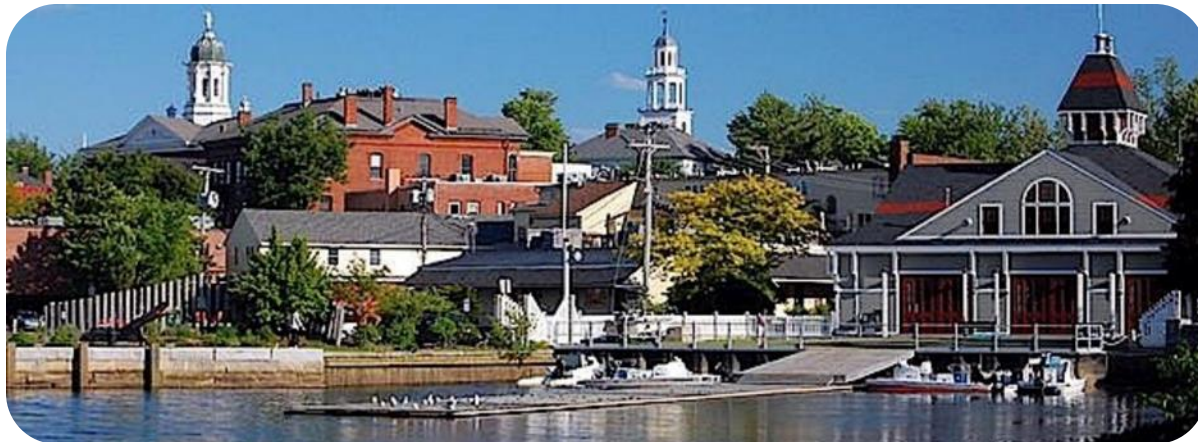
1. New Hampshire coastal communities have experienced rising populations resulting in an increase in impervious surfaces, stormwater runoff, and associated flooding.
2. At the same time, communities are faced with a changing climate including extreme rainfall events and sea-level rise.
3. Green infrastructure is an important form of climate adaptation which can improve water quality and avoid stormwater related flood damages.
4. The Exeter Resilience project conducted a cost impact analysis to evaluate the potential for flood damage avoidance with implementation of green infrastructure.
5. The use of green infrastructure supports other economic and quality of life benefits such as creation of attractive public spaces, and landscaping that supports walkable communities.





# REGIONAL CONTEXT

- In 2009, NHDES concluded that many sub-estuaries in the Great Bay Estuary were impaired by nitrogen, and the Great Bay was placed on the Clean Water Act (CWA) Sec. 303(d) list of impaired and threatened waters (NHDES, 2009).
- New and revised discharge permits in the watershed are now subject to additional nitrogen requirements including the National Pollutant Discharge Elimination System (NPDES) permits for wastewater treatment facilities, and Municipal Separate Storm Sewer Discharge (MS4) permits for stormwater.
- 2017 NH Small MS4 issued, effective in 2018, includes significant new elements such as a focus on illicit discharge detection and elimination, and nutrient management through BMP retrofits.



# Innovative Communications

## Climate Change – Adaptation - Resilience

### Ensuring a Successful Initiative

What is unique about the watershed or area of interest?

What resources are important, prominent, and tell the story?

What is the place-based connection?

Who are the key stakeholders to engage?

What is the community benefit?

**Identify the Audience**

**Maximize Exposure**

**Develop Impactful Message(s)**

**Permanent/Repeatable**

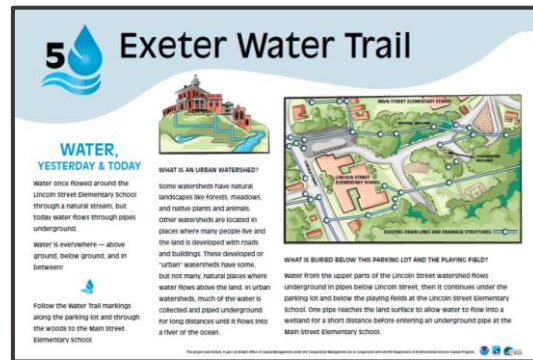
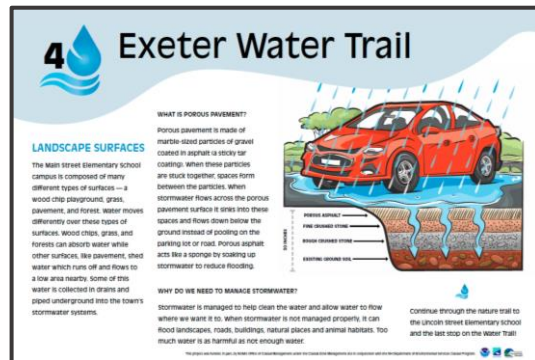
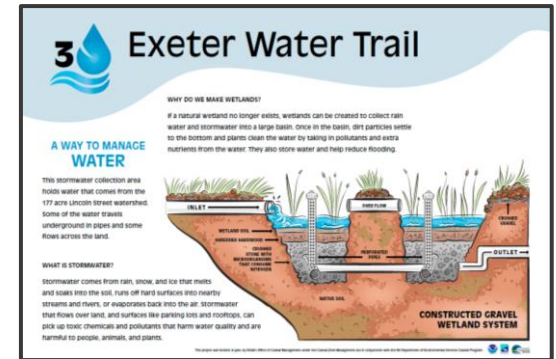
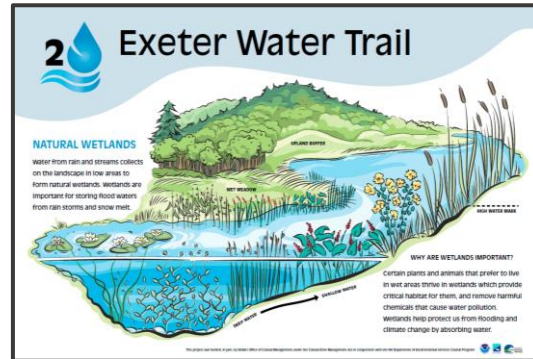
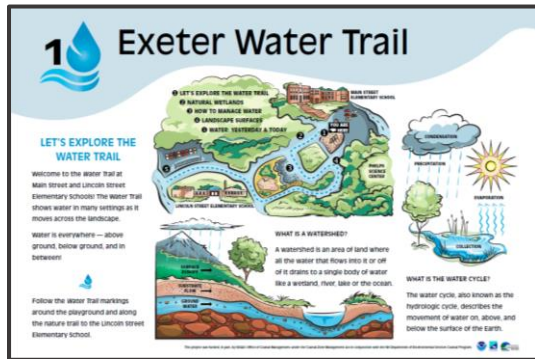
**Installation or Event**



# Innovative Communications

Educational installation at Main Street and Lincoln Street Elementary Schools

Reaches students Kindergarten through grade 5, yearly reinforcement, workbooks



*Water Cycle, Flooding*

*Surface interactions*

*Natural Wetlands*

*Constructed Wetlands*


*Porous Pavement*

*Stormwater Management*


# Innovative Communications

Educational installation at Swasey Parkway, Exeter

Highly Visited Area – Permanent Messaging – Expand with Future Installations



## The Place Of Two Rivers



**THE EXETER-SQUAMSCOTT RIVER**

The Exeter River is a 128-square mile (81,726 acre) freshwater watershed which drains all, or portions of, 12 towns in the seacoast area of New Hampshire. The Squamscott River is a tidal tributary of the Great Bay Estuary which drains to the Atlantic Ocean. The Exeter River and the Squamscott River meet

In downtown Exeter, just above Swasey Parkway near the String Bridge.

**WHAT TYPES OF FISH AND WATERFOWL LIVE HERE?**

In 2016, the Great Dam on the Exeter River was removed, restoring 21 miles of habitat for anadromous fish, which are fish that live in salt water but travel each year up the Exeter River to spawn. Species of anadromous fish include Alewife and Blueback Herring. The Exeter-Squamscott River provides habitat for over 17 fish species including Brook Trout, Small and Large Mouth Bass, Yellow Perch, Smelt, and Chain Pickerel.

A variety of shorebirds feed on animals and fish that live in the saltmarshes including the Mallard Duck, Black Duck, Blue-Wing Teal Duck, Green-Wing Teal Duck, Osprey, Bald Eagle, Great Blue Heron,

Kingfisher, Egret, Sand Piper, Killdeer, Cormorant, and many kinds of hawks, owls, and seagulls.


**WHAT IS THE IMPORTANCE OF A TIDAL SALTMARSH?**

Saltmarsh is abundant along the shores of the Squamscott River. Flooded by the tidal waters of the Great Bay Estuary, it is a complex ecosystem containing a variety of plants and animals. A saltmarsh has low marsh grass which is submerged at high tide, and high marsh grass along its upper fringe. Saltmarsh plays an important role in protecting roads, buildings and homes by storing tidal floodwater during highest annual tides and during storm events. However, because of its proximity to development, saltmarsh is threatened by pollution running off of the land.

**WHAT IS SEA-LEVEL RISE AND HOW MAY IT EFFECT THE RIVERS AND THE ESTUARY?**

Sea levels adjust locally and globally to changes in the Earth's environment. Sea-level rise is caused by several factors, including the melting of glaciers and sea ice, and an increase of ocean temperatures. Research in N.H. reports that sea levels may rise up to several feet, or more, by 2100 projections range from a low of 1.7 feet to a high of 6.6 feet. In a natural environment, saltmarsh is able to move inland with rising sea levels, but in a "built" environment where obstacles such as roads and buildings prevent this process from happening, an increase in sea level could transform saltmarsh into mudflats or open water.

This project was funded, in part, by NOAA's Office of Coastal Management under the Coastal Zone Management Act in conjunction with the NH Department of Environmental Services Coastal Program.



*Exeter-Squamscott Rivers*

*Watershed Facts*

*Importance of Saltmarsh*

*Riverine Ecosystems*

*Impacts of Sea-level Rise*





## EXETER STORMWATER RESILIENCE LINCOLN STREET PHASE II PROJECT



### Project Summary and Goals

1. Achieve municipal capacity building around planning for climate change and flood events.
2. Implement public outreach and communication to build support for and understanding of adaptation planning including economic considerations.
3. Advance green infrastructure and other effective means of adaptation implementation for flood damage avoidance and water quality improvements.



Resilient Green Infrastructure

Climate Adaptation Policy

Innovative Messaging

### Watershed Assessment, Flood Analysis, and Adaptation with Green Infrastructure

1. The total annual nitrogen load from the entire Lincoln Street watershed is 1,265 pounds.
2. Installation of BMPs 1, 2, 3, 4, 5, 7, 8 and 9 is expected to reduce this load by 691 pounds annually, a 76% reduction.
3. The BMP unit cost performance ranged from \$498 - \$5,080 per pound of nitrogen in comparison with \$1,200 for the new wastewater facility.
4. Flood reductions are estimated 10-15% for 10-year storm and 50% for 100-year storm.
5. These activities address the NH Small MS4 General Permit nitrogen source identification optimization and priorities.



## EXETER STORMWATER RESILIENCE STORMWATER RETROFIT OPPORTUNITIES



Retrofit Opportunity

### Resilient Green Infrastructure

1. New Hampshire coastal communities have experienced rising populations resulting in an increase in development in nitrogen pollution and flooding from impervious surfaces.
2. Green infrastructure is an effective method to both improve water quality and avoid stormwater related flood damages.
3. The use of green infrastructure supports other economic and quality of life benefits such as creation of attractive public spaces, and landscaping that supports walkable communities.
4. This project developed construction-ready designs for inclusion in future capital improvement projects in Exeter's largest subwatershed.



### Performance of Stormwater Retrofits

1. The total annual nitrogen load from the 179-acre Lincoln Street watershed is 1,265 pounds.
2. The project Exeter Resilience project identified green infrastructure retrofit opportunities for 14 stormwater installations expected to reduce nitrogen load by 691 pounds annually, a 76% reduction.
3. Retrofit unit costs averaged \$1,000 and ranged from \$498 - \$5,080 per pound of nitrogen in comparison with \$1,200 for the new wastewater facility.
4. The estimated cost to implement green infrastructure retrofits at these 14 locations is \$689,000.



Support for this project was provided by the National Oceanic and Atmospheric Administration Office for Coastal Management pursuant to the Coastal Zone Management Act of 1972 in conjunction with the NH Department of Environmental Services Coastal Program, as a FY2018 Project of Special Merit Grant, Award # NA18OCS4180157.

## EXETER STORMWATER RESILIENCE ECONOMIC BENEFITS OF FLOOD AVOIDANCE



Photo: Flooding at Exeter Town Landing March 2018 Nor'easter

### Green Infrastructure and Climate Adaptation

1. New Hampshire coastal communities have experienced rising populations resulting in an increase in impervious surfaces, stormwater runoff, and associated flooding.
2. At the same time, communities are faced with a changing climate including extreme rainfall events and sea-level rise.
3. Green infrastructure is an important form of climate adaptation which can have significant economic benefits for flood damage avoidance.
4. The Exeter Resilience project conducted a cost impact analysis to evaluate the potential for flood damage avoidance with implementation of green infrastructure.

### Green Infrastructure Flood Reduction



### Flood Damage Avoidance

1. The cost impact analysis graphic at right shows the potential for flood damage avoidance with implementation of green infrastructure.
2. The estimated flood loss from a current 10-year storm is \$1.1 million or \$3.43 million with green infrastructure, a 76% reduction. The total estimated cost to implement green infrastructure 14 sites is \$689,000. The greatest benefit is from small sized Best Management Practices that provide water quality and flood protection for a 0.5" storm, the most frequent annual rainfall event.



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## EXETER STORMWATER RESILIENCE FLOOD REDUCTION FROM GREEN INFRASTRUCTURE



### Flood Reduction from Green Infrastructure

1. New Hampshire coastal communities have experienced rising populations resulting in an increase in development in nitrogen pollution and flooding from increased impervious surfaces and increased stormwater runoff.
2. At the same time, communities are faced with a changing climate, including increased extreme rainfall events and sea-level rise.
3. Green infrastructure is an important method to both improve water quality and avoid flood related damages.
4. Flood reductions from green infrastructure implementation are estimated at 60% for the current 10-year storm and 50% for the projected year 2040 storm event with 9.21 feet of storm surge.
5. The figure below shows the modeled flood impact with and without green infrastructure for the projected year 2040 rainfall and storm conditions with and without water quality volume best management practices.



Support for this project was provided by the National Oceanic and Atmospheric Administration Office for Coastal Management pursuant to the Coastal Zone Management Act of 1972 in conjunction with the NH Department of Environmental Services Coastal Program, as a FY2018 Project of Special Merit Grant, Award # NA18OCS4180157.

## EXETER STORMWATER RESILIENCE LINCOLN STREET PHASE II PROJECT



### Project Summary and Goals

1. Achieve municipal capacity building around planning for climate change and flood events.
2. Implement public outreach and communication to build support for and understanding of adaptation planning including economic considerations.
3. Advance green infrastructure and other effective means of adaptation implementation for flood damage avoidance and water quality improvements.



Resilient Green Infrastructure

Climate Adaptation Policy

Innovative Messaging

### Exeter Climate Adaptation Policy (draft)

The purpose of a **Climate Adaptation Policy (CAP)** is to guide local decision making and investment in climate adaptation and implementation actions. The CAP is supported by statements in the Vision section of the Master Plan (draft 2017) which states that local government will protect the welfare of residents and continue to provide support that helps prepare for a changing climate. Elsewhere in the Master Plan, responses to changes in climate and its impacts are detailed in the Support, Steward and Prepare sections as well as in the Action Agenda.

**VISION FOR THE FUTURE** "Proactive strategies are identified and implemented that address the impacts of climate change to create a more sustainable and resilient community."

#### CLIMATE ADAPTATION POLICY PRINCIPLES

Ensure the community is better prepared to protect the security, health and safety of its citizens.

Protect natural resources from the impacts of flooding from sea-level rise and storm events.

Provide for a stable and viable economic future.

Minimize the future costs of infrastructure replacement and maintenance.

Support installations of green infrastructure, renewable energy systems and electric vehicle charging stations.

#### IMPLEMENTATION ACTIONS - FOCUS AREAS

- Municipal Policy and Actions
- Management and Investment
- Environment-Natural Resources
- Regulatory and Land Use Planning
- Community-Based



# Climate Adaptation Policy *(draft)*

## Vision Statement

*Proactive strategies are identified and implemented that address the impacts of coastal hazards and climate change to create a more sustainable and resilient community.*

## Purpose

Unified vision, goals, and actions

Guide planning, investment, management, regulations

Support for grants and other funding sources

Living document, informed by best available science/information



# Climate Adaptation Policy *(draft)*

## Goals

Ensure the community is better prepared to protect the security, health and safety of its citizens.

Protect natural resources from the impacts of flooding from sea-level rise and storm events.

Provide for a stable and viable economic future.

Minimize the future costs of infrastructure replacement and maintenance.

Support installations of renewable energy systems and electric vehicle charging stations.

***Municipal Policy and Actions***

***Management and Investment***

***Environment-Natural Resources***

***Regulatory and Land Use Planning***

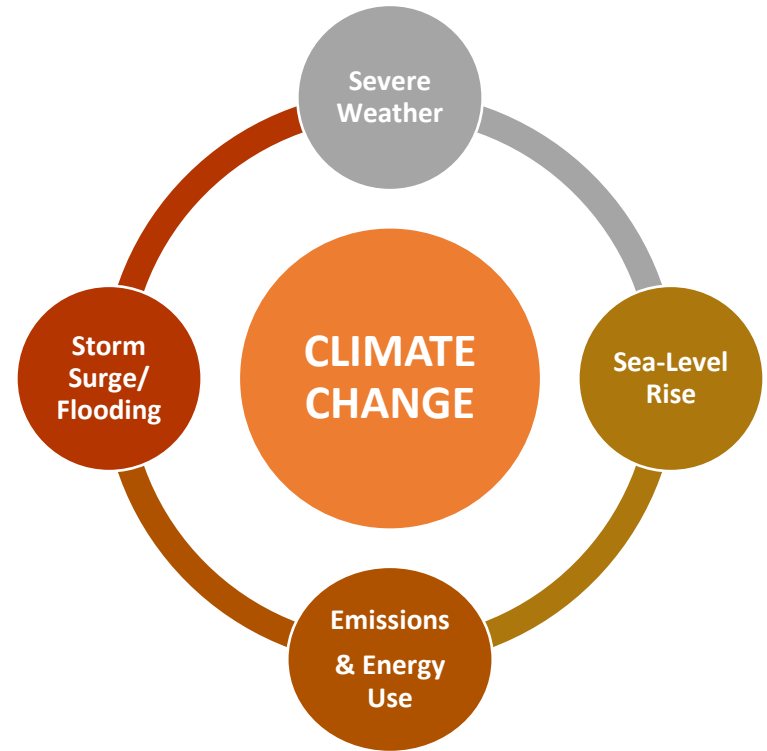
***Community-Based***



# Climate Adaptation Policy *(draft)*

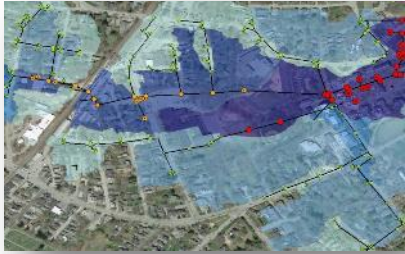
## Recipe for Process/Methods

- ✓ Supported by Master Plan
- ✓ Audit of Zoning and Regulations
- ✓ Community Initiatives and Activities
- ✓ Capital Improvement/Infrastructure Management Plans
- ✓ Coordination with elected officials, staff, boards, commissions
- ✓ Exeter “Climate Proclamation” (to uphold principles of Paris Climate Accord)





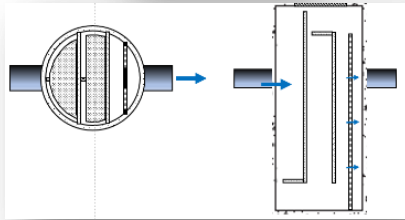
# Tasks



1. Watershed Modeling



2. Identify Green Infrastructure Retrofit Locations



3. Project Design



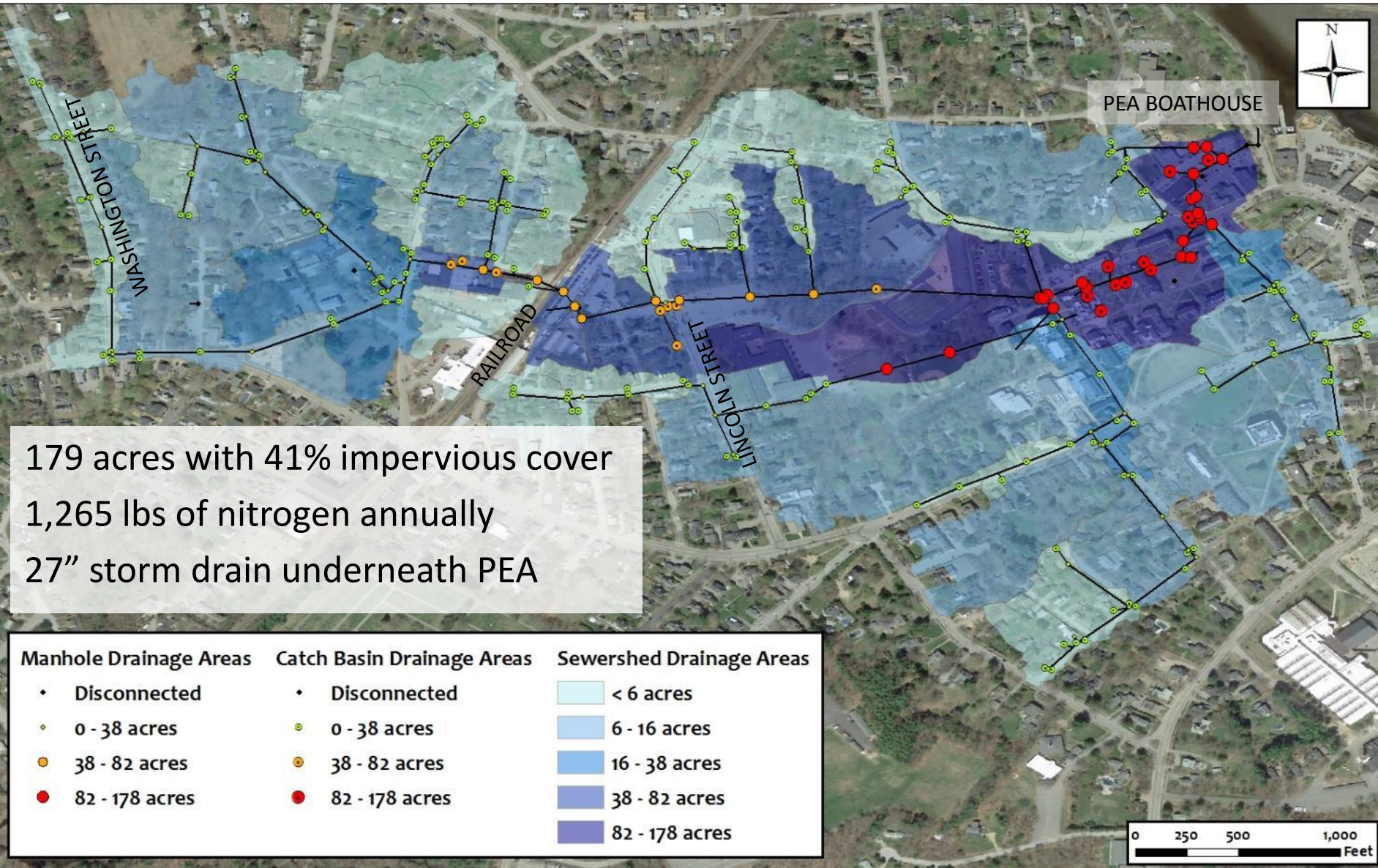
4. Nutrient and Flooding Reduction



5. HAZUS Damage Costing

# Watershed Characteristics

ADD REGIONAL MAP  
ANIMATION





# STORMWATER RETROFIT OPPORTUNITIES



Retrofit Opportunity

Rain Garden



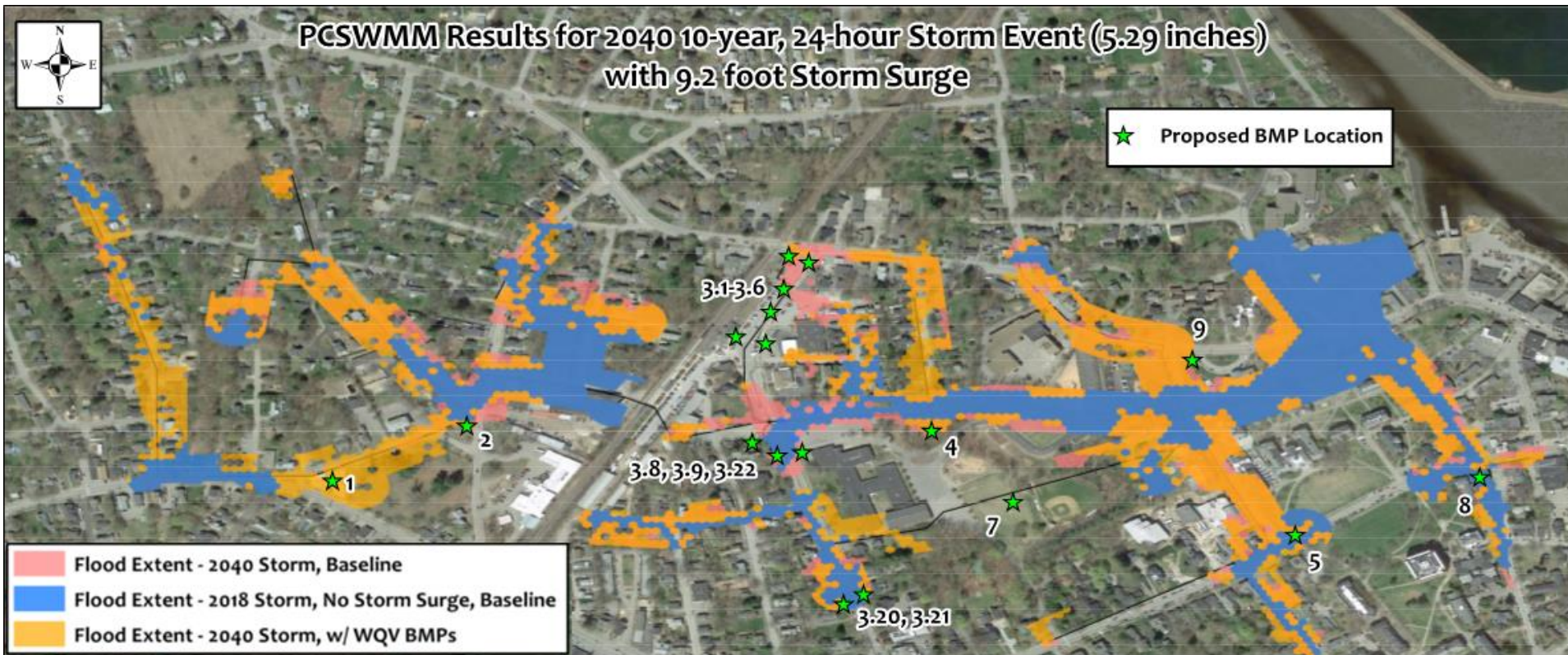
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Tree Filter





# FLOOD REDUCTION FROM GREEN INFRASTRUCTURE



1. Flood reductions as runoff volume from green infrastructure implementation are estimated at 60% for the current 10-year storm and 50% for the projected year 2040 storm event with 9.21 feet of storm surge.
2. The figure shows the modeled flood impact with and without green infrastructure for the projected year 2040 rainfall and storm conditions with and without water quality volume best management practices

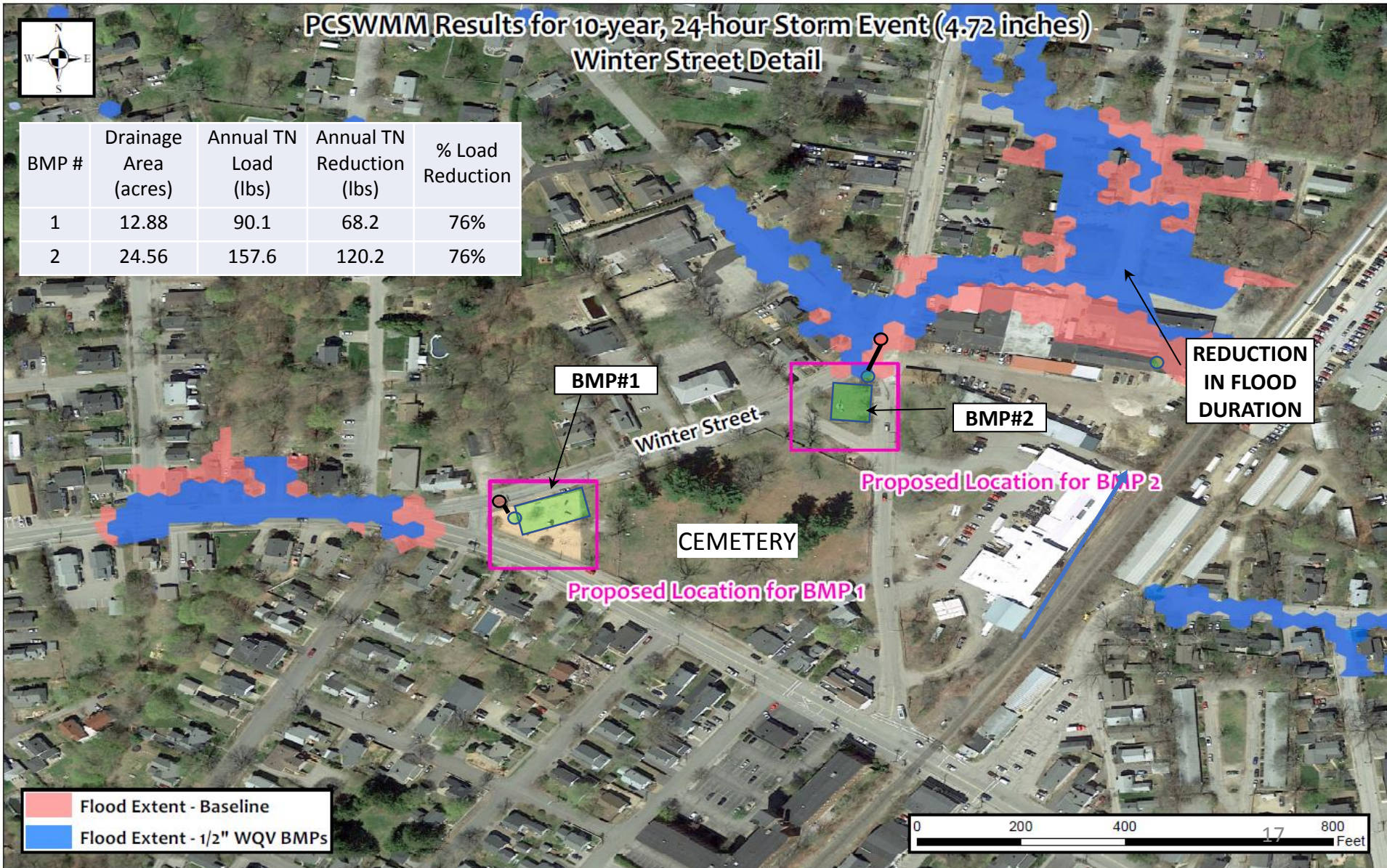


# FLOODING BEFORE AND AFTER– WINTER & RAILROAD



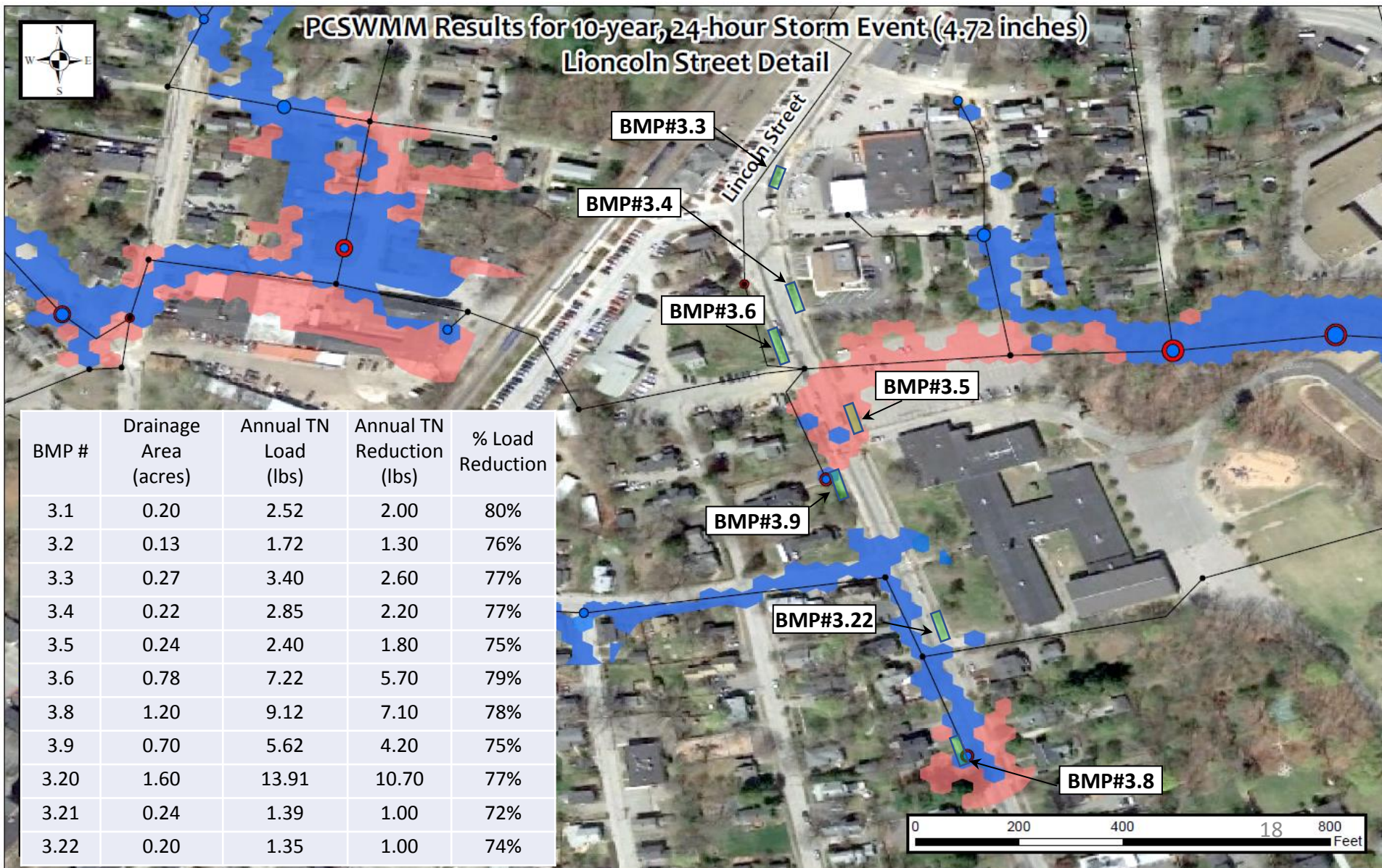
PCSWMM Results for 10-year, 24-hour Storm Event (4.72 inches)  
Winter Street Detail

BMP #	Drainage Area (acres)	Annual TN Load (lbs)	Annual TN Reduction (lbs)	% Load Reduction
1	12.88	90.1	68.2	76%
2	24.56	157.6	120.2	76%



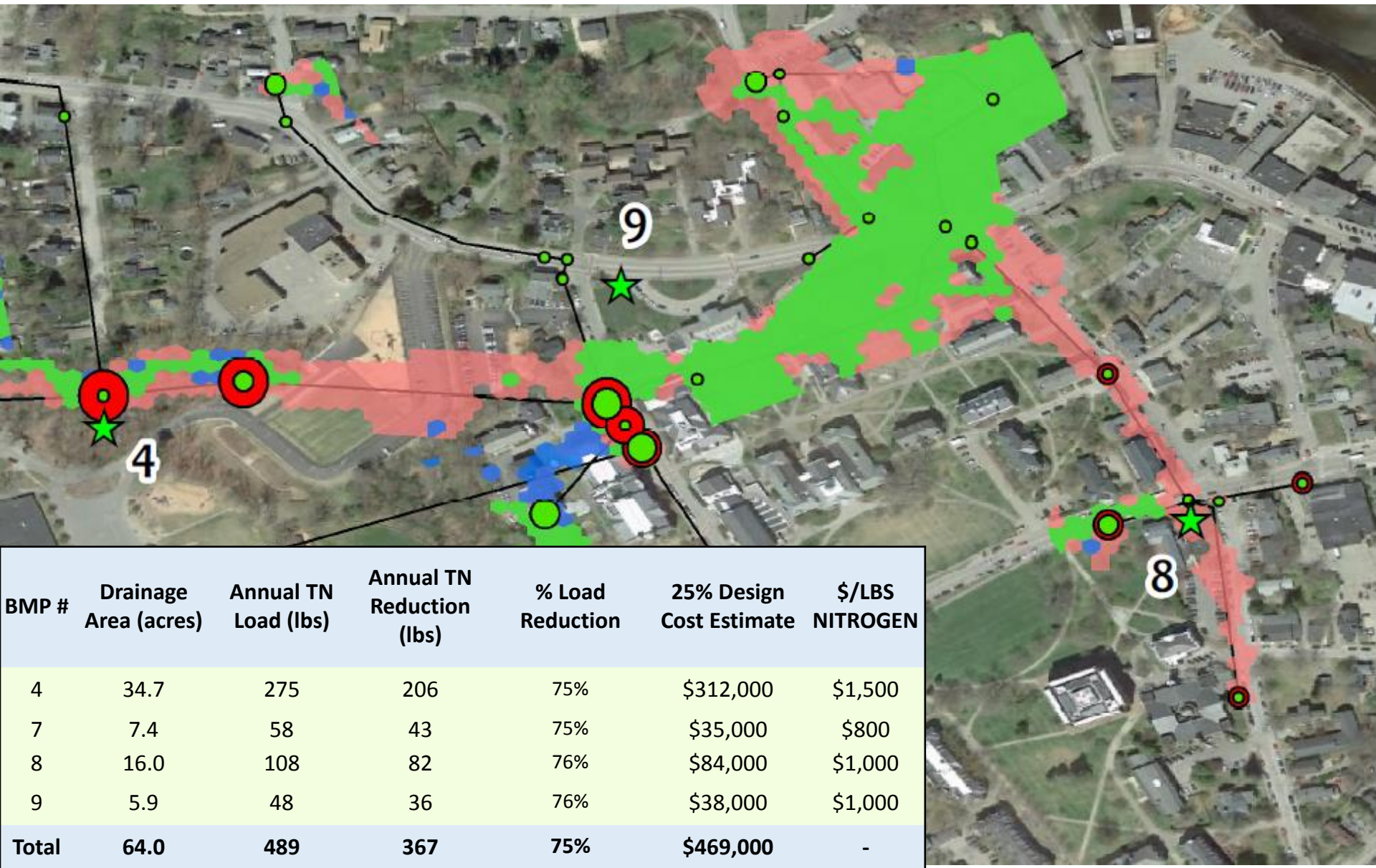


# FLOODING BEFORE AND AFTER– RAILROAD AND LINCOLN ST





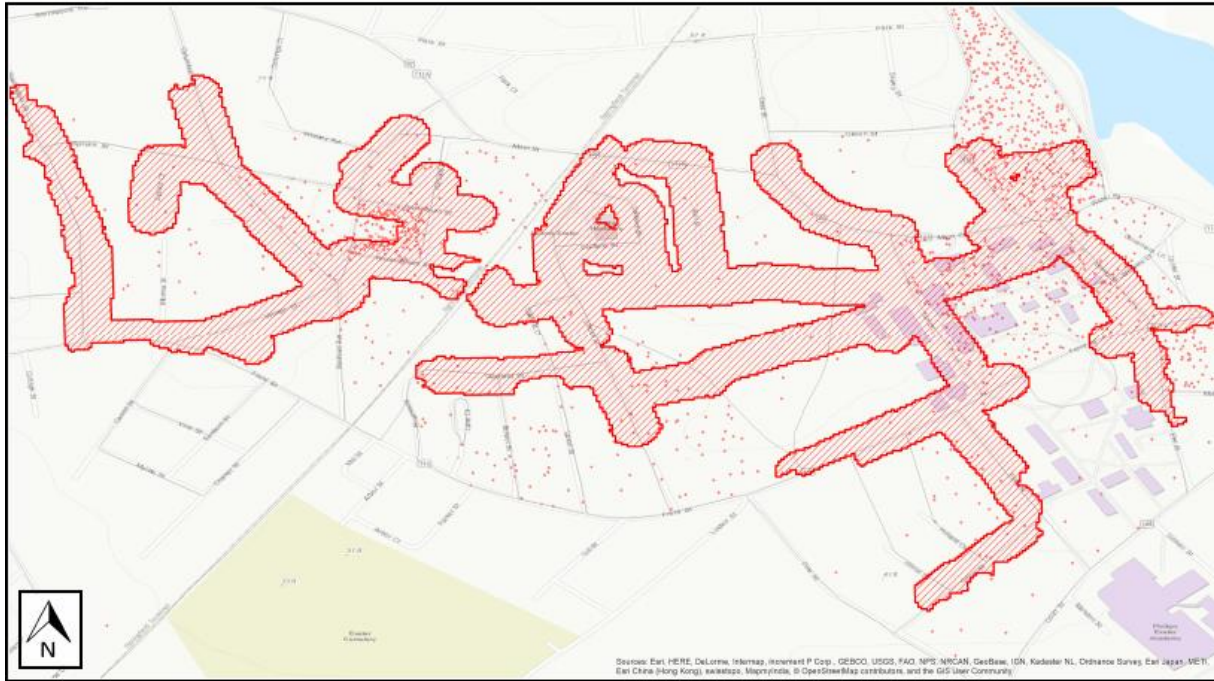
# FLOODING BEFORE AND AFTER— ELM ST, FRONT ST & TAN LANE





# HAZUS Analysis and Damage Cost Avoidance

Total Economic Loss (1 dot = \$300K) Overview Map



24-hour Storm Event (4.72 inches)

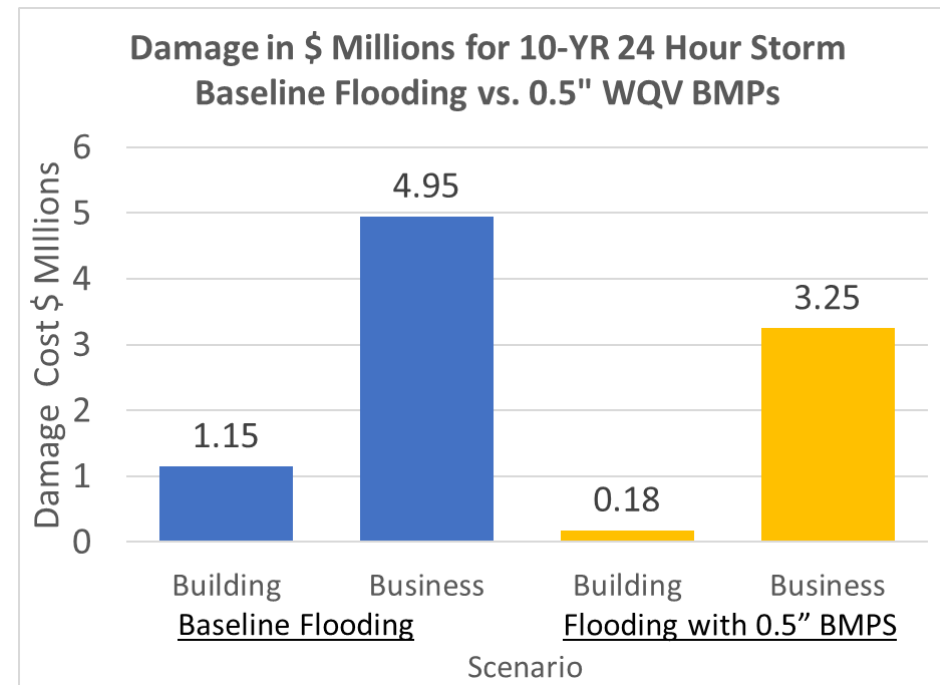


# ECONOMIC BENEFITS OF FLOOD AVOIDANCE



Photo: Flooding at Exeter Town Landing March 2018 Nor'easter

1. The cost impact analysis graphic at right shows the potential for flood damage avoidance with implementation of green infrastructure.
2. The estimated flood loss from a current 10-year storm is \$6.11 million or \$3.43 million with green infrastructure, a 51% reduction.
3. The total estimated cost to implement green infrastructure at 14 sites is \$689,000.
4. The greatest benefit is from small sized Best Management Practices that provide water quality and flood protection for a 0.5" storm, the most frequent annual rainfall event.





# SUBSURFACE INFILTRATION

MH-138  
 PROPOSED RIM EL. = 35.0 FT  
 EXISTING RIM EL. = 27.76 FT  
 EXISTING INV. IN = 23.63 FT, 24" DIAM.  
 EXISTING INV. IN = 24.63 FT, 12" DIAM.  
 PROPOSED INV. IN = 23.0 FT, 12" DIAM.  
 EXISTING INV. OUT = 23.63 FT, 24" DIAM.

FILL AREA B (23,500 SF, 58,000 CF)  
 EL. 33.94 FT

INV. OUT = 26.10 FT  
 12" DIAM.

FILL AREA A (2,568 SF, 6,420 CF)  
 EL. 30.0 FT

SLOPE FILL AREA (2,800 SF, 11,100 CF)  
 EL. 26 FT (2/2)

MH-137 24" ACCESS MANHOLE  
 RIM EL. = 37.14 FT  
 EXISTING INV. IN = 26.30 FT, 24" DIAM.  
 EXISTING INV. OUT = 26.13 FT, 24" DIAM.  
 PROPOSED INV. OUT = 26.10 FT, 24" DIAM.

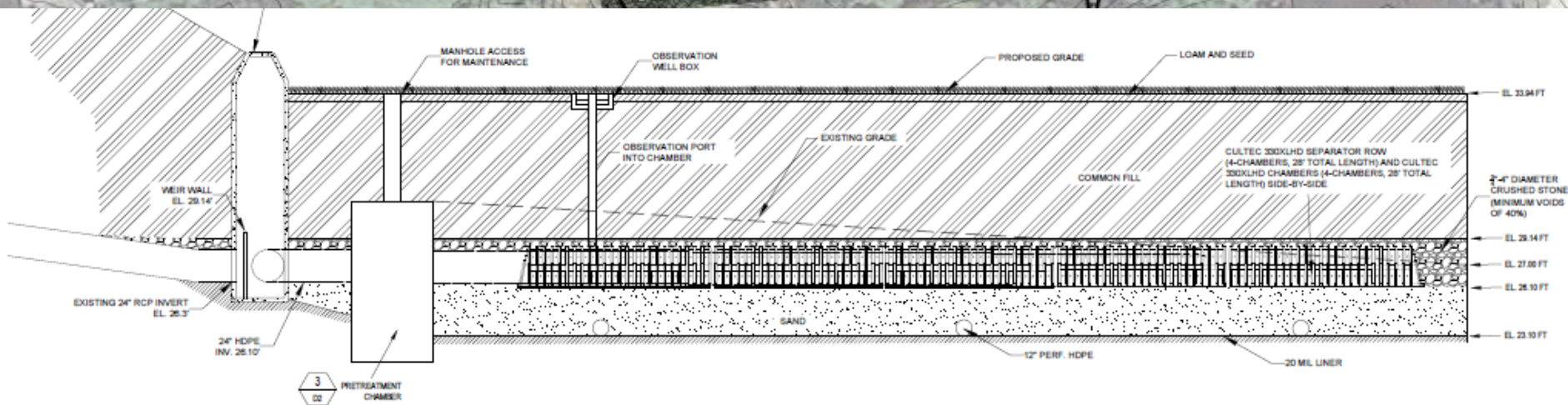
PRETREATMENT  
 CHAMBER  
 (3/2)

CB-136  
 RIM EL. = 43.14 FT  
 INV. IN = 31.48 FT, 24" DIAM.  
 INV. IN = 36.06 FT, 12" DIAM.  
 INV. OUT = 31.14 FT, 12" DIAM.

INV. OUT = 26.10 FT  
 24" DIAM.

BMP 4 - 120'L X 90'W X 3'D  
 SUBSURFACE INFILTRATION  
 10,800 SQUARE-FOOT OF STORAGE  
 22,700 CUBIC-FOOT OF STORAGE  
 (SEE DETAIL D1)

TEST PITS  
 TEST PITS MUST BE  
 CONDUCTED AT EACH LOCATION  
 TO VERIFY SOILS AND  
 SEASONAL HIGH WATER TABLE

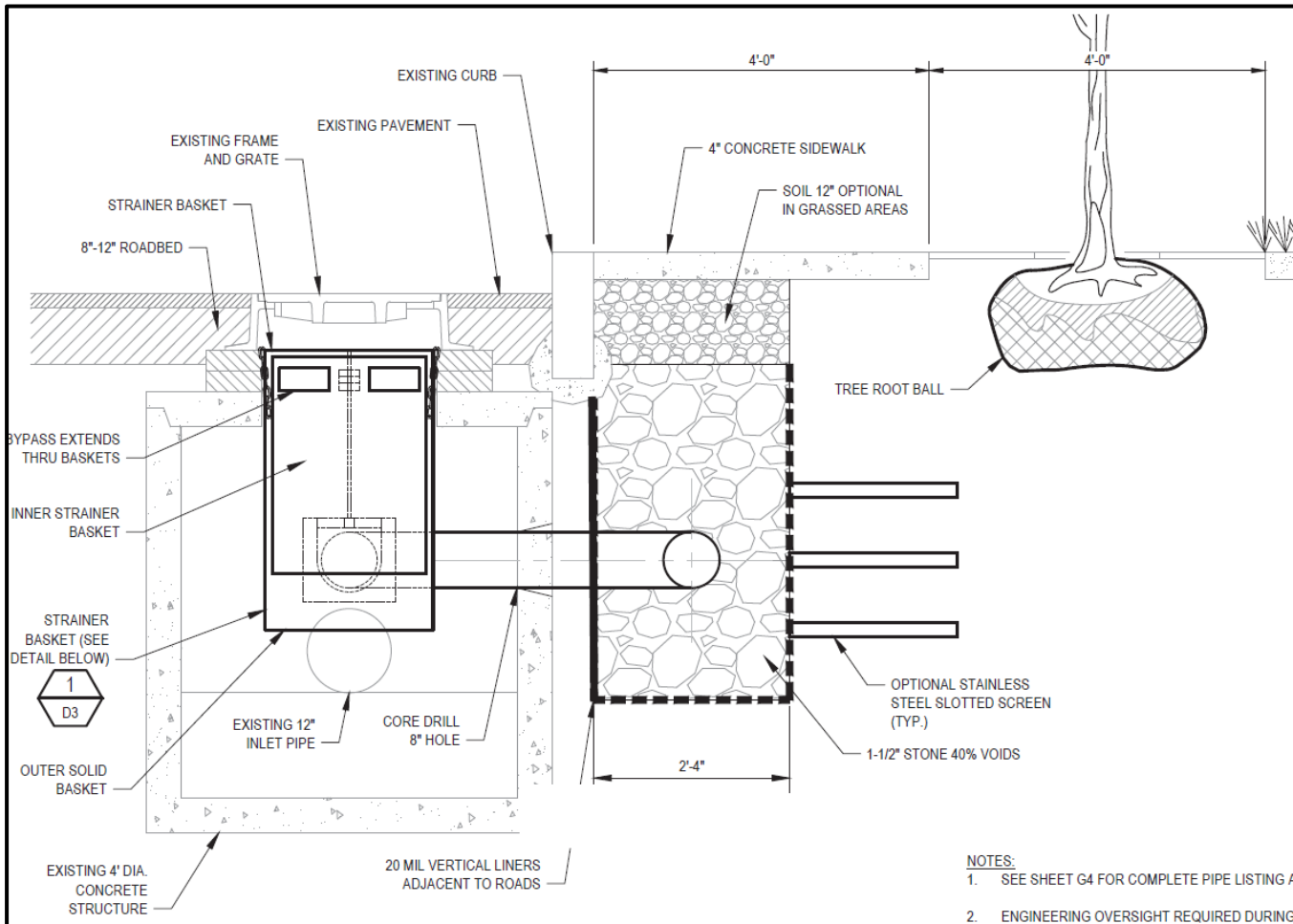




# RIGHT-OF-WAY INFILTRATION



# RIGHT-OF-WAY INFILTRATION



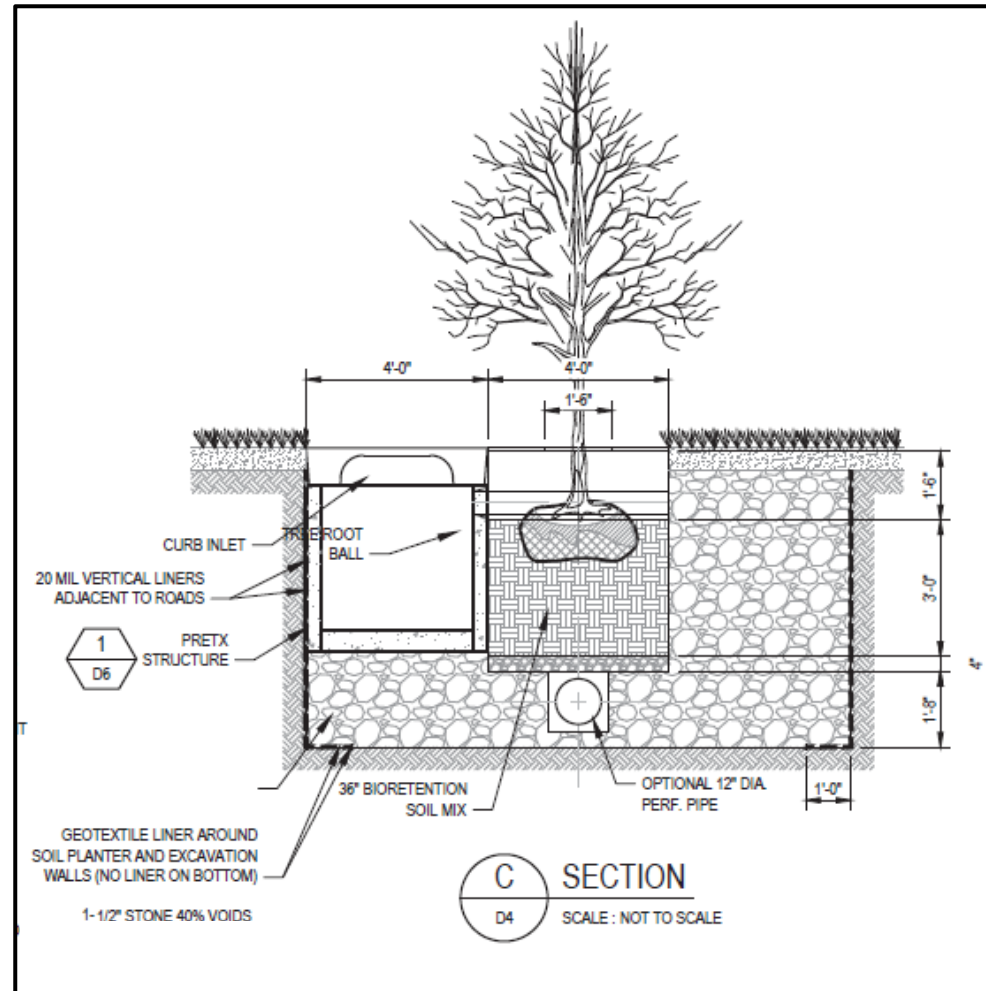
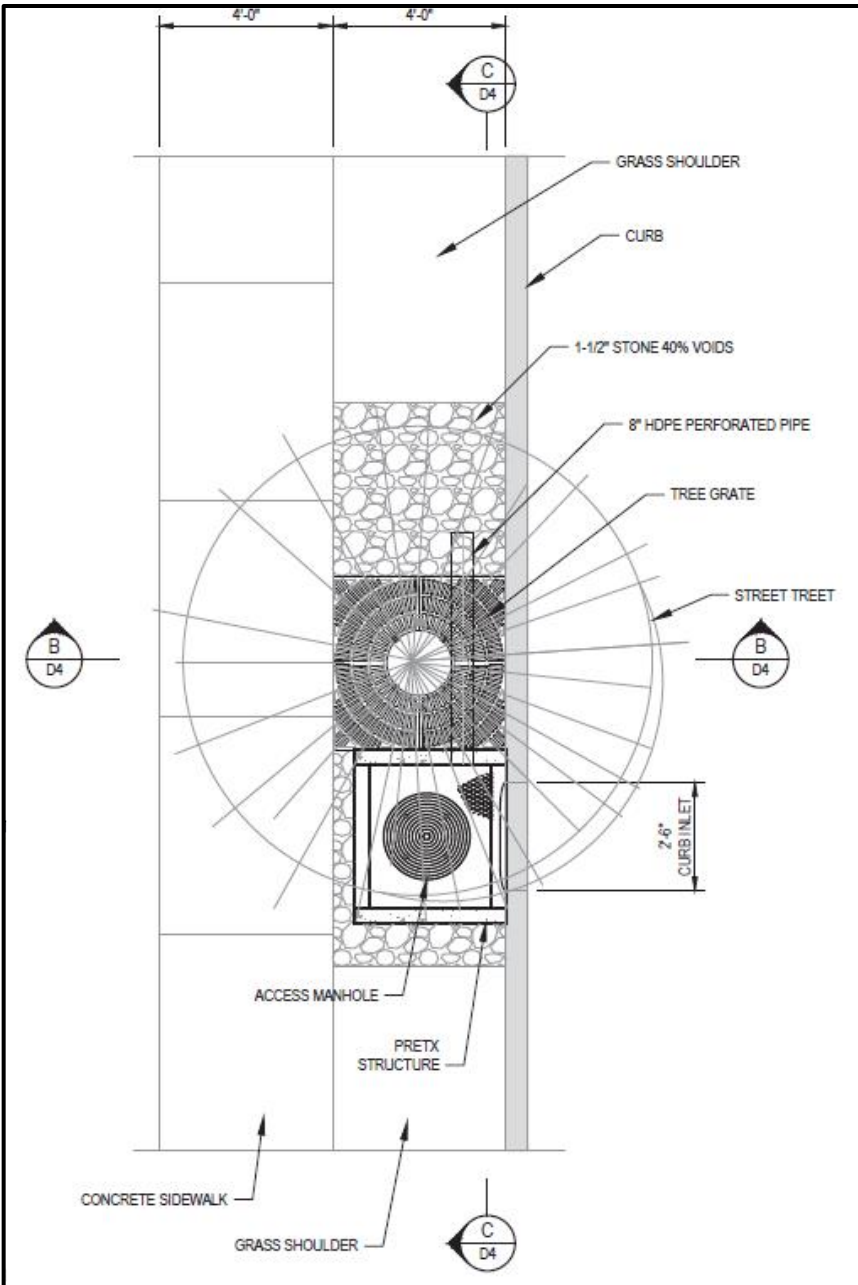
- LOW COST PRETREATMENT INSTALLED IN EXISTING CATCH BASINS AND DRAINAGE INFRASTRUCTURE AND INFILTRATION IN RIGHT-OF-WAY
- MAINTENANCE IS BY STANDARD VACUUM TRUCKS WITH NO SPECIAL EQUIPMENT OR TRAINING



# TREE PLANTERS



# TREE PLANTERS



- LOW COST PRETREATMENT INSTALLED IN EXISTING CATCH BASINS AND DRAINAGE INFRASTRUCTURE AND PLANTERS UNDERNEATH SIDEWALK FOR MAXIMUM PEDESTRIAN USAGE
- MAINTENANCE IS BY STANDARD VACUUM TRUCKS WITH NO SPECIAL EQUIPMENT OR TRAINING



# Low Maintenance Asset Management With Pretreatment

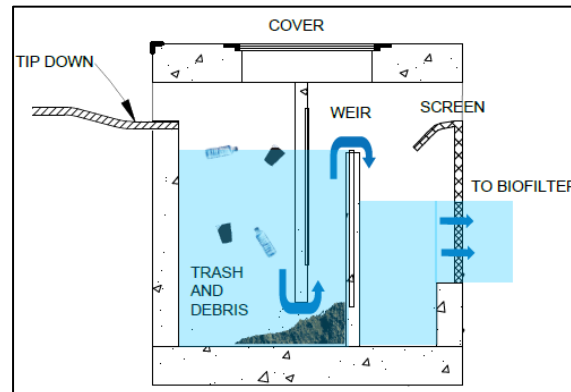
- In urban environments return on investment may be 1-2 years
- Goal is to use existing staff, equipment for standard catch basin cleaning
- Land-use and trash and debris load
- Aesthetics
- Cost to maintain versus cost of pretreatment



Condition Shortly After Install



Anderson Street Bioswale



Pretreatment by ACF



Condition After Winter

Table 7: Engineering Cost Estimates for BMPs 1, 2, 3, 4, 5, 7, 8 and 9

LOCATION	BMP #	DRAINAGE AREA (ACRES)	ANNUAL TN REDUCTION (LBS)	% LOAD REDUCTION	95% DESIGN COST ESTIMATE	\$/LBS NITROGEN
WINTER STREET	1	12.9	68.2	76%	\$45,900	\$680
	2	24.6	120.2	76%	\$79,000	\$660
Subtotal	-	<b>37.4</b>	<b>188.4</b>	<b>76%</b>	<b>\$124,900</b>	-
LINCOLN STREET NORTH	3.1	0.2	2.0	80%	\$8,000	\$4,000
	3.2	0.1	1.3	76%	\$6,600	\$5,080
	3.3	0.3	2.6	77%	\$12,000	\$4,620
	3.4	0.2	2.2	77%	\$9,900	\$4,500
	3.5	0.2	1.8	75%	\$7,000	\$3,890
	3.6	0.8	5.7	79%	\$21,800	\$3,830
	3.8	1.2	7.1	78%	\$22,000	\$3,100
	3.9	0.7	4.2	75%	\$13,600	\$3,240
	3.22	0.2	1.0	77%	\$3,000	\$3,000
Subtotal	-	<b>3.9</b>	<b>27.9</b>	<b>77%</b>	<b>\$103,900</b>	-
LINCOLN STREET SOUTH	3.20	1.6	10.7	77%	\$33,000	\$3,090
	3.21	0.2	1.0	72%	\$2,800	\$2,800
Subtotal	-	<b>1.8</b>	<b>11.7</b>	<b>76%</b>	<b>\$35,800</b>	-
FRONT STREET	5	20.3	71.7	52%	\$45,200	\$640
PHASE 2	4	32.43	230	90%	\$259,900	\$1,130
	7	7.41	7	12%	\$33,100	\$4,560
	8	15.99	107	99%	\$53,500	\$500
	9	5.86	47	99%	\$33,600	\$700
Subtotal	-	<b>61.7</b>	<b>391</b>	<b>83%</b>	<b>\$380,000</b>	<b>\$970</b>
Total	-	<b>125</b>	<b>691</b>	<b>76%</b>	<b>\$689,825</b>	-



# Nutrient Removal Unit Cost Comparison

Nutrient Control Strategy	Total Annual Cost	Life Cycle Cost Estimate	Lbs N Reduced Per Year	Unit Cost \$/Lb N
Durham WW 5 mg/L <sup>1</sup>	\$971,140	\$13,800,000	5,254	\$2,627
Durham WW 3 mg/L <sup>1</sup>	\$1,680,340	\$23,200,000	8,757	\$2,649
WW Incremental Increase <sup>1</sup>	\$709,200	\$9,400,000	3,503	\$2,683
Durham NPS IC Program <sup>1</sup>	\$95,000	\$475,000	250	\$1,900
WISE NPS @ IP 3/5/8 mg/L <sup>2</sup>	\$453,333	\$13,600,000	17,000	\$800
WISE WW @ IP 3/5/8 mg/L <sup>2</sup>	\$3,046,667	\$91,400,000	95,000	\$962
WISE Total @ IP 3/5/8 mg/L <sup>2</sup>	\$3,500,000	\$105,000,000	112,000	\$938
Exeter WW 3 mg/L <sup>3</sup>	\$5,789,000	\$115,780,000	95,400	\$1,214

## Notes and Assumptions

Data is from 2012 Oyster River Watershed Integrated Management Plan by VHB, NOS data generated by VHB, WW data by Wright Pierce Facilities Plan Draft

WW data reported is based on 7 month period. It was not adjusted for 12 months as perhaps should be considered for direct comparison with NPS

Assumes 20 Yr SRF Loan for Exeter @3.25% with no state or federal aid

Life Cycle includes capital and operations and maintenance

Present worth is capital at 20-yr;

Data sources: <sup>1</sup> ORWIMP 2014; <sup>2</sup> WISE 2015, <sup>3</sup> Wright Pierce 2014

# *Thank you!*



**Robert M. Roseen, PE**

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**WATERSTONE  
ENGINEERING**  
INNOVATIVE STORMWATER MANAGEMENT

**Julie LaBranche, Senior Planner**

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