

# **Green Infrastructure for Coastal Resilience**

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



# What Is “Resilience”?

*Introducing Green Infrastructure for Coastal Resilience*



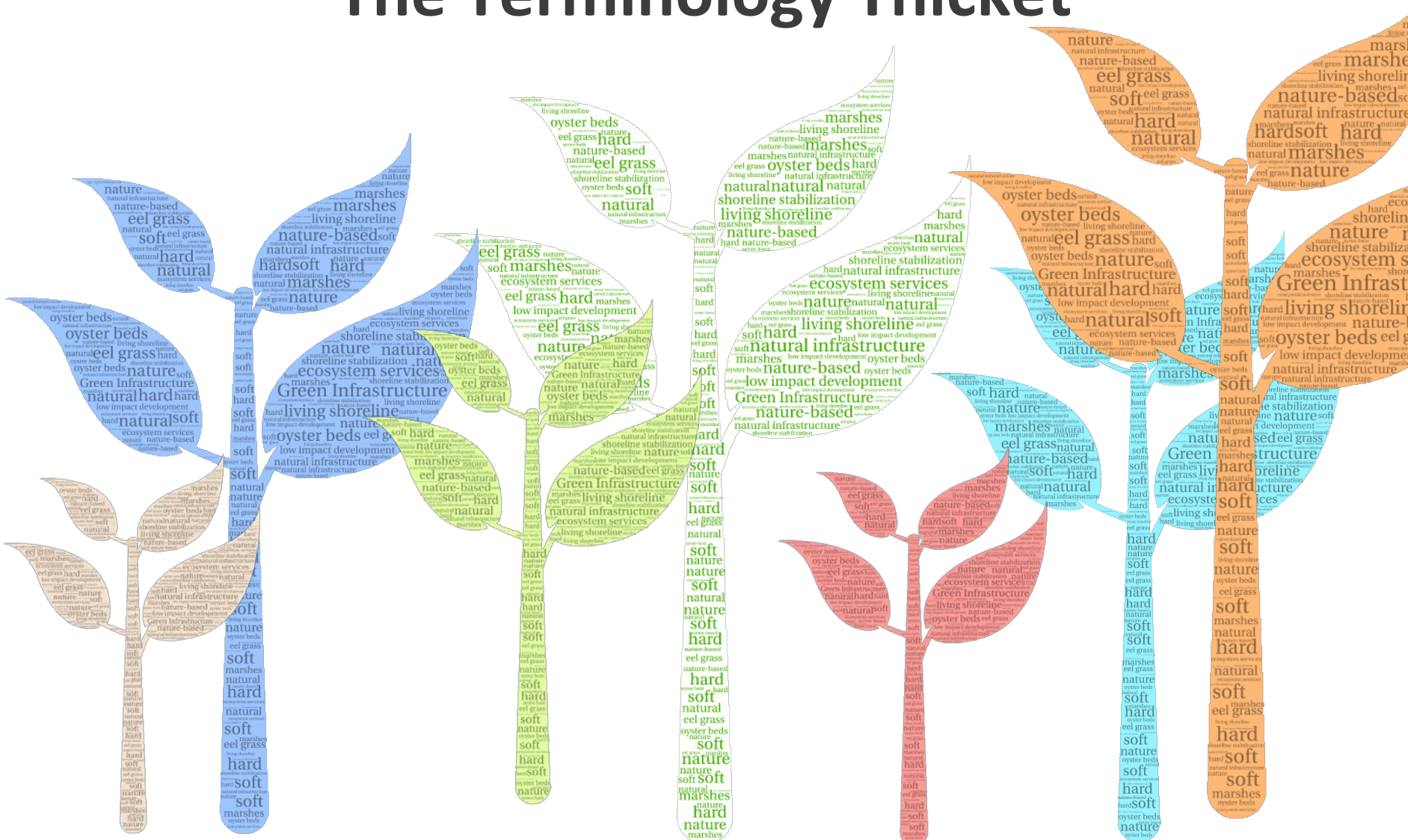
“Resilience is our ability to prevent a short-term hazard event from turning into a long-term community-wide disaster.”

# Section 1

## Green Infrastructure Concepts and Principles



# The Terminology Thicket



# Foundations of Green Infrastructure

*Green Infrastructure Concepts and Principles*

Landscape approach?



Site-level approach?



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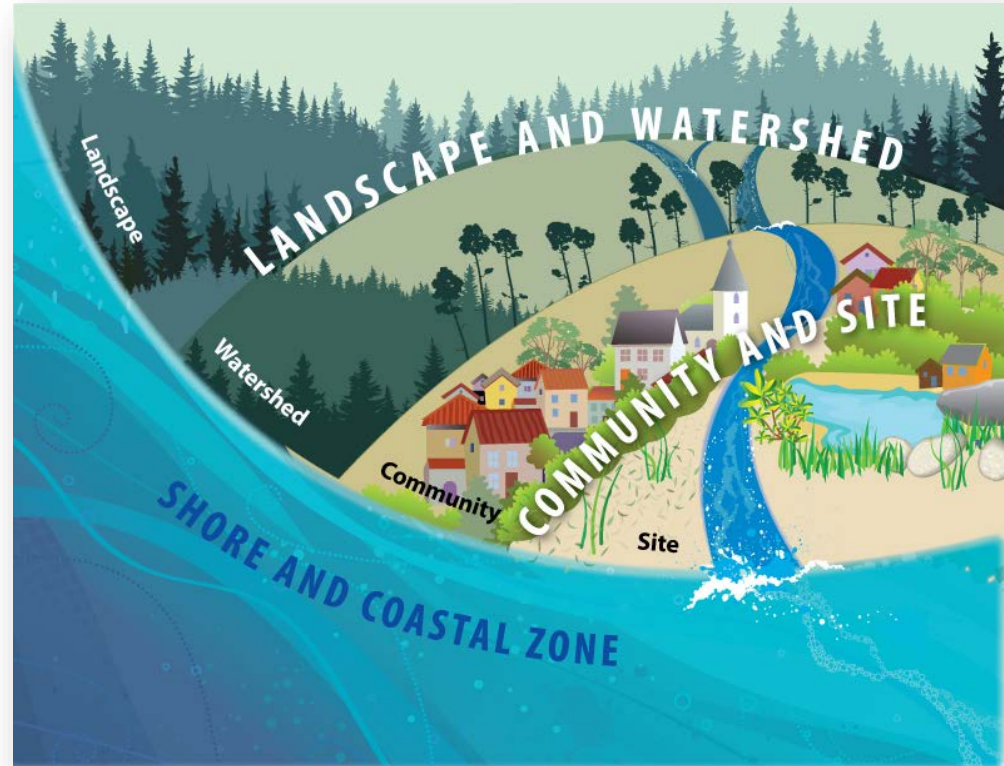
# Applicability across Scales

*Green Infrastructure Concepts and Principles*

Landscape and watershed

Community and site

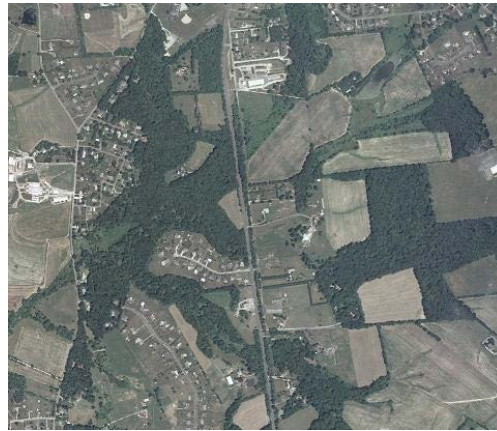
Shore and coastal zone



# Importance of Context

*Green Infrastructure Concepts and Principles*

Green infrastructure practices are context sensitive.



Rural

Urban

Coastal

Upland



# Why Green Infrastructure?

*Green Infrastructure Concepts and Principles*



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# Why Green Infrastructure?

## Green Infrastructure Concepts and Principles

11/15/2017 Saved by Sand Dunes – Cool Green Science

# Cool Green Science

Smarter By Nature

| CLIMATE CHANGE |

## Saved by Sand Dunes

BY CARA BYINGTON  
OCTOBER 24, 2017 | Follow Cara



Houses behind the dunes at Midway Beach on the Jersey Shore © Cara Byington/TNC


### A Hurricane Sandy Story

This is a story of nature's defense against nature's strength, and it plays out behind the sprawling sand dunes that separate the neighboring Jersey Shore communities of Midway Beach and South Seaside Park from the sea.

<https://blog.nature.org/science/2017/10/24/saved-by-the-dunes/?arc=cs>

1/8

11/15/2017 Saved by Sand Dunes – Cool Green Science



Aerial views of damage from Hurricane Sandy taken during a search and rescue mission by 1-150 Assault Helicopter Battalion, New Jersey Army National Guard, Oct. 30, 2012. The Seaside Heights' Jet Star roller coaster was left stranded in the ocean after Casino Pier was destroyed by the storm. © Master Sgt. Mark C. Olsen/U.S. Air Force/New Jersey National Guard

community immediately. "The only logical explanation for why we weren't like everywhere else," he says, "was because we had a dune system that was able to protect us from that ocean surge."

Still, while the violence of the storm may not have shown itself in the destruction of their homes, their dunes were a much different story. A quick survey revealed how much sand and vegetation Sandy scoured away from dunes that had – before the storm – been 25 feet tall and 125-feet wide. It was a sobering glimpse of the power of the storm surge the dunes had absorbed and deflected from the homes behind them.

If members of the community had once privately lamented the loss of ocean views as the dunes grew over the years, they don't anymore. "Sandy really was the turning point about the choice between having dunes and having ocean views," says Solazzo. "Now, post-Sandy, it's a different understanding. The community is totally engaged and is totally bought into the idea that these dunes are the lifeline of our existence on a barrier island."

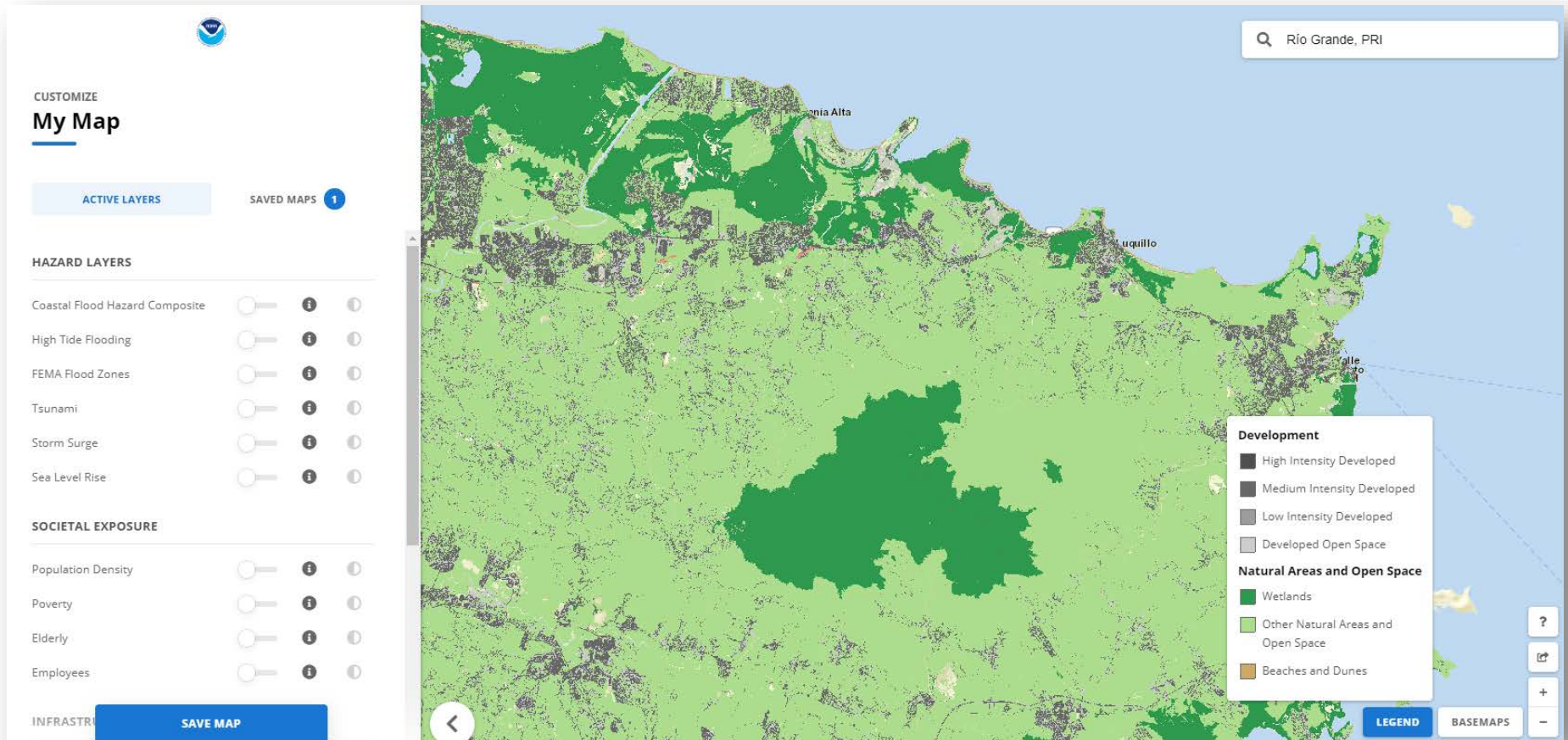
<https://blog.nature.org/science/2017/10/24/saved-by-the-dunes/?arc=cs>

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<https://blog.nature.org/science/2017/10/24/saved-by-the-dunes/>

# Exposure to Coastal Hazards

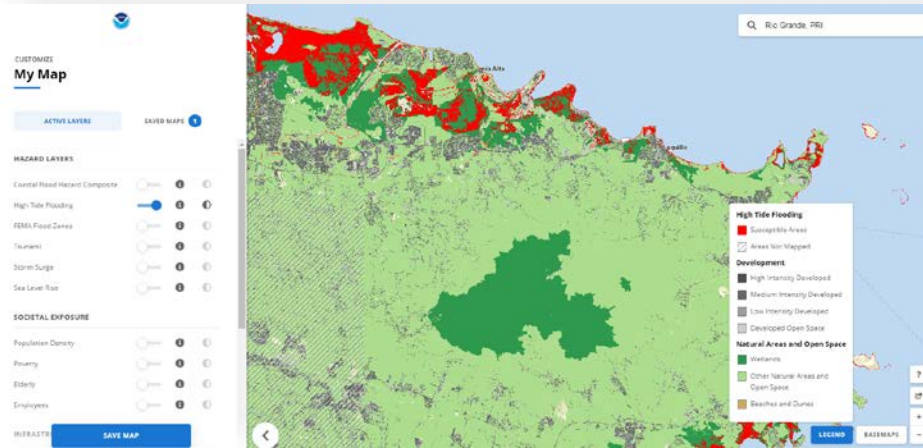
## *Green Infrastructure Concepts and Principles*



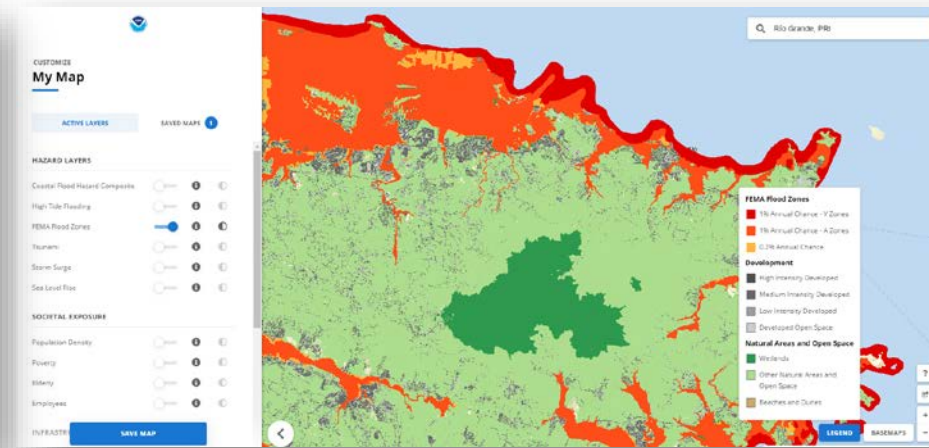
[coast.noaa.gov/digitalcoast/tools/flood-exposure](https://coast.noaa.gov/digitalcoast/tools/flood-exposure)

# Exposure to Coastal Hazards

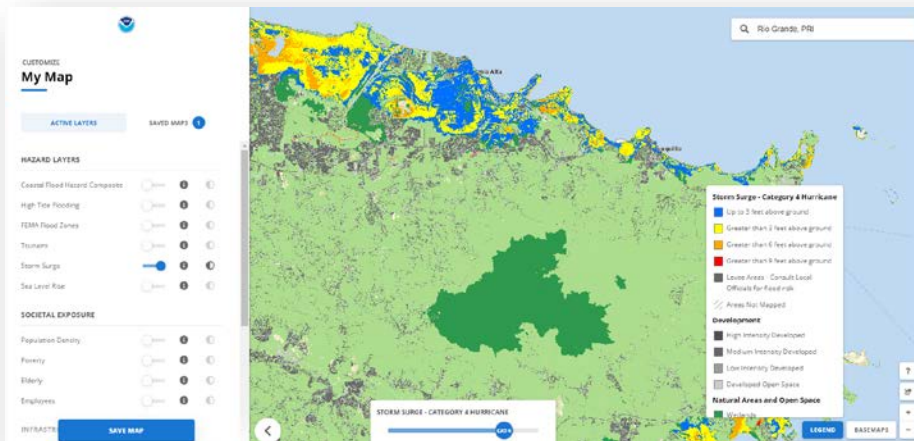
*Green Infrastructure Concepts and Principles*



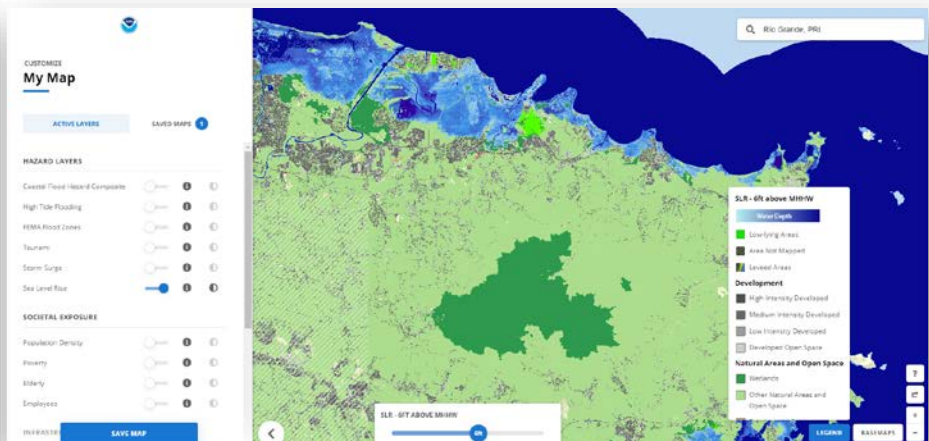
**High Tide Flooding**



**FEMA Flood Zones**



**Storm Surge**



**Sea Level Rise**

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

# Ecosystem Services

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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



## Section 2

# The Practice of Green Infrastructure



# Planning Concepts

*The Practice of Green Infrastructure*

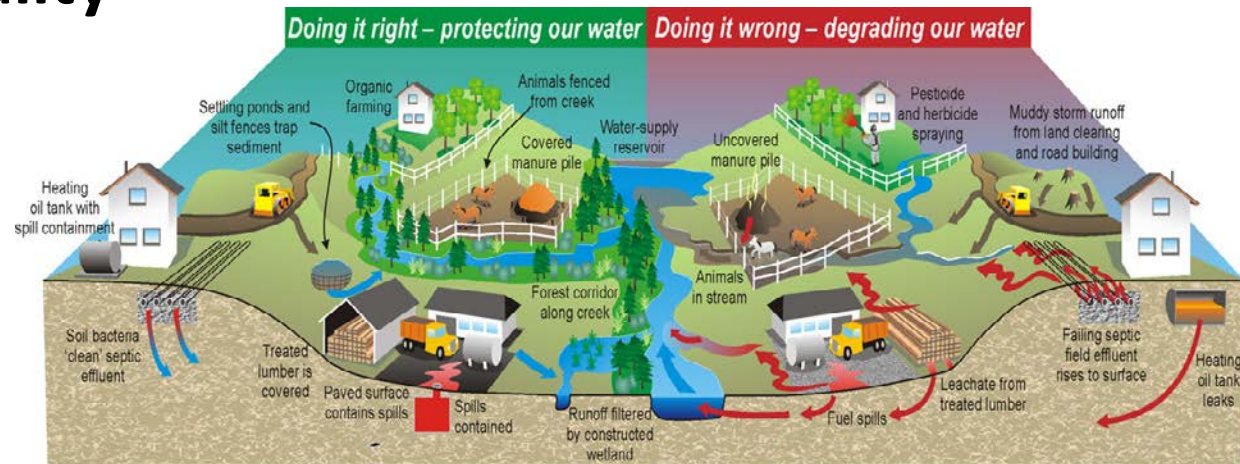
- **Scale**
- **Service**
- **Science**



# Design Concepts

*The Practice of Green Infrastructure*

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





# Green Infrastructure in Practice

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Landscape and  
watershed

Community  
and site







Shore and  
coastal zone



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# Landscape Design Concepts

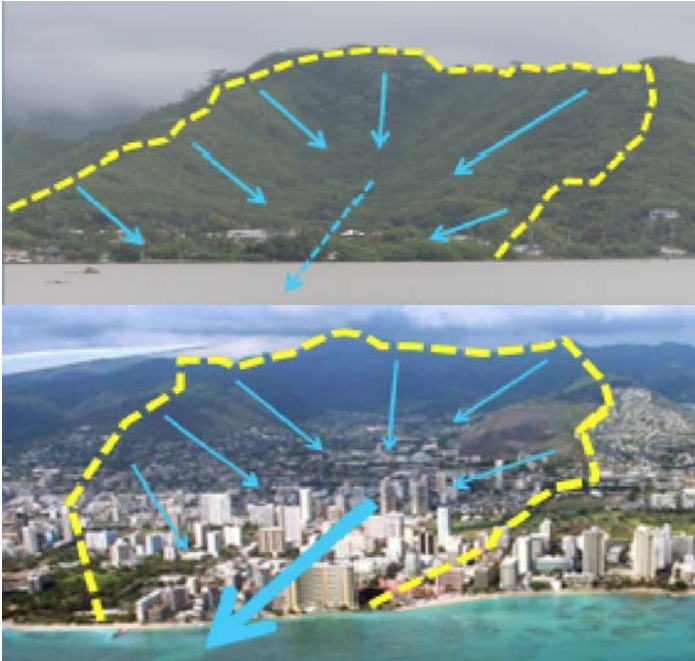
*The Practice of Green Infrastructure*

|              | BETTER  | WORSE  |
|--------------|---|--|
| Area         |   |   |
| Proximity    |   |   |
| Connectivity |  |  |



# Watershed Design Concepts

*The Practice of Green Infrastructure*



Source: Horsley Witten Group; Center for Watershed Protection

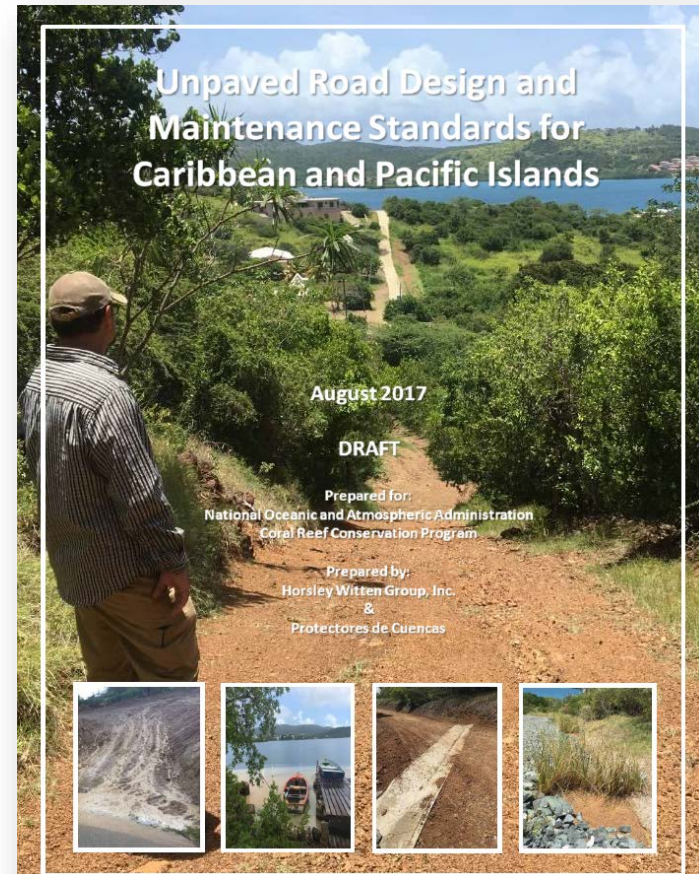
- Preserve native vegetation
- Protect steep slopes
- Buffer stream channels
- Reduce connected impervious cover
- Seek multiple benefits



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# Watershed Design Concepts

*The Practice of Green Infrastructure*



[https://data.nodc.noaa.gov/coris/library/NOAA/CRCP/NMFS/OHC/Projects/30033/HorsleyWittenGroup2017\\_Island\\_Unpaved\\_Road\\_Standards.pdf](https://data.nodc.noaa.gov/coris/library/NOAA/CRCP/NMFS/OHC/Projects/30033/HorsleyWittenGroup2017_Island_Unpaved_Road_Standards.pdf)

# Landscape Approaches and Resilience

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- 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 reduces 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

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- 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

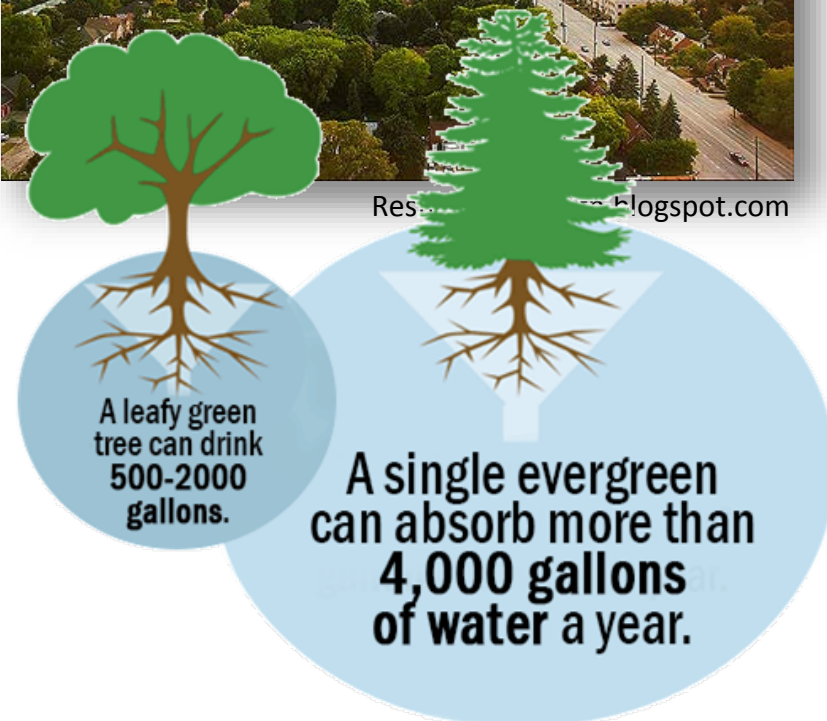


# Community and Site Approaches

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## 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



# 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



# Community and Site Approaches

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## 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



# Community and Site Approaches

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Culebra,  
Puerto Rico



Stormwater  
runoff  
damaging  
coral reefs



Before

After

<https://oceanservice.noaa.gov/news/feb16/reef-to-ridge-conservation.html>

# Community and Site Approaches

## The Practice of Green Infrastructure

### Stormwater Management in Pacific and Caribbean Islands: A Practitioner's Guide to Implementing LID

February 2014

Prepared for:  
NOAA Coral Reef Conservation Program

Prepared by:  
Horsley Witten Group, Inc. and  
Center for Watershed Protection, Inc.

STORM DRAIN

### Chapter 1 Island Stormwater Management

The fundamental concepts of stormwater management on tropical islands are not entirely different from other regions. Water still flows downhill. Flood control is still an engineering priority. Impervious cover and compacted soils still generate surface runoff, and that runoff is still contaminated. Recharge remains an important strategy for sustaining groundwater supplies in the long-term, and removing pollutants prior to discharge is critical to protecting the quality of receiving waters. Island watersheds respond negatively when the natural hydrology is altered by human activities.

It is true, however, that precipitation frequencies and intensities in the tropics differ from more temperate regions; best management practice (BMP) selection and design will require special attention depending on location or unique climatic conditions, and some construction materials may have to travel great distances. Economically important coral reefs, sea urchin grazing water columns, and more mangroves on coral ponds are often the downstream receiving waters. Strategic infrastructure, where it exists, is often designed and constructed based on available space and materials rather than a preferred set of design standards. In fact, there may not be any local stormwater standards to guide engineers on how to use and design BMPs. Lack of design standards may lead to the proliferation of contaminated stormwater into groundwater supplies, the undersizing of practices, or nonuse.

Island Stormwater Management

### Chapter 2.0 Methods for Stormwater BMP Design

This chapter contains a "typical" stormwater best management practice (BMP) design method, beginning with identifying big picture management objectives and ending with a detailed BMP design. This can be considered a generic method that can be adapted to the needs of each individual jurisdiction.

Obviously, several jurisdictions already have stormwater regulations and/or associated design manuals, so it is not the intent of this chapter to duplicate those existing resources. Rather, the method is a structured, step-by-step process so that all stakeholders involved in stormwater BMP planning and design can find common ground as they move from idea to implementation. It is not anticipated that all stormwater projects will use ALL six steps outlined below, as the method can be tailored to local needs. The six steps include:

1. Identify Management Objectives
2. Develop Performance Standards Based on Management Objectives
3. Select Candidate Structural & Non-Structural BMPs
4. Determine Sizing & Volume for BMPs
5. Allocate Storage to Various Components of Your BMP Design
6. Address Other BMP Design Elements

Method for Stormwater BMP Design

### Chapter 3.0 Using Vegetated Areas to Manage Stormwater

Most sites have areas of vegetation or turf grass that serve as aesthetic landscaping, barriers between parking stalls and driving aisles, buffers between adjacent land uses, or recreational open spaces. Many of these areas can also provide stormwater management benefits without compromising other functions or significantly increasing overall site maintenance costs. Plants can absorb a tremendous amount of water, take up pollutants, and transport water vapor back into the atmosphere. Roots help water infiltrate into the ground and provide surface area for microbes that can remove contaminants. Soils can filter the runoff, removing pollutants before recharging the groundwater. Vegetation can also provide shade and cleaner air for humans, and habitat for wildlife.

In addition, as designers or practitioners interested in retrofitting an existing site taking advantage of stormwater as a resource that can reduce irrigation needs and increase site services can be a winning strategy—particularly if you site is on the edge of the island or if you are limited in your vegetation options due to seasonal capital patterns. Existing open spaces can offer the ideal locations for cost effective stormwater benefits. In some cases, if you need a shadow, some plants, and a few friends!

This chapter aims to help you envision the typical vegetated areas at a site as multifunctional landscapes integral to LID objectives.

Using Vegetated Areas

### Chapter 4 Rethinking Parking Lots and other Hardscapes

Parking lots, roads, highways, and other hardscapes often consume a high percentage of a site's development envelope. These surfaces are impervious and generate surface stormwater runoff when it rains. Interestingly, runoff from such is generally viewed as a nuisance, while runoff from parking lots and other paved areas is considered a nuisance to the specific community off site. On many islands, rooftops are frequently used to harvest rainwater for on-site use. For both potable and non-potable reuse. Alternatively, pavements are generally designed exclusively for transport and parking of vehicles and provision of pedestrian walkways with little consideration of hydrologic impacts. Composites of concrete, asphalt, compacted gravel, or crushed coral, the runoff generated from these surfaces is often contaminated by oils, heavy metals, trash, and other pollutants that have collected on the pavement.

Given that these hardscapes take up significant acreages of the developed landscape and generate excessive runoff and pollutant loads, it makes sense to rethink how these areas can be more effectively utilized to meet vehicular needs, pedestrian access, water supply, and stormwater management functions. This can be done with a series of common sense approaches to parking lot, street, driveway, and roof design that maintain function and safety while reducing that amount of runoff that must be managed by other practices.

Rethinking Parking Lots

### Chapter 5 Improving Treatment Capacity of Existing Basins

Many jurisdictions already have an array of existing stormwater management practices, both new and old. Existing BMPs may include ponding basins, detention ponds, or sediment basins. Often, these practices were designed using older standards to address flooding or to control erosion during construction, but not long-term water quality treatment. In northern Guam, for example, ponding basins over-accumulate algal blooms, and have the potential to erode and pollute runoff into drinking water aquifers. In addition, many existing basins do not perform as designed due to lack of maintenance (e.g., clogging, filling with sediment and unmanaged vegetation, or bypassing, under sizing and/or substandard construction).

These existing practices are ideal candidates for retrofitting in order to improve water quality treatment. This can be done in the context of a redevelopment project or as part of a more holistic watershed restoration plan. Benefits of reworking ponding basins and other practices can be used to enhance water quality treatment, ensure that sedimented stormwater does not contaminate groundwater, and provide downstream benefits for flood and channel protection. It is important with retrofits to investigate and understand the treatment objectives of the existing practice. For instance, if a BMP is providing storage to

Rethinking Existing Stormwater Practices

# 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%.



# 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

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## Natural or Nature-based



### **Dune and Beach Creation**

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



### **Salt Marshes, Wetlands, Vegetation, Mangroves, SAV**

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



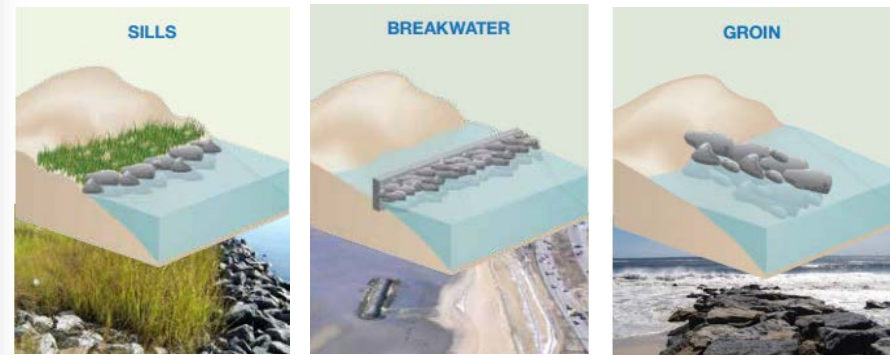
### **Oyster and Coral Reefs**

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

# Shoreline Approaches

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## 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



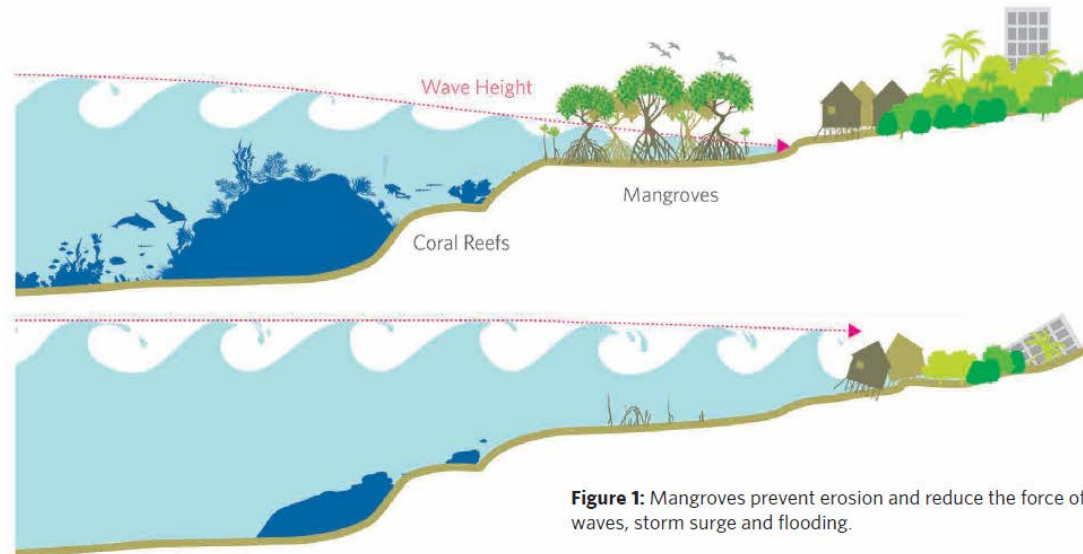
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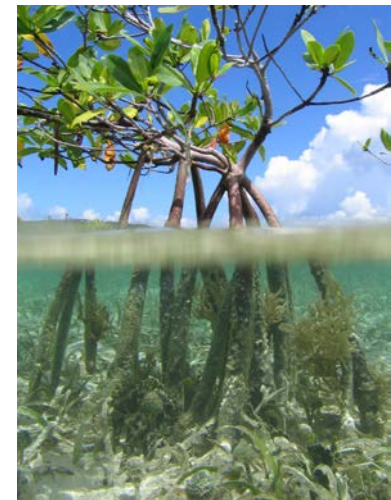
# Landscape Approaches and Resilience

*The Practice of Green Infrastructure*

- Recent study on flood reduction benefits of mangroves:
  - A **500 meter wide** mangrove forest can reduce wave heights by **50-100%**
  - Mangroves reduce annual flooding to more than **18 million** people.
  - Without mangroves, **39%** more people would flood annually, increasing flood damages by **16%** or **\$82 billion**.



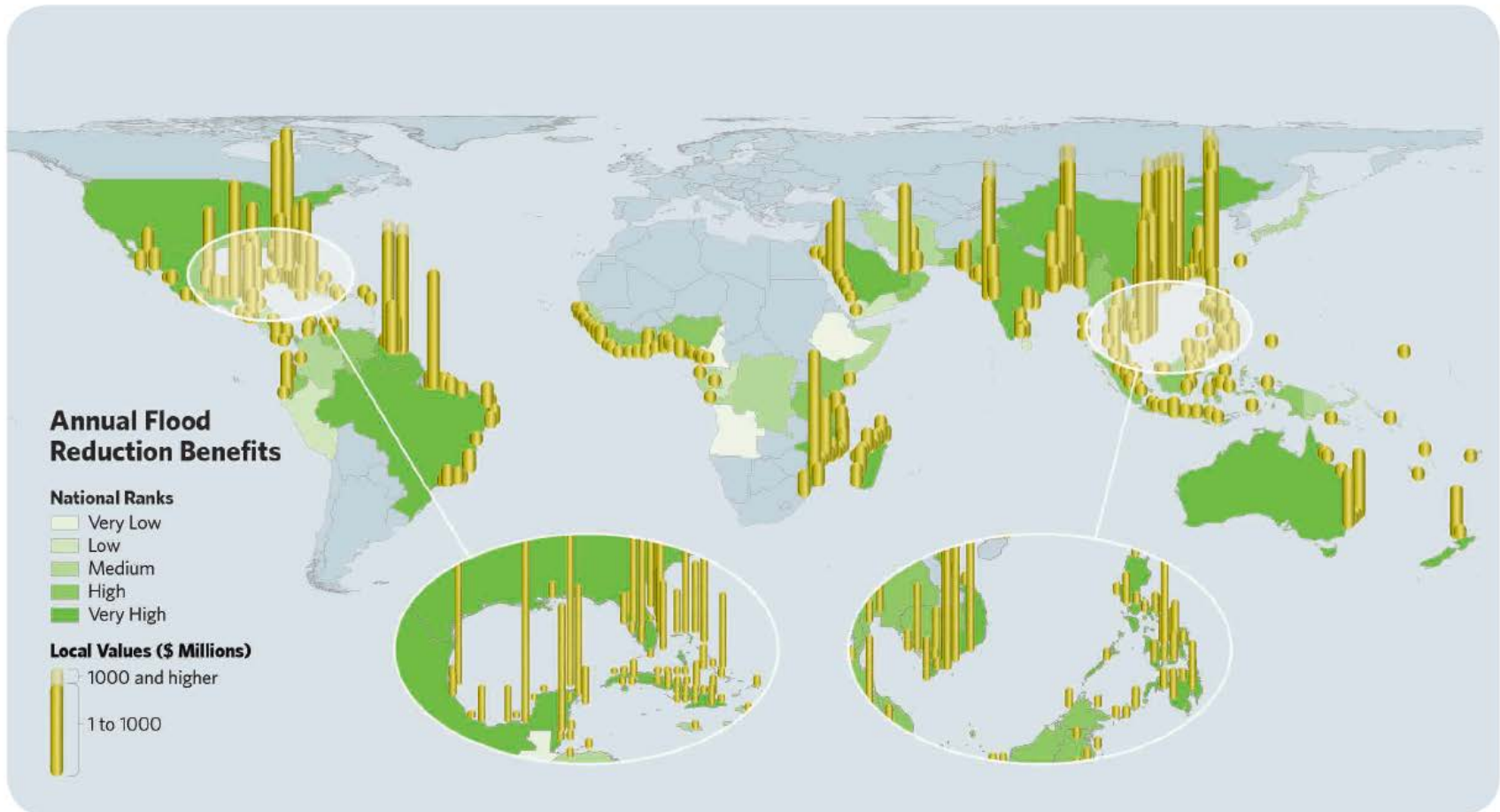
**Figure 1:** Mangroves prevent erosion and reduce the force of waves, storm surge and flooding.



[nature.org/GlobalMangrovesRiskReductionSummaryReport](https://www.nature.org/GlobalMangrovesRiskReductionSummaryReport) and  
[nature.org/GlobalMangrovesRiskReductionTechnicalReport](https://www.nature.org/GlobalMangrovesRiskReductionTechnicalReport)

# Landscape Approaches and Resilience

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**Figure 4:** The map shows where mangroves provide the greatest flood reduction benefits for property. The values represent the difference in annual expected damages in US \$ millions with and without mangroves per 100 km of coast.

[nature.org/GlobalMangrovesRiskReductionSummaryReport](https://www.nature.org/GlobalMangrovesRiskReductionSummaryReport) and  
[nature.org/GlobalMangrovesRiskReductionTechnicalReport](https://www.nature.org/GlobalMangrovesRiskReductionTechnicalReport)

# Shoreline Approaches and Resilience

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Hurricane Irene, North Carolina

76% of bulkheads were damaged in the storm



No damage occurred to shorelines with or without sills



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

# Green Infrastructure and Resilience

*The Practice of Green Infrastructure*

## Green Infrastructure Effectiveness Database

This database is a compilation of literature resources documenting the effectiveness of using green infrastructure to reduce impacts from coastal hazards.

**i** Please fill in one or more fields below to narrow the search. Use quotes to search for an exact phrase. [Return to basic search](#) ▲

|                 |   |                            |  |
|-----------------|---|----------------------------|--|
| Title:          | <input type="text" value="Enter a (partial) title"/>                | Green Infrastructure Type: | <input type="text" value="Coral reef"/>  |
| Author(s):      | <input type="text" value="e.g. author(s), comma separated"/>        | Hazards:                   | <input type="text"/>                     |
| Year published: | <input type="text" value="1980"/> <input type="text" value="2016"/> | Methodological Approaches: | <input type="text"/>                     |
| Source:         | <input type="text" value="e.g. journal name"/>                      | Study Scale:               | <input type="text"/>                     |
| Source Type:    | <input type="text"/>  | Region:                    | <input type="text" value="Caribbean"/>   |
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[Clear form](#)

Search

# Green Infrastructure and Resilience

## *The Practice of Green Infrastructure*

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| Source Type: | <input type="text" value=""/>                                 | Region:      | <input type="text" value="Caribbean"/>   |
| Keywords:    | <input type="text" value="e.g. keyword(s), comma separated"/> | State:       | <input type="text" value="Puerto Rico"/> |

[Clear form](#)

Search

1 resources found.

Sort by:

### Community Based Coral Reef Rehabilitation in a Changing Climate: Lessons learned from hurricanes, extreme rainfall, and changing land use impacts

2014 Peer reviewed Caribbean

Show

*Hernández-Delgado, E.A.; Mercado-Molina, A.E.; Alejandro-Camis, P.J.; Candelas-Sánchez, F.; Fonseca-Miranda, J.S.; González-Ramos, C.M.; Guzmán-Rodríguez, R.; Mège, P.; Montañez-Acuña, A.A.; Maldonado, I.O.; Otaño-Cruz, A.*

The worldwide decline of coral reefs can be slowed by low-tech coral farming and reef rehabilitation methods. Future threats such as climate change, increasing sea surface temperatures, sea level rise, and increasing storm severity will not only impact existing corals but will also impact the ...

Reefs; Flood Percip; Flood Coastal; Field measurements; Erosion; Community outreach; Climate Change

# Green Infrastructure and Resilience

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Source:  Source Type:  Keywords:

1 resources found.

Community Based Coral Reef Rehabilitation in a Changing Climate: Lessons learned from hurricanes, extreme rainfall, and changing land use impacts

2014 Peer reviewed

*Hernández-Delgado, E.A.; Mercado-Molina, A.E.; Alejandro-Camis, P.J.; Candelas-Sánchez, F.; Fonseca-Miranda, J.S.; González-Ramos, C.M.; Guzmán-Rodríguez, R.; Mège, P.; Montañez-Acuña, A.A.; Maldonado, I.O.; Otaño-Cruz, A.*

The worldwide decline of coral reefs due to increasing sea surface temperatures, sea level rise, and increasing ocean acidification.

Reefs; Flood Percip; Flood Coastal

United States Department of Commerce |

← Share

Community Based Coral Reef Rehabilitation in a Changing Climate: Lessons learned from hurricanes, extreme rainfall, and changing land use impacts

🔗 **Link to Resource:** [http://file.scirp.org/Html/6-1380299\\_50930.htm](http://file.scirp.org/Html/6-1380299_50930.htm)

🔍 **Keywords:** Reefs; Flood Percip; Flood Coastal; Field measurements; Erosion; Community outreach; Climate Change

### Basic Information

|                |  |
|----------------|--|
| AUTHOR(S)      | Hernández-Delgado, E.A.; Mercado-Molina, A.E.; Alejandro-Camis, P.J.; Candelas-Sánchez, F.; Fonseca-Miranda, J.S.; González-Ramos, C.M.; Guzmán-Rodríguez, R.; Mège, P.; Montañez-Acuña, A.A.; Maldonado, I.O.; Otaño-Cruz, A. |
| YEAR PUBLISHED | 2014   |
| SOURCE         | Open Journal of Ecology  |
| SOURCE TYPE    | Peer reviewed  |
|                | Hernández-Delgado, Edwin A., Alex E. Mercado-Molina, Pedro J. Alejandro-Camis, Frances Candelas-Sánchez, Jaime S. Fonseca-Miranda, Carmen M. González-Ramos, Roger   |

# Section 3

## Implementing Green Infrastructure



# 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

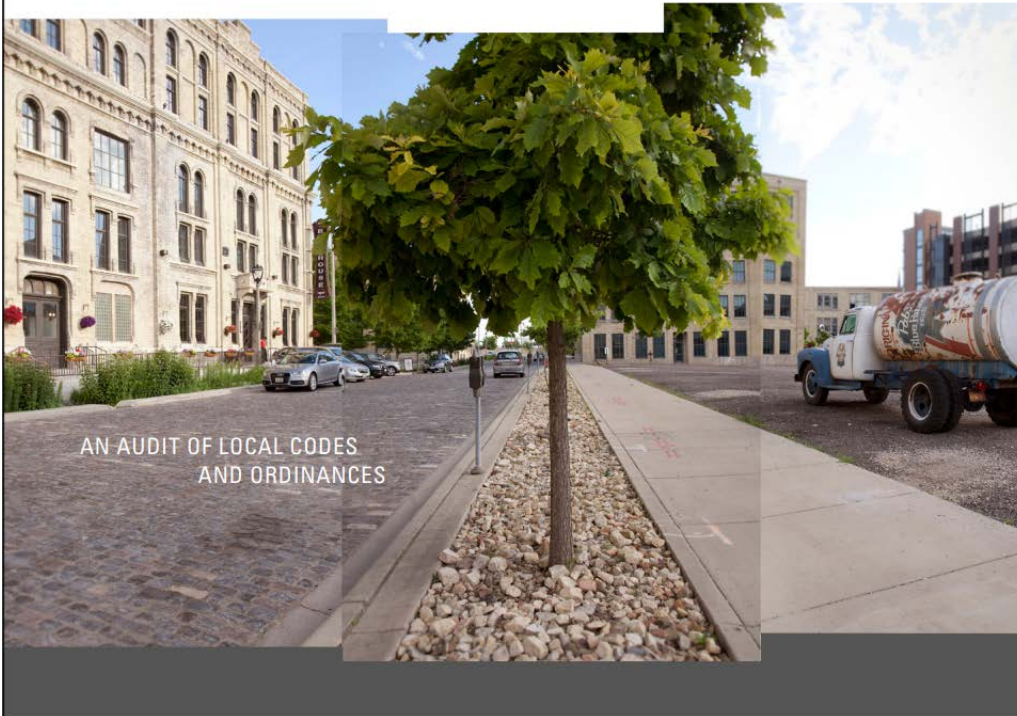




# Local Codes and Ordinances

## Implementing Green Infrastructure

### TACKLING BARRIERS TO Green Infrastructure



[seagrant.wisc.edu/home/Portals/0/Files/Coastal%20Communities/Green\\_Infrastructure/DRAFT\\_GIworkbook\\_complete.pdf](http://seagrant.wisc.edu/home/Portals/0/Files/Coastal%20Communities/Green_Infrastructure/DRAFT_GIworkbook_complete.pdf)

#### WHAT'S THE IMPACT: LANDSCAPING WITH NATIVE GRASSES, TREE PLANTINGS AND BIORETENTION

**Code Revision:** Encourage use of bioretention as landscaping and landscape-based stormwater control

- All yards sodded or seeded on at least 4 inches of topsoil. Rain gardens defined in the Chapter may be incorporated into lawn areas where planned and designed to receive drainage or runoff.
- Trees and shrubbery appropriate for the development, and according to the plan approved under subsection (a) above. The incorporation of arroyo and area stormwater trees, and other vegetative stormwater control measures into landscaping plans is encouraged.

**Site:** Non-residential development (total area 4.12 acres)

- All parking areas drain to bioretention treatment or tree boxes (10,000 square feet)
- Roof-top drains to rain gardens in landscaped areas surrounding building
- Access drive drains through native vegetation filter strip
- All turfgrass replaced with native vegetation

#### (e) Parking Lot Landscaping

- Landscaping shall be provided on the perimeter and within the interior of all parking areas to provide screening, canopy cover, and stormwater treatment and control. The integration of vegetated stormwater control measures with parking lot landscaping is strongly encouraged. All landscaped areas shall be mulched or seeded in keeping with the overall landscaping plan. The Village may maintain a list of accepted species of trees and landscaping materials, including plants and trees suitable for use in vegetated stormwater control measures.
- In parking lots, at least 5% of the interior parking area shall be landscaped with planting, and one tree of a minimum 2-inch caliper, for each 10 spaces, all as shall be submitted and approved as part of the plan provided for herein above. Planting required within the parking lot shall be in addition to, and not in lieu of, other planting requirements, such as for street trees. The planting plan may be varied to accommodate the design of vegetated stormwater control measures, so long as the total number of required trees is met within the overall parking area. The use of deciduous trees (which may function as stormwater trees, as defined in the Chapter) is encouraged to provide canopy shading within parking areas. Each interior landscaped area shall be a minimum of 25 square feet in size.

Runoff volume reduction: **56%**  
Total suspended solids reduction: **64%**

TACKLING BARRIERS TO GREEN INFRASTRUCTURE

WHAT'S THE IMPACT 43

#### Do design standards allow siting of stormwater-control measures along facades?

| Type of Barrier         | Typs   | Code References and Language | Notes, Mess and Strategies | Grade |
|-------------------------|--|------------------------------|----------------------------|-------|
| Design guidelines       | Zoning often will limit the structures that can be attached to a building facade or located within a setback. Codes should specify that rain barrels or cisterns and planter boxes may be sited along facades or extend into setbacks. |                              |                            |       |
| Architectural standards |  |                              |                            |       |
| Zoning setbacks         |  |                              |                            |       |

#### Do standards allow for the waiver of design or architectural provisions to accommodate stormwater-control measures (planters, cisterns, green roofs, etc.)?

| Type of Barrier         | Typs  | Code References and Language | Notes, Mess and Strategies | Grade |
|-------------------------|---|------------------------------|----------------------------|-------|
| Design guidelines       | Where a community provides for waivers of architectural standards, "siting of green infrastructure measures" should be a specific reason for the grant of a waiver. |                              |                            |       |
| Architectural standards |   |                              |                            |       |
| Zoning setbacks         |   |                              |                            |       |

#### Are pitched roofs required? If so, is a waiver or provision for green roofs or rainwater harvesting made?

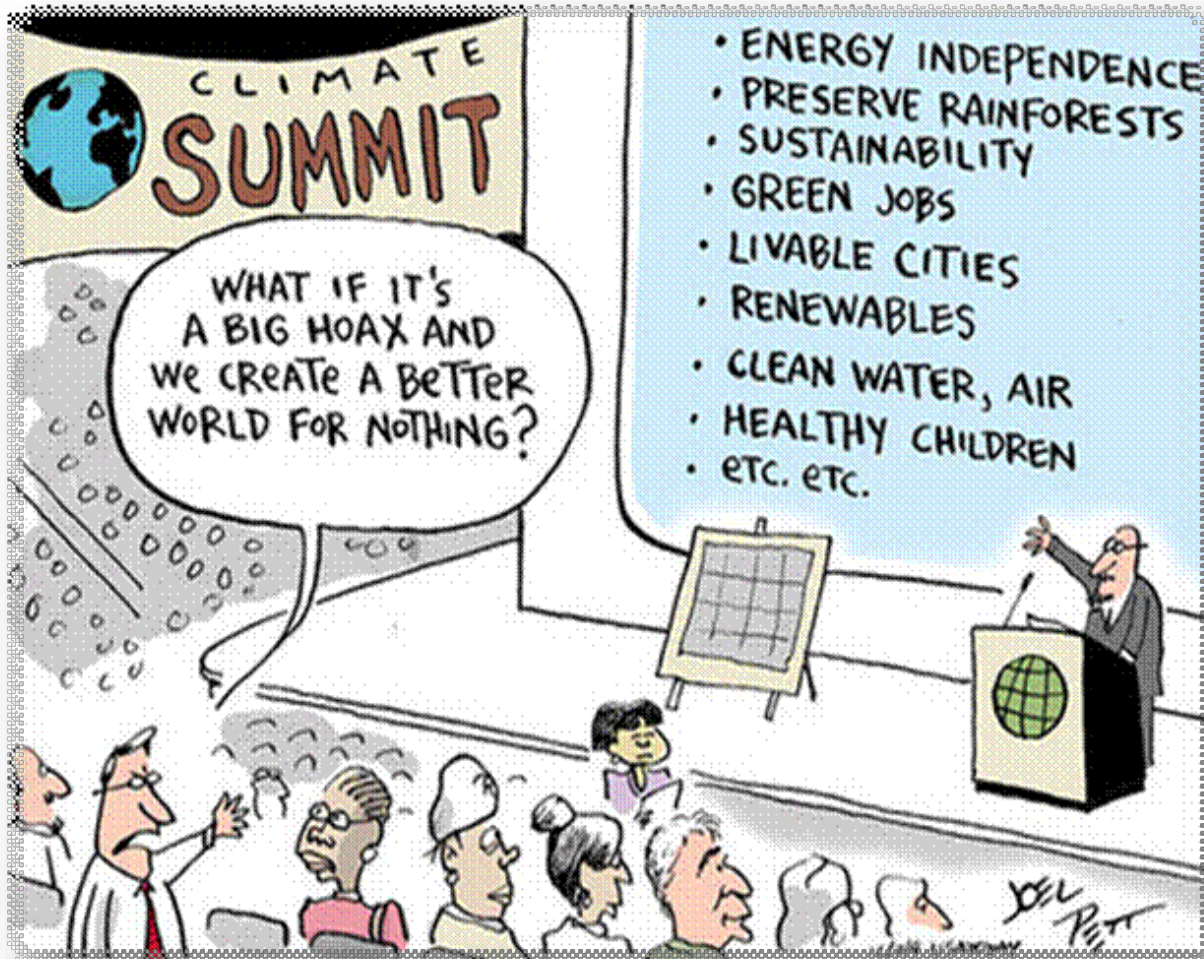
| Type of Barrier         | Typs  | Code References and Language | Notes, Mess and Strategies | Grade |
|-------------------------|---|------------------------------|----------------------------|-------|
| Design guidelines       | If design standards require pitched roofs of a certain slope (i.e., 3:1) or for buildings to match adjacent roof pitches, some allowance for changing pitch should be made for rainwater harvesting or green roof installation. |                              |                            |       |
| Architectural standards |   |                              |                            |       |
| Zoning setbacks         |   |                              |                            |       |

ARCHITECTURAL DESIGN STANDARDS

GREEN INFRASTRUCTURE ASSESS TOOL 43

# Multiple Benefits

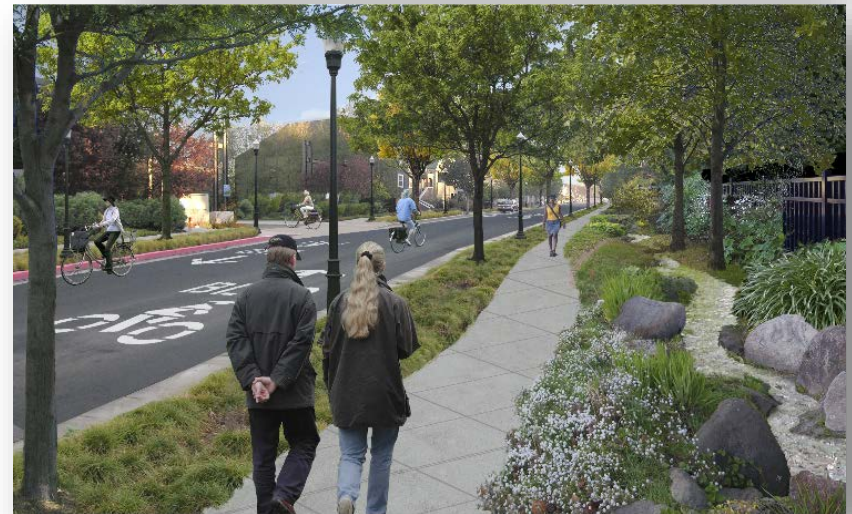
*Implementing Green Infrastructure*



# 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*

Animations!



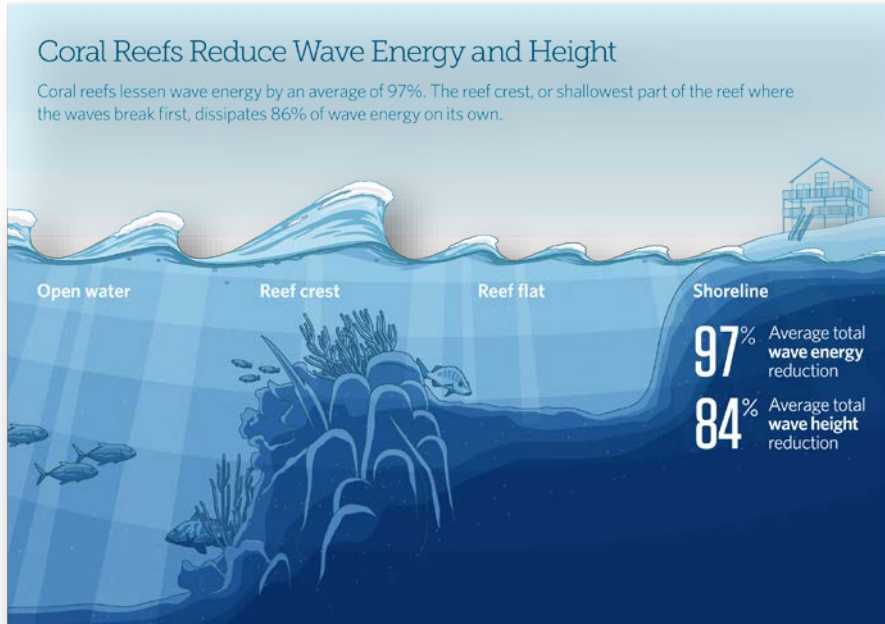
[coast.noaa.gov/digitalcoast/training/gi-animation](https://coast.noaa.gov/digitalcoast/training/gi-animation)



[https://youtu.be/rtyT\\_H8hXzE](https://youtu.be/rtyT_H8hXzE)

# Engaging Stakeholders

Implementing Green Infrastructure



Source: F. Ferrario, M.W. Beck, C.D. Storlazzi, F. Micheli, C.C. Shepard, and L. Airoidi, "The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation," *Nature Communications* (2014), doi: 10.1038/ncomms4794  
© 2014 The Pew Charitable Trusts

[www.pewtrusts.org/en/research-and-analysis/data-visualizations/2014/coral-reefs-reduce-wave-energy-and-height](http://www.pewtrusts.org/en/research-and-analysis/data-visualizations/2014/coral-reefs-reduce-wave-energy-and-height)

## Infographics!



<http://oceanwealth.org/resources/infographics/>

# Engaging Stakeholders

## Implementing Green Infrastructure

Naturally **RESILIENT** Communities

Home Funding Resources **Explore Solutions & Case Studies**

### EXPLORE THE DIFFERENT TYPES OF NATURE-BASED SOLUTIONS

**BIOSWALE**

Bioswales are cost-effective drainage courses with vegetated or permeable materials that concentrate and remove silt and pollution from stormwater runoff.

[LEARN MORE](#)

COASTAL FLOODING & EROSION RIVER FLOODING & EROSION URBAN STORMWATER FLOODING

Naturally **RESILIENT** Communities

Home Funding Resources **Explore Solutions & Case Studies**

### EXPLORE THE DIFFERENT TYPES OF NATURE-BASED SOLUTIONS

COASTAL FLOODING & EROSION RIVER FLOODING & EROSION URBAN STORMWATER FLOODING

### FIND YOUR SOLUTION

**HELP ME CHOOSE**

**Hazard Types**

- Coastal Erosion
- Flood Flooding
- Coastal Flooding
- Riverine Erosion
- Riverine Flooding
- Stormwater Flooding

**Region**

- Coastal West
- Great Lakes
- Gulf of Mexico
- Mid-Atlantic
- Midwest
- Northeast
- Pacific Northwest
- Rocky Mountain West
- Southeast
- Southwest

**Community Type**

- Rural
- Suburban
- Urban

**Scale**

- Community
- Neighborhood
- Site

**SOLUTIONS**  
30 Results

**CASE STUDIES**  
23 Results

**Rivers, Streams, and Floodplains**

Floodplains are the areas of low-lying ground adjacent to rivers, formed mainly...

**Coastal Marshes**

Coastal wetlands occur along marine, estuarine, and freshwater coastlines and may be...

**Beaches and Dunes**

Beaches and dunes occur in a variety of shapes, sizes, compositions, and...

**Mangroves**

Mangroves are a type of coastal or estuarine wetland, characterized by the...

**Seagrasses**

Seagrasses are a type of submerged aquatic vegetation that evolved over time...

**Oyster Reefs**

Oysters are a bivalve shellfish that are often referred to as "ecosystems"...

**Nrcsolutions.org**

# 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).

Office for Coastal Management  
Digital Coast



# 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





# Thank You!

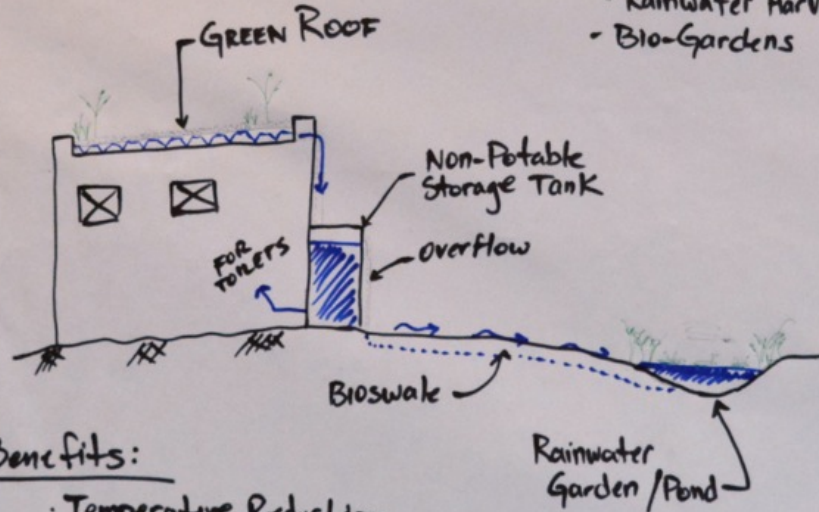
*Stephanie.Bennett@noaa.gov*



TABLE # 5

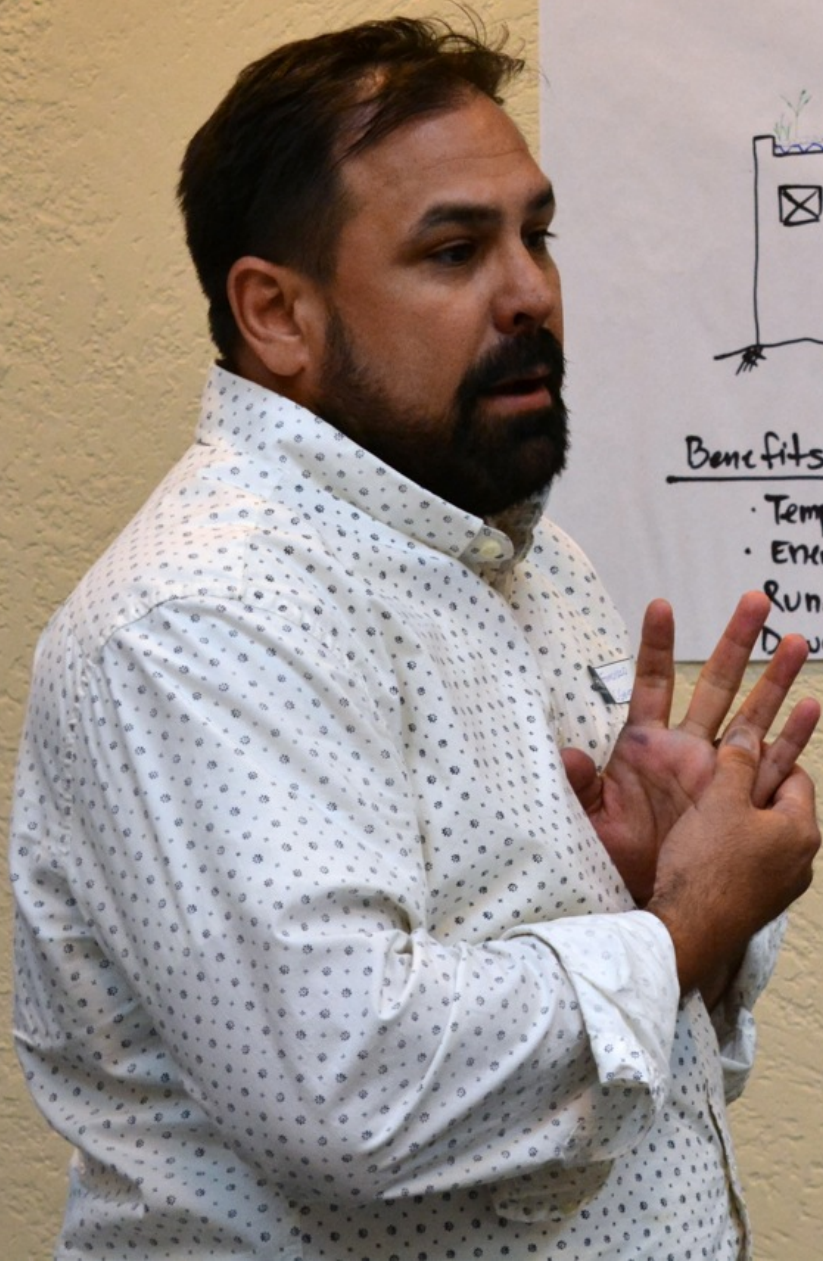
# "DEL CIELO A LA TIERRA"

- Techo Verde
- Rainwater Harvest
- Bio-Gardens



## Benefits:

- Temperature Reduction
- Energy Savings
- Runoff Quantity & Quality Mitigation
- Drought Mitigation
- Biodiversity





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