

# **Introducing Green Infrastructure for Coastal Resilience**

**National Oceanic and Atmospheric Administration (NOAA)  
Office for Coastal Management**

# What Is “Resilience”?

*Introducing Green Infrastructure for Coastal Resilience*



Courtesy, Waquoit Bay NERR



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# Course Objectives

*Introducing Green Infrastructure for Coastal Resilience*

## Participants:

- Recognize green infrastructure terms and concepts that contribute to community resilience
- Understand ecological, economic, and societal benefits of green infrastructure
- Understand the wide variety of contexts and scales of approaches
- Understanding of how green infrastructure fits into existing planning processes, tips on engaging stakeholders, and potential funding opportunities
- Identify local green infrastructure activities and experts with additional information and resources



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# Course Outline

*Introducing Green Infrastructure for Coastal Resilience*

1. Green Infrastructure Concepts and Principles
2. The Practice of Green Infrastructure
3. Implementing Green Infrastructure



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# A Quick Hello!

- **Name**
- **Affiliation**
- **One Word** you think of when you hear the term “Green Infrastructure”





# Section 1

## Green Infrastructure Concepts and Principles





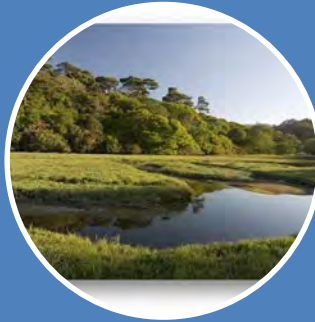
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# Foundations of Green Infrastructure

*Green Infrastructure Concepts and Principles*



Landscape  
Architecture  
1860s



Landscape  
Ecology  
1930s



Design with  
Nature  
1960s



Conservation  
Biology  
1970s



Clean Water  
Act  
1970s



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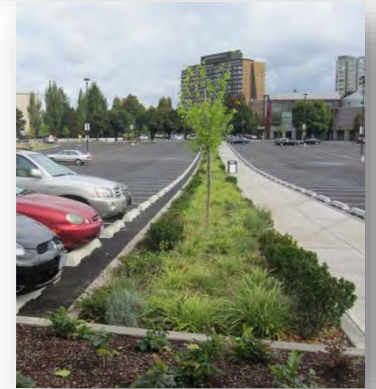
# Foundations of Green Infrastructure

*Green Infrastructure Concepts and Principles*

Landscape approach?



Site-level  
approach?



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# Applicability across Scales

*Green Infrastructure Concepts and Principles*

Landscape and  
watershed

Community  
and site

Shore and  
coastal zone



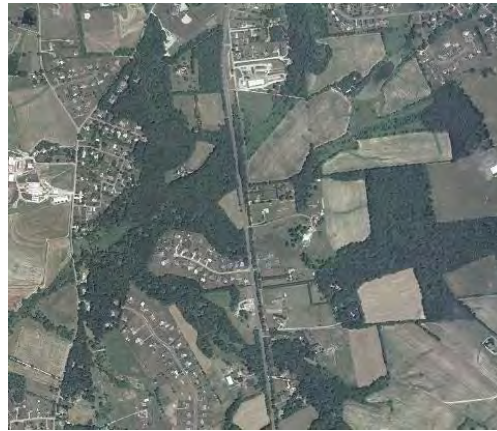
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# Importance of Context

*Green Infrastructure Concepts and Principles*

Green infrastructure practices are context sensitive.



Rural  
Coastal



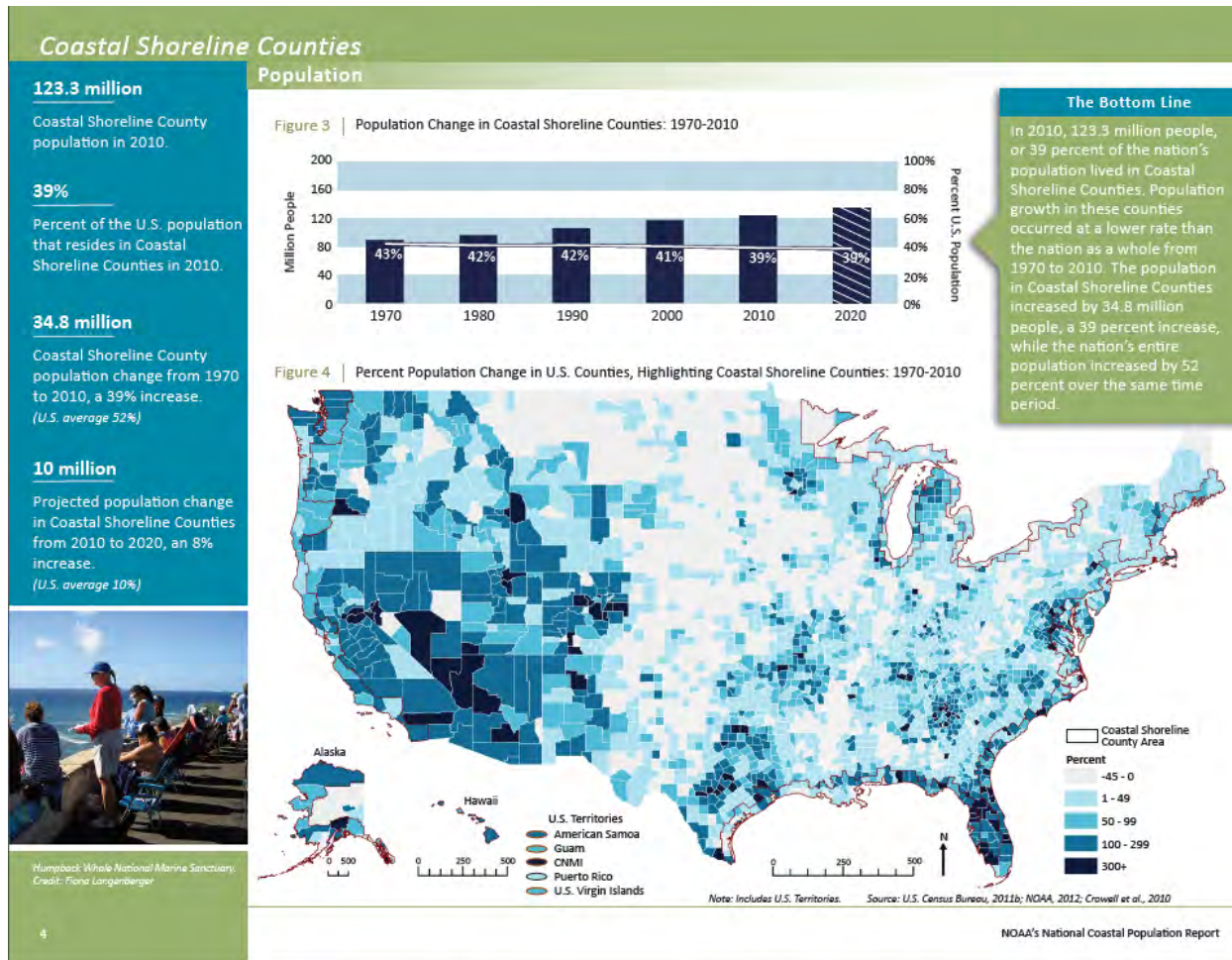
Urban  
Upland



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# Why Green Infrastructure?

## Green Infrastructure Concepts and Principles



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# Why Green Infrastructure?

*Green Infrastructure Concepts and Principles*



Courtesy, CapeHomepage.com

# Why Green Infrastructure?

*Green Infrastructure Concepts and Principles*



Adam Whelchel, TNC



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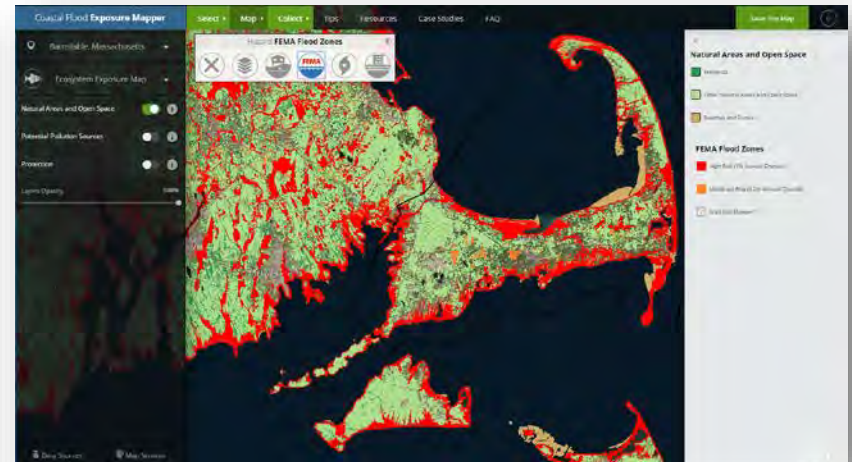


# Exposure to Coastal Hazards

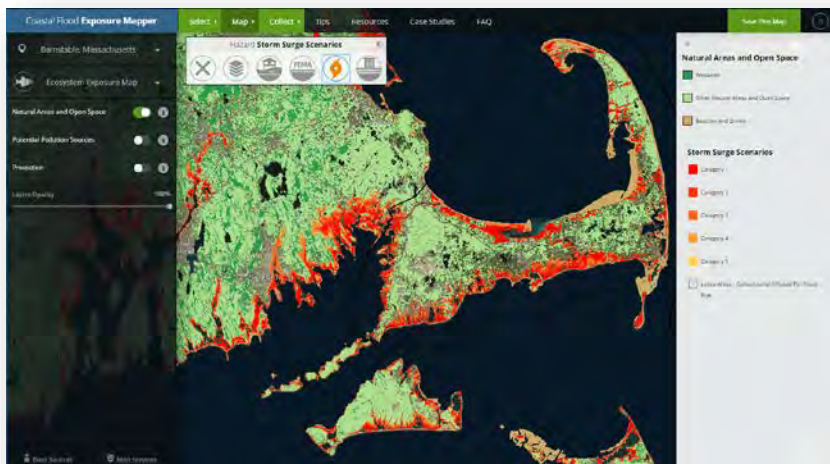
## *Green Infrastructure Concepts and Principles*



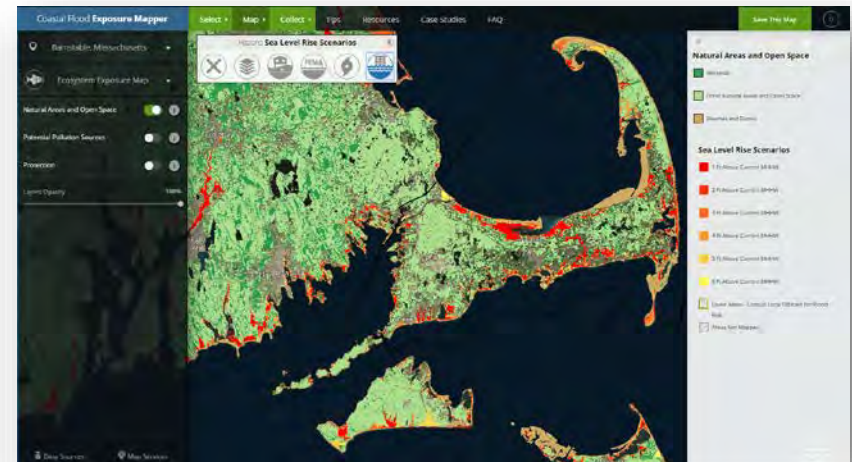
**Shallow Coastal Flooding**



**FEMA Flood Zones**



**Storm Surge**



**Sea Level Rise**

[coast.noaa.gov/digitalcoast/tools/flood-exposure](https://coast.noaa.gov/digitalcoast/tools/flood-exposure)

# Visualizing Land Cover

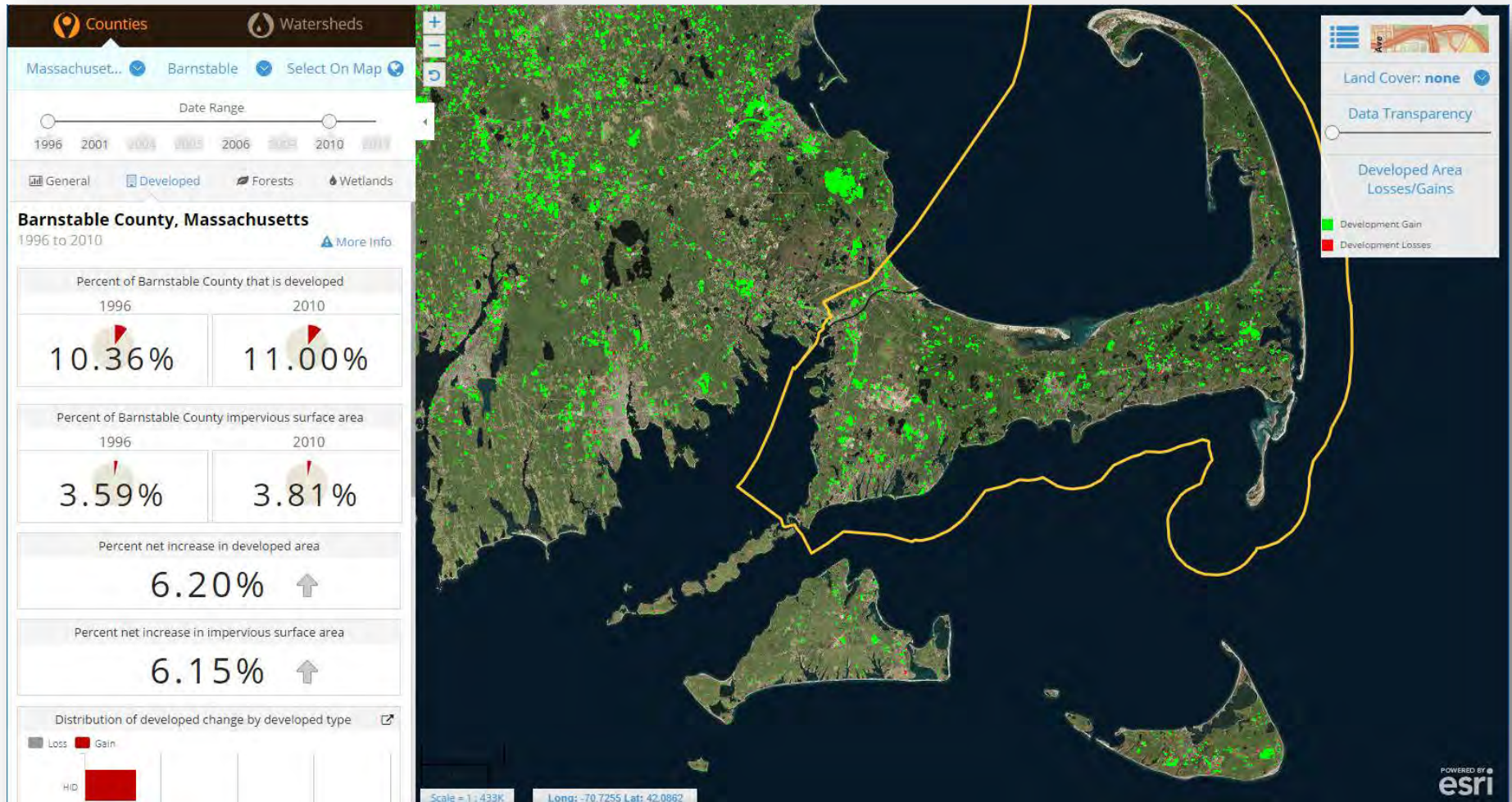
## *Green Infrastructure Concepts and Principles*





# Visualizing Land Cover

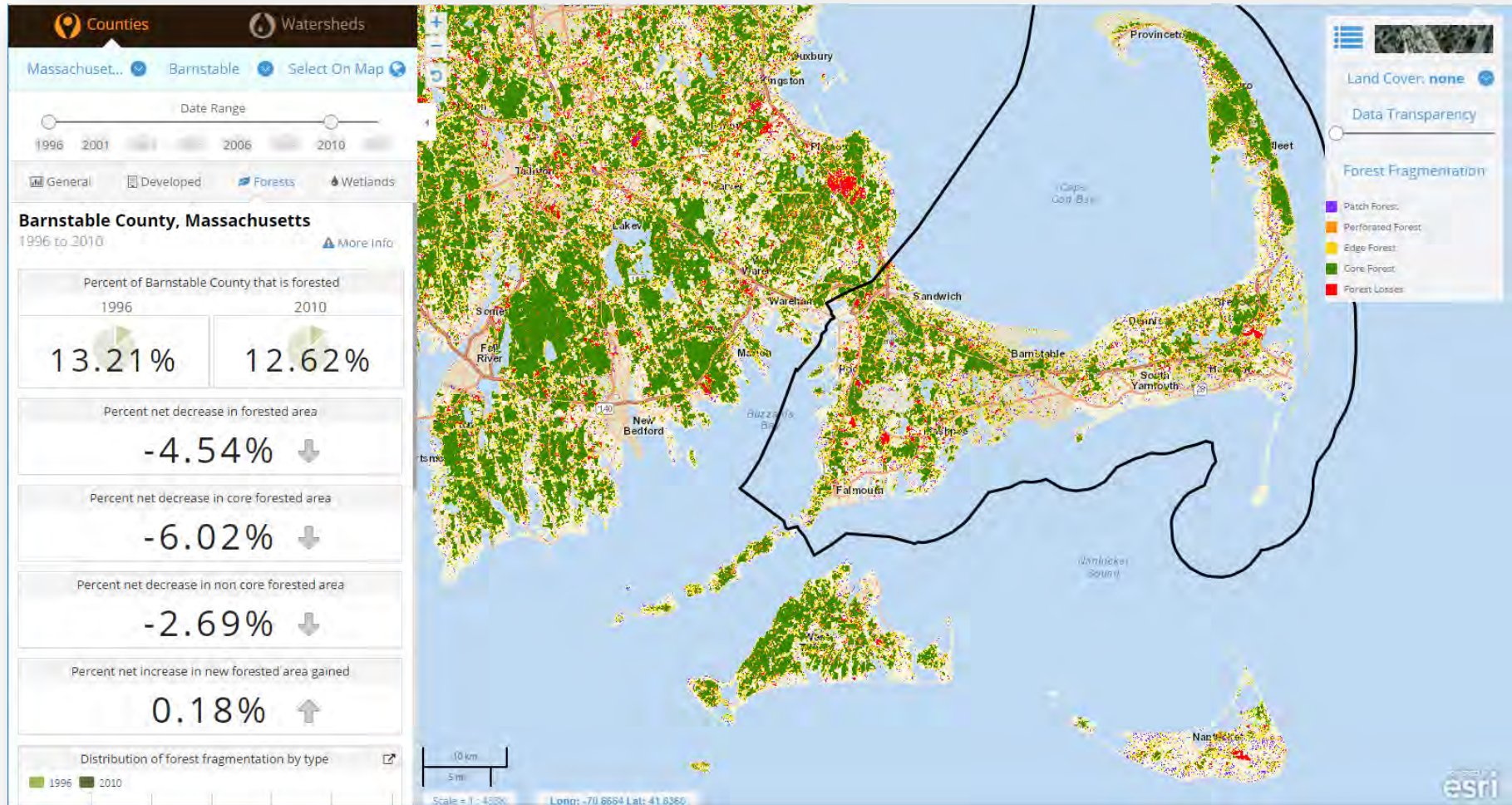
## *Green Infrastructure Concepts and Principles*





# Visualizing Land Cover

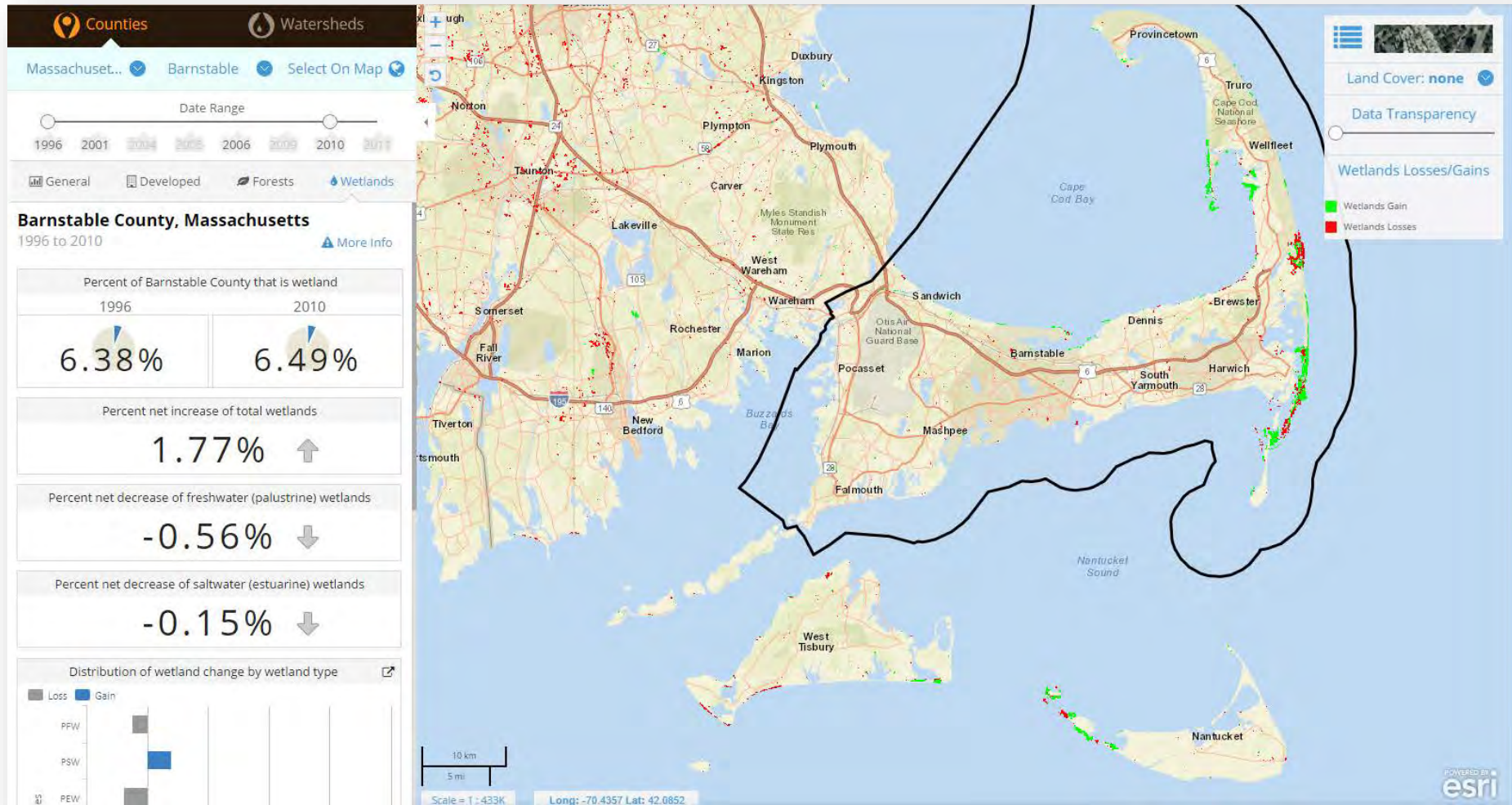
## *Green Infrastructure Concepts and Principles*





# Visualizing Land Cover

## Green Infrastructure Concepts and Principles



# Ecosystem Services

*Green Infrastructure Concepts and Principles*

Natural ecosystems provide multiple benefits to people, including food and water production, improved air and water quality, and recreation and spiritual inspiration.



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# Multiple Benefits

- Environmental
- Societal
- Economic



# Who's Benefit

*Green Infrastructure Concepts and Principles*

A wide variety of stakeholders stand to benefit. Engaging stakeholders is an essential part of understanding the benefits and how they are valued by people.



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# ***Table Discussion 1***

*Green Infrastructure Concepts and Principles*

What coastal hazard issues is your community experiencing? (e.g., flooding, stormwater runoff)



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# Section 2

## The Practice of Green Infrastructure





# Planning Concepts

*The Practice of Green Infrastructure*

- Approach will depend on the **scale** you are addressing
- All practices, regardless of scale, use **ecosystem services** to acquire maximum benefits
- Design methods are repeatable and grounded in **science**
- **Context** is important



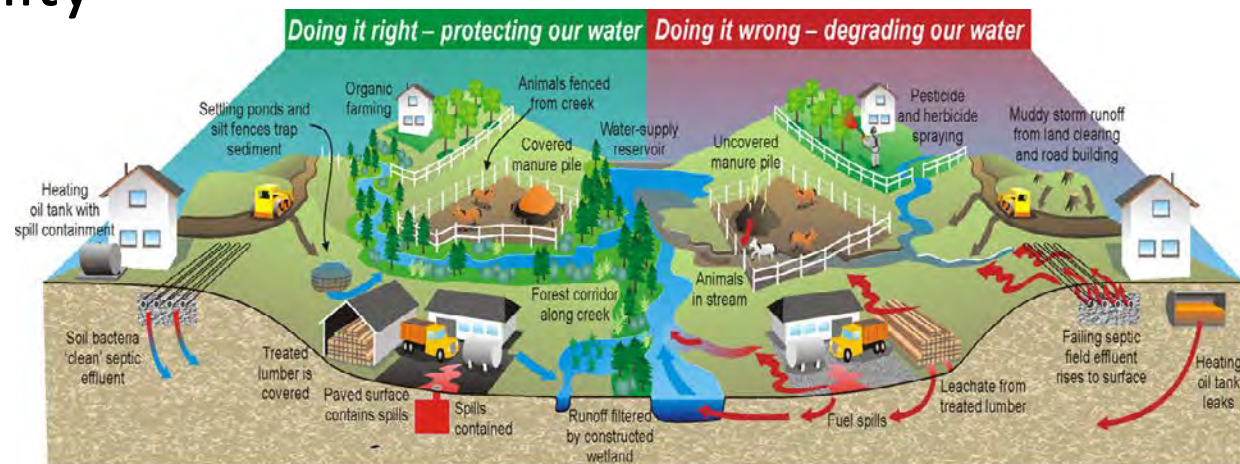
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# Design Concepts

*The Practice of Green Infrastructure*

Successful green infrastructure practices incorporate

- Multi-functionality
- Resilience
- Sense of place
- Return on investment



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# Green Infrastructure in Practice

*The Practice of Green Infrastructure*

Landscape and  
watershed

Community  
and site







Shore and  
coastal zone



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# Landscape Design Concepts

*The Practice of Green Infrastructure*

	BETTER	WORSE
Area		
Proximity		
Connectivity		



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# Landscape and Watershed Approaches and Resilience

*The Practice of Green Infrastructure*

- Recent study\* on flood reduction during Hurricane Sandy showed:
  - Coastal wetlands saved more than \$625 million in flood damages
  - Where they exist, coastal wetlands reduced damages by more the 10% on average
  - In Ocean County, NJ wetland conservation can reduce average annual losses by more than 20%



\*Coastal Wetlands and Flood Damage Reduction: Using Risk Industry-Based Models to Assess Natural Defenses in the NE USA, 2016.



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# Community and Site Design Concepts

*The Practice of Green Infrastructure*

- Natural areas and open spaces should serve multiple functions (e.g., recreation, stormwater storage, filtration)
- Connect people to open areas through greenways and trails
- Preserve or mimic the natural hydrological functions of a site or drainage area
- Use urban streetscapes to provide ecosystem benefits in urban areas



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# Community and Site Approaches

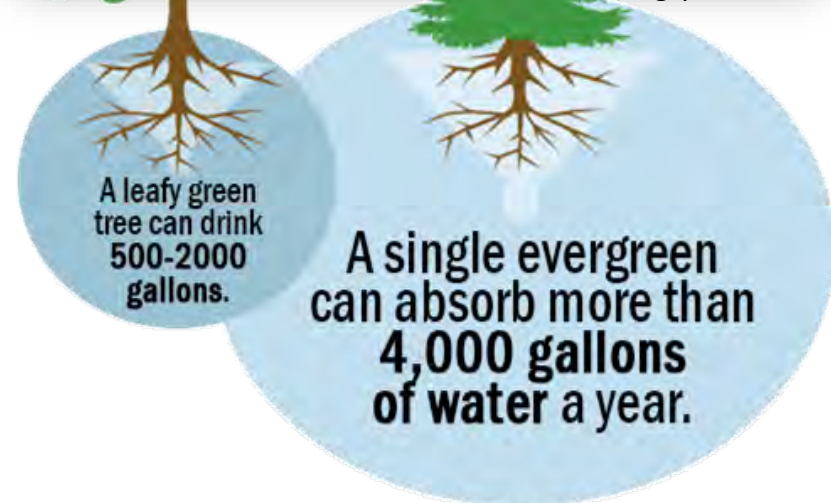
*The Practice of Green Infrastructure*

## Urban Forestry

- Trees provide enormous environmental, economic, and societal benefits
- Develop a tree planting program designed to maximize benefits
- To the extent possible, protect existing forested areas, particularly large specimen trees



Res...blogspot.com



# Community and Site Approaches

*The Practice of Green Infrastructure*

## Green Streets

- Key linking component in green infrastructure network
- Design dependent on local conditions but generally include
  - Alternative street widths
  - Swales
  - Bioretention
  - Permeable pavements
- Provides multiple benefits



Philadelphia Water Department



Coos Bay, Oregon



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# Community and Site Approaches

*The Practice of Green Infrastructure*

## Environmental Site Design

- Place the site in context to greater community
- Preserve and enhance natural features
- Mimic or enhance existing hydrology
- Minimize impervious cover
- Key component of low impact development (LID)



TrockWorks Architectural Services



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# Community and Site Approaches

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## Low Impact Development Practices



### Bioretention (Infiltration and Filtering)

- Rain gardens
- Bioswales
- Stormwater planters



### Green Roofs (Storage and Evapotranspiration)

- Blue roofs
- Cisterns



### Permeable Pavements (Infiltration)

- Porous asphalt/concrete
- Grass or gravel pavers
- Pavers



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# Community and Site Approaches and Resilience

*The Practice of Green Infrastructure*

- Many studies on the effectiveness of these practices for
  - Reducing the heat island effect
  - Improving water quality
  - Recharging groundwater
  - Providing societal benefits
- For LID, flood reduction is a ‘co-benefit’
  - City of Portland, OR reduced peak flow of stormwater runoff by 93%, cooling costs by 27%, and heating costs by 15%.



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# Shoreline Design Concepts

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- Natural or Nature-Based
  - Dunes and beaches
  - Vegetated features (salt marsh, wetlands, submerged aquatic vegetation)
  - Oyster and coral reefs
  - Barrier islands
  - Maritime forest/shrub communities
- Hybrid
  - Natural and structural features
- Nonstructural
  - Floodplain policy and management
  - Flood proofing





# Shoreline Approaches

*The Practice of Green Infrastructure*

## Natural or Nature-based



### Dune and Beach Creation

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer



### Salt Marshes, Wetlands, Vegetation, SAV

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer
- Increase infiltration



### Oyster and Coral Reefs

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer

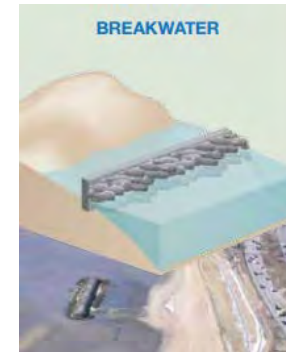
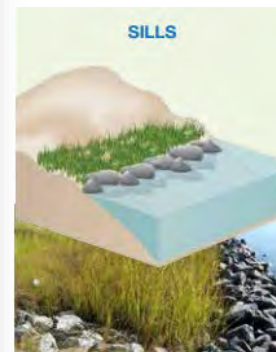


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# Shoreline Approaches

*The Practice of Green Infrastructure*

## Hybrid



<http://sagecoast.org/info/information.html>

- Blends both nature-based and structural approaches
- Derives benefit of wave energy dissipation from structural practices
- Derives ecosystem service benefits from nature-based practices



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# Shoreline Approaches and Resilience

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- Study\* conducted in North Carolina before and after Hurricane Irene showed:
  - Marshes with and without sills are more durable and protected shorelines from erosion better than the bulkheads during the Category 1 storm.
  - 76% of bulkheads were damaged in the storm.
  - No damage occurred to shorelines with or without sills.



Courtesy, Tracy Skrabal, NC Coastal Federation

\*Marshes with and without sills protect estuarine shorelines from erosion better than bulkheads during a Category 1 hurricane, 2014

# ***Table Discussion 2***

*The Practice of Green Infrastructure*

What green infrastructure-related projects are you working on now, or hope to, that contribute to preserving resilience-enhancing ecosystem services in your community? **Record one sentence project description, location, your contact information (put a “P” if it is an existing or planned project and put an “I” if it is an idea).**



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## Section 3

# Implementing Green Infrastructure





# Barriers to Green Infrastructure

## *Implementing Green Infrastructure*

### Technical and Physical

- Lack of understanding
- Lack of data showing benefits, costs, and so on
- Insufficient technical knowledge or experience
- Lack of design standards, codes, and ordinances

### Legal and Regulatory

- Local rules lacking, conflicting, or restrictive
- State policies
- Property rights issues
- Federal rules can be conflicting

### Financial

- Not enough data about costs and economic benefits
- Perceived high costs over short and long terms
- Lack of funding for implementation
- Too much risk – not enough incentives

### Community and Institutional

- Insufficient information and green infrastructure benefits for political leaders, administrators, staff, developers, builders, and landscapers
- Community and institutional values that underappreciate green infrastructure aesthetics and characteristics
- Lack of interagency and community cooperation



# Green Infrastructure Can Inform Planning

*Implementing Green Infrastructure*

Incorporate green infrastructure into planning efforts:

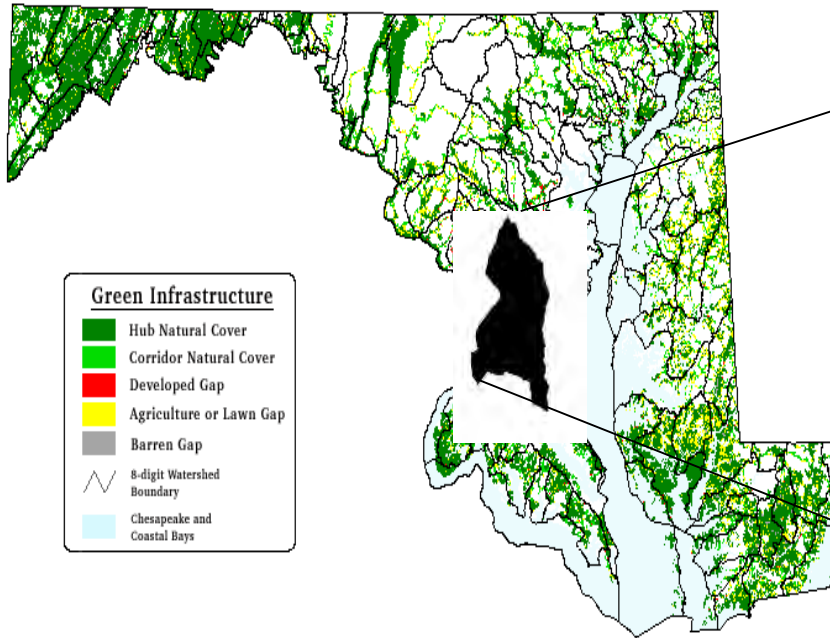
- Comprehensive
- Transportation
- Smart growth
- Watershed
- Conservation
- Hazard mitigation
- Stormwater
- Climate change adaptation
- Resilience
- Land use



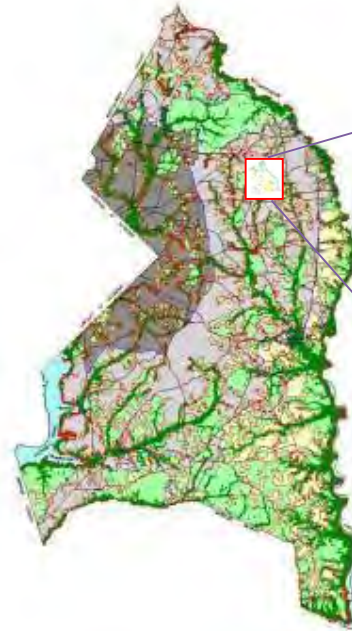
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# Green Infrastructure Can Inform Planning

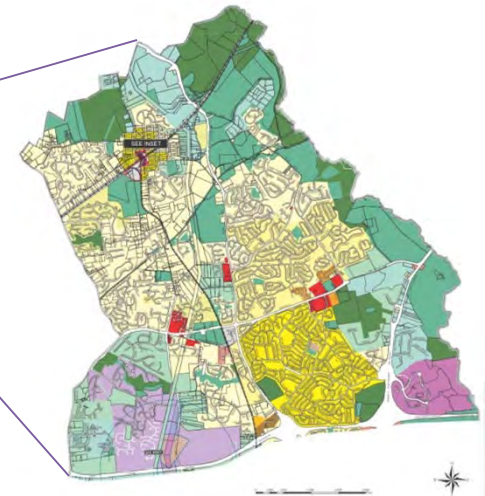
*Implementing Green Infrastructure*



**Maryland State Plan**



**Prince George's County**



**Bowie Planning Area**



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# Comprehensive, Hazard Mitigation, and Climate Adaptation Planning

*Implementing Green Infrastructure*

TOWN OF BARNSTABLE COMPREHENSIVE PLAN 2010  
SEVEN VILLAGES - ONE COMMUNITY



Balancing growth, infrastructure and natural systems

## City of Boston Natural Hazard Mitigation Plan

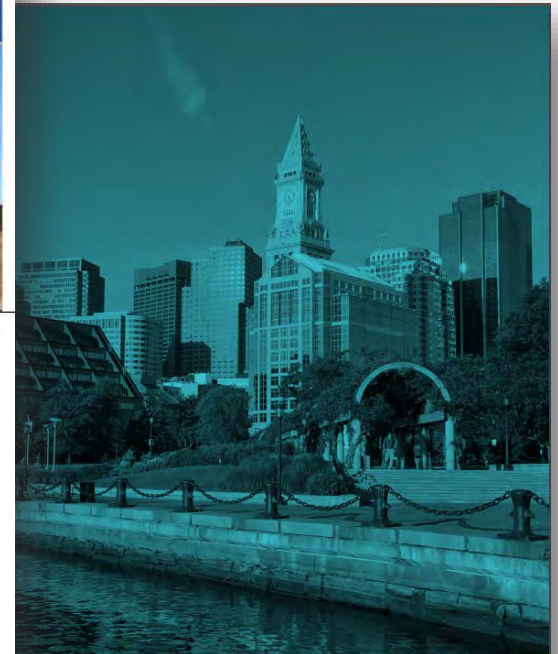
Current Plan of Boston's Comprehensive Emergency Management Program



Draft 2014 Plan Update

Revised Draft for MEMA and FEMA Review

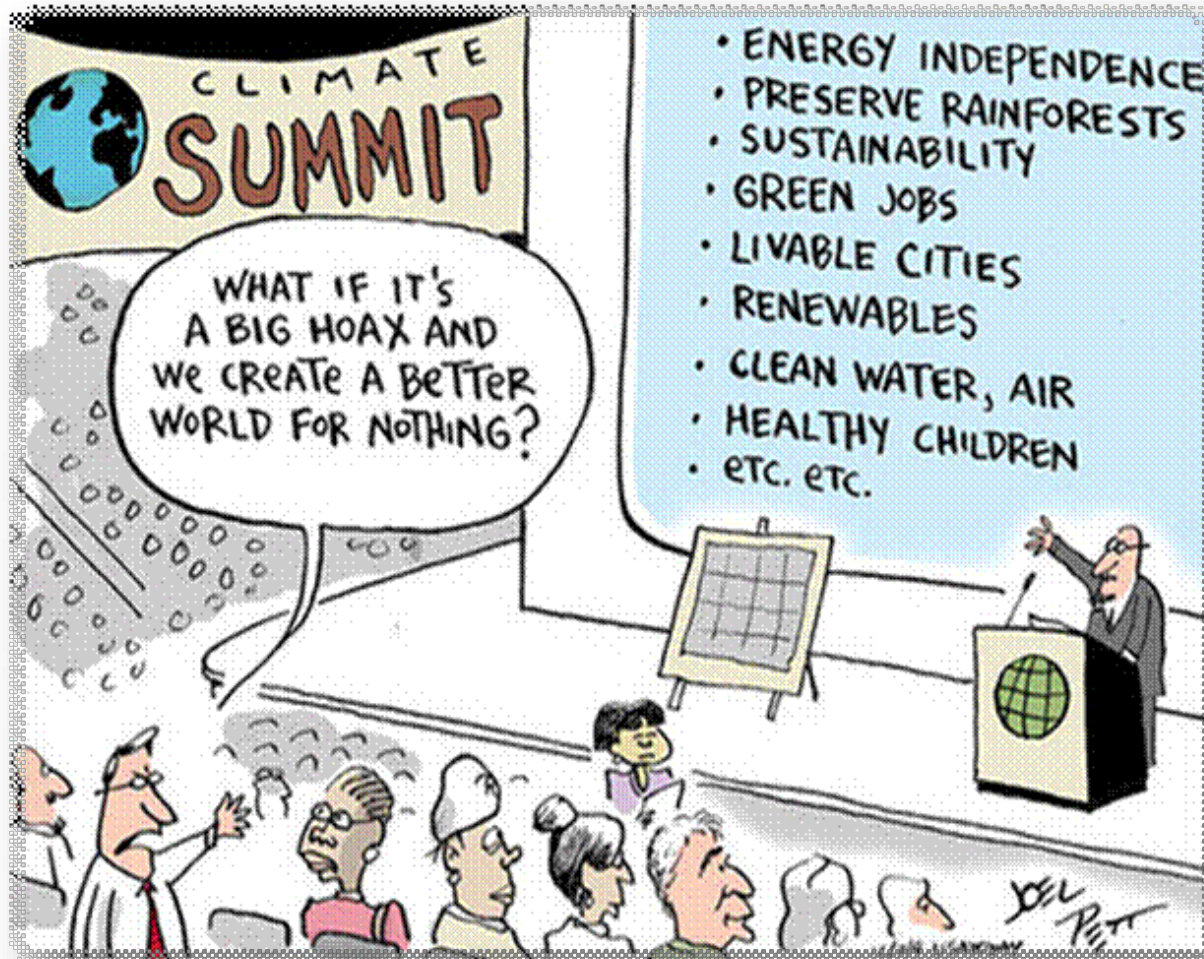
March 31, 2015



**CLIMATE READY BOSTON**  
FINAL REPORT

# Multiple Benefits

## *Implementing Green Infrastructure*



# Engaging Stakeholders

## *Implementing Green Infrastructure*

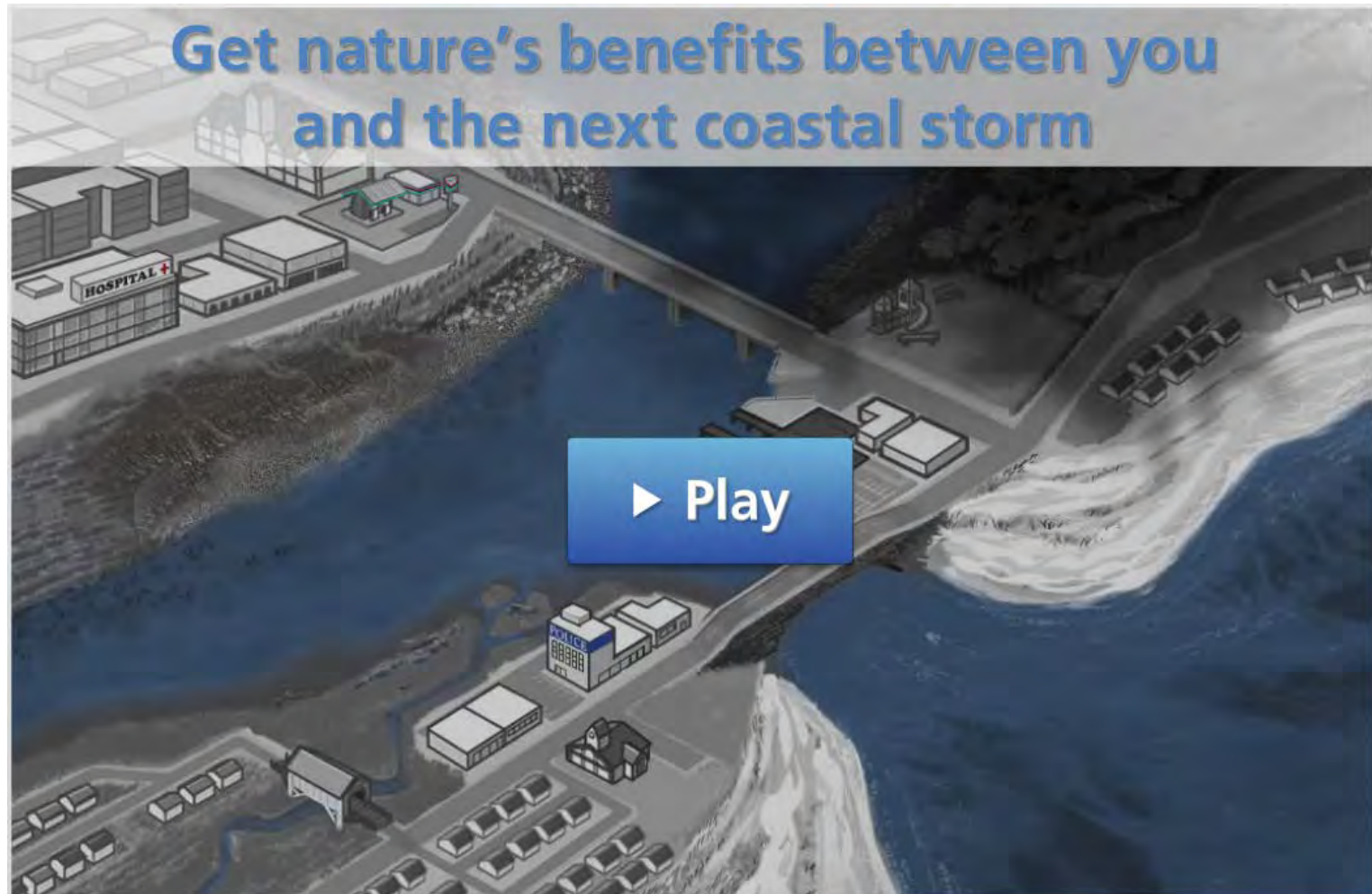
- Have a plan
- Speak to their interests, not yours
- Explain the hazard risk and offer solutions
- Use multiple ways to communicate





# Engaging Stakeholders

*Implementing Green Infrastructure*



# Engaging Stakeholders

## Implementing Green Infrastructure



### Put Green Infrastructure between Your Community and the Next Coastal Storm.

There are many benefits.

#### Tidal and Forested Wetlands

- Slow waves
- Filter and clean floodwaters
- Provide food and jobs

#### Green Streets

- Capture and clean stormwater
- Beautify streets and encourage economic development
- Provide pedestrian-friendly walkways

#### Oyster and Coral Reefs

- Slow storm surge
- Provide food
- Clean water

#### Sand Dunes

- Buffer waves as a first line of defense
- Build economy through tourism

#### Open Space and Parks

- Store floodwaters and recharge aquifers
- Increase property values

#### Urban Trees

- Reduce runoff and absorb floodwaters
- Shade and cool homes and businesses
- Provide clean air and water

#### Living Shorelines

- Slow waves and reduce erosion
- Protect property

Office for Coastal Management  
Digital Coast



See the reverse of this page to learn more.

### Here's What You Can Do to Protect Your Community.

Green infrastructure can have multiple functions and cost less than using only gray infrastructure.



#### Conserve Existing Natural Areas

Natural areas such as wetlands, dunes, and vegetated shorelines absorb storm surge waves, reducing damage to nearby homes and roads.

**How do we know it works?** A study after Hurricane Sandy showed that areas containing wetlands had less damage than those without. Wetlands prevented an estimated \$600 million in property losses.



#### Increase Your Community's Ability to Absorb Stormwater

- Protect and plant trees.
- Implement other practices such as green streets to keep stormwater from running into sewers, lessening the strain on existing systems.
- Use capital improvement projects as an opportunity to fund stormwater projects.

**How do we know it works?** The City of Portland, Oregon, used a combination of green roofs, green streets, trees, and rain gardens to reduce the peak flow of stormwater runoff by 93 percent, cooling costs by 27 percent, and heating costs by 15 percent.



Photo: Tracy Skrabal, North Carolina Coastal Federation

#### Create Natural Shorelines

Create living shorelines using oysters, marsh grass, and other natural materials to absorb wave energy and reduce erosion.

**How do we know it works?** North Carolina properties that used natural shoreline protection measures withstood wind and storm surge during Hurricane Irene better than properties using seawalls or bulkheads.

To learn more, visit [coast.noaa.gov/digitalcoast/topics/green-infrastructure](http://coast.noaa.gov/digitalcoast/topics/green-infrastructure).

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# Engaging Stakeholders

## Implementing Green Infrastructure

### Costs of Low Impact Development

LID Saves Money and Protects Your Community's Resources



#### Are Low Impact Development (LID) Practices More Economical Than Conventional Practices?

In many cases, the answer is yes. LID typically includes a variety of low-cost elements such as bioswales that retain rain water and encourage it to soak into the ground rather than allowing it to run off into storm drains where it would otherwise contribute to flooding and pollution problems. LID projects typically include smaller overall development footprints, reduce the amount of runoff generated and increase the amount of natural areas on a site, thereby reducing costs when compared to traditional stormwater management and flood control.

#### FAQ

Isn't LID too costly?  
**Barrier Busted!**  
Communities recognize that using LID can save money.

EPA's LID Barrier Busters fact sheet series, helping to overcome misconceptions that can block adoption of LID.



#### Example Economic Benefits of LID Elements

- Adding roadside bioswales, making roads narrower and parking lots with on-site runoff retention saves money by pavement, curbs and gutters needed.
- Installing green roofs, disconnecting roof downspouts from (driveways or streets), and incorporating bioretention areas saves money by eliminating the need for costly runoff pipe delivery systems.
- Designing more compact residential lots saves money by building preparation costs, and can increase the for sale.
- Preserving natural features in the neighborhood can increase price of residential lots.
- Using existing trees and vegetation saves money by reducing and decreasing stormwater volume.

#### Cost-Savings Nationwide: LID Case Studies

A U.S. Environmental Protection Agency study of 17 LID case studies found that, in the majority of cases, total capital cost to 80 percent when LID methods were used. (For details, see costs07).

Sherwood, Arkansas: Gap Creek subdivision included 2 natural drainage areas and traffic-calming circles that also reduce street widths. Results? The lots sold for \$3,000 more to develop than comparable conventional lots. The LID did for stormwater control features, which allowed the developer additional lots.

- Seattle, Washington: Seattle's 2nd Avenue Street Edge Alternative project redesigned an entire block with LID techniques such as bioswales in the rights-of-way. Results? Reducing street widths and sidewalks lowered paving costs by 40 percent. Overall, incorporating LID techniques cost \$651,548—a savings of \$217,255 compared to a conventional retrofit of the block, which would have cost an estimated \$868,803.
- Naperville, Illinois: Developers at the 55-acre Telford corporate campus preserved much of the site's natural drainage features and topography, reducing grading and earthwork costs. They used bioswales and other infiltration techniques in parking lots to manage stormwater. They maximized the amount of natural areas, eliminating the need for irrigation systems and lowering maintenance costs when compared to turf grass. Results? As seen in the table below, total LID project costs were \$461,510 less than a conventional design would have been.

#### Sample Costs: Comparing Conventional Stormwater Controls with LID Techniques in a Corporate Development (Telford) in Naperville, Illinois

Construction Item	Cost of Conventional Development	Cost When Using LID Practices	Dollars Saved with LID
Site preparation	\$2,178,500	\$1,966,000	\$212,500
Stormwater management	\$480,910	\$418,000	\$62,910
Landscape development	\$502,730	\$316,850	\$185,880
<b>Total</b>	<b>\$3,162,140</b>	<b>\$2,700,650</b>	<b>\$461,510</b>

#### LID Provides Added Value for Communities

Besides reducing the capital and other actual costs, using LID practices provides numerous additional economic benefits, some of which are difficult to quantify, including:

- Improved aesthetics for communities
- Expanded recreational opportunities
- Increased property values due to the desirability of the lots and their proximity to open space
- Increased marketing potential and faster sales for residential and commercial properties
- Reduced stream channel damage and pollutant loadings in downstream waters
- Reduced drinking water treatment costs
- Reduced costs associated with combined sewer overflows, where applicable

LID offers great flexibility for developing and re-developing properties. A wide range of LID technology choices are available to match the needs of individual sites and the desires of the parties developing or buying the property.

United States Environmental Protection Agency • Office of Wetlands, Oceans, and Watersheds  
1200 Pennsylvania Avenue, NW, Washington, DC 20460  
EPA 843-N-12-003 • March 2012



A roadside water capture and retention system in Seattle, Washington. The city saves money with LID by avoiding costly stormwater infrastructure and reducing paving costs.



This bioretention pond in Williamsville, Oregon collects runoff from the rooftop, sidewalks and yards. The pond offers valuable aesthetics and wildlife habitat benefits while also reducing stormwater control costs.



Philadelphia has been extending its use of LID by implementing new policies and demonstration projects, such as the rooftop bioswale that treats runoff from an adjacent parking lot. The city's use of LID has reduced stormwater runoff volume, saving approximately \$17.8 million in combined sewer overflow costs since 2004.

### Maintenance of Low Impact Development

Communities Are Easily Managing LID Practices



LID Barrier Busters Fact Sheet Series

Communities contemplating "green" LID approaches may be concerned that maintenance costs will grow as a result of switching from traditional "grey" stormwater practices. While this may be true in some cases, in general LID practices have lower long-term life-cycle costs, perform better, and provide additional benefits such as improved aesthetics and enhanced property values. Communities that install traditional "grey" stormwater infrastructure (curbs, pipes, tanks, etc.) typically look only at the initial capital costs of installing the practices and do not evaluate the performance of the systems or fully account for operation and maintenance costs such as pond dredging and water quality inlet pumping and residuals disposal. In contrast, LID practices typically require a lower initial investment and more ongoing maintenance—especially in the early years as vegetation becomes established in bioretention areas. Once established, LID practices can often be maintained in the same manner as other landscaping elements that require mowing, weeding and debris removal (Figures 1 and 2). Note that permeable pavement requires frequent vacuum sweeping to maintain water quality benefits, result in cost savings by avoiding the land space and costs needed to

#### FAQ

Aren't maintenance costs for LID still unknown?

**Barrier Busted!**  
Results show that life cycle costs of LID are usually less than traditional practices.



#### Green Values® Calculator

<http://greenvalues.epa.org/national/calculator.php>  
Developed by the Center for Neighborhood Technology, this online tool guides users through a process to determine the performance, costs and benefits of LID/green infrastructure practices as compared to conventional stormwater management practices.

#### What Can Your Community Do to Ensure Maintenance of LID Practices?

As communities rely more on LID, they must adapt to managing practices that are dispersed across the landscape rather than aggregated in a few locations. Portland, Oregon, employs staff to oversee both the installation and maintenance of LID practices (Figure 3). The city hires landscaping companies to regularly check that the practices are functioning properly and to remove built-up debris and unwanted vegetation. The city also encourages community involvement, inviting residents to volunteer as Green Street Stewards to help watch over and maintain these sites on a daily basis—clearing debris after storms and watering plants in dry lines (Figure 4). By providing a consistent city-wide maintenance program and engaging volunteers, Portland has adapted well to its changing stormwater management needs.

Some municipalities rely on property owners or homeowners' associations to maintain the LID practices that are on private property. Before installing a LID practice, a municipality or developer should establish clear ownership of the practice and designate operation and maintenance responsibilities clearly through a written agreement. To formalize this approach, some municipalities have established ordinances requiring BMP maintenance (see <http://water.epa.gov/pressroom/stormwater.cfm>). Focusing LID on public rights-of-way can help ensure that maintenance occurs.

Education can improve maintenance of LID practices. In 2007 the North Carolina State University Cooperative Extension Service developed a 1.5-day stormwater BMP inspection and maintenance training program—since then, more than 1,250 local government officials, design professionals and landscape maintenance practitioners from across the United States have taken part (see [www.bae.ncsu.edu/topic/lid/](http://www.bae.ncsu.edu/topic/lid/)). For access to the most recent information on LID maintenance available, check [www.epa.gov/govinfo](http://www.epa.gov/govinfo) and [www.epa.gov/greeninfrastructure](http://www.epa.gov/greeninfrastructure).



Figure 3: This stormwater planter is one of a suite of dispersed stormwater management practices that Portland, Oregon, city employees help to manage.



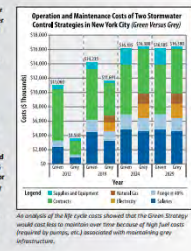
Figure 4: Volunteers with Portland's Green Street Stewards program care for a LID feature in their neighborhood by removing debris and weeding.

#### New York City's Green Strategy Will Pay Off Over Time

In 2010 New York City released a green infrastructure plan that outlines options for adding LID practices such as swales and green roofs to help reduce combined sewer overflows (CSO) and protect water quality. Modeling and data analyses conducted during development showed that operating and maintaining the green infrastructure elements of the plan (the "Green Strategy") will be higher in the initial years as these controls are built quickly, while operating and maintaining the grey infrastructure (the "Grey Strategy") will be higher in the long run as large tanks, tunnels and expansion costs come online over time.

By 2034, New York City would pay about \$200,000 less annually to operate and maintain the Green Strategy as compared to the Grey Strategy. Over a 20-year period, the New York Department of Environmental Protection estimates that the Green Strategy will reduce CSO volumes by nearly 2 billion gallons more than could be achieved by the Grey Strategy. In total, the Green Strategy would cost approximately \$5.3 billion, about \$1.5 billion less than the \$6.8 billion required for the Grey Strategy. Plus, the Green Strategy provides additional valuable benefits not provided by the Grey Strategy, including improved neighborhood aesthetics, lower summer temperatures, reduced energy use, cleaner air and water, and increased property values.

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An analysis of the life cycle costs showed that the Green Strategy would cost less to maintain over time because of high first costs (associated with tanks, etc.) associated with maintaining grey infrastructure.

[www.epa.gov/green-infrastructure/overcoming-barriers-green-infrastructure](http://www.epa.gov/green-infrastructure/overcoming-barriers-green-infrastructure)



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# Funding for Green Infrastructure

*Implementing Green Infrastructure*

- US Environmental Protection Agency
- NOAA
- Federal Emergency Management Agency
- National Park Service
- National Endowment for the Arts
- US Department of Transportation
- Economic Development Administration
- National Recreation and Parks Association
- Funders Network for Smart Growth and Livable Communities
- Qualified Energy Conservation Bonds



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# ***Table Discussion 3***

## *Implementing Green Infrastructure*

- **Part 1**: What barriers have you run into around implementing green infrastructure?
- **Part 2**: How can you overcome these barriers?



# One Last Thing . . .



***Please fill out the Evaluation!***

**<http://bit.ly/2np6HNq>**



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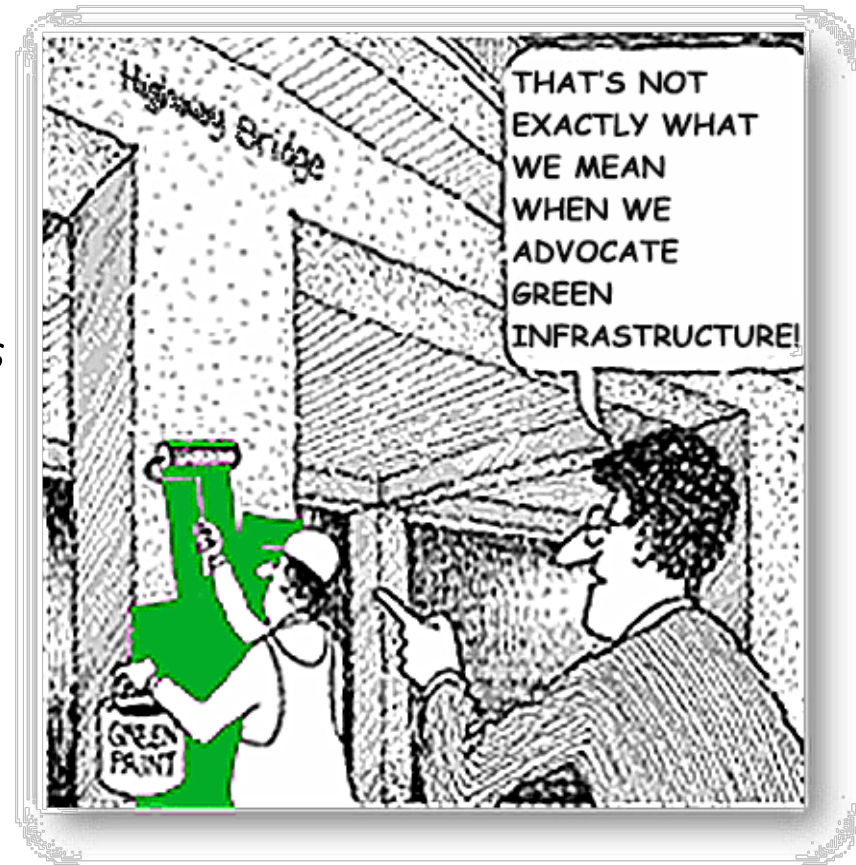


# Thank You!

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