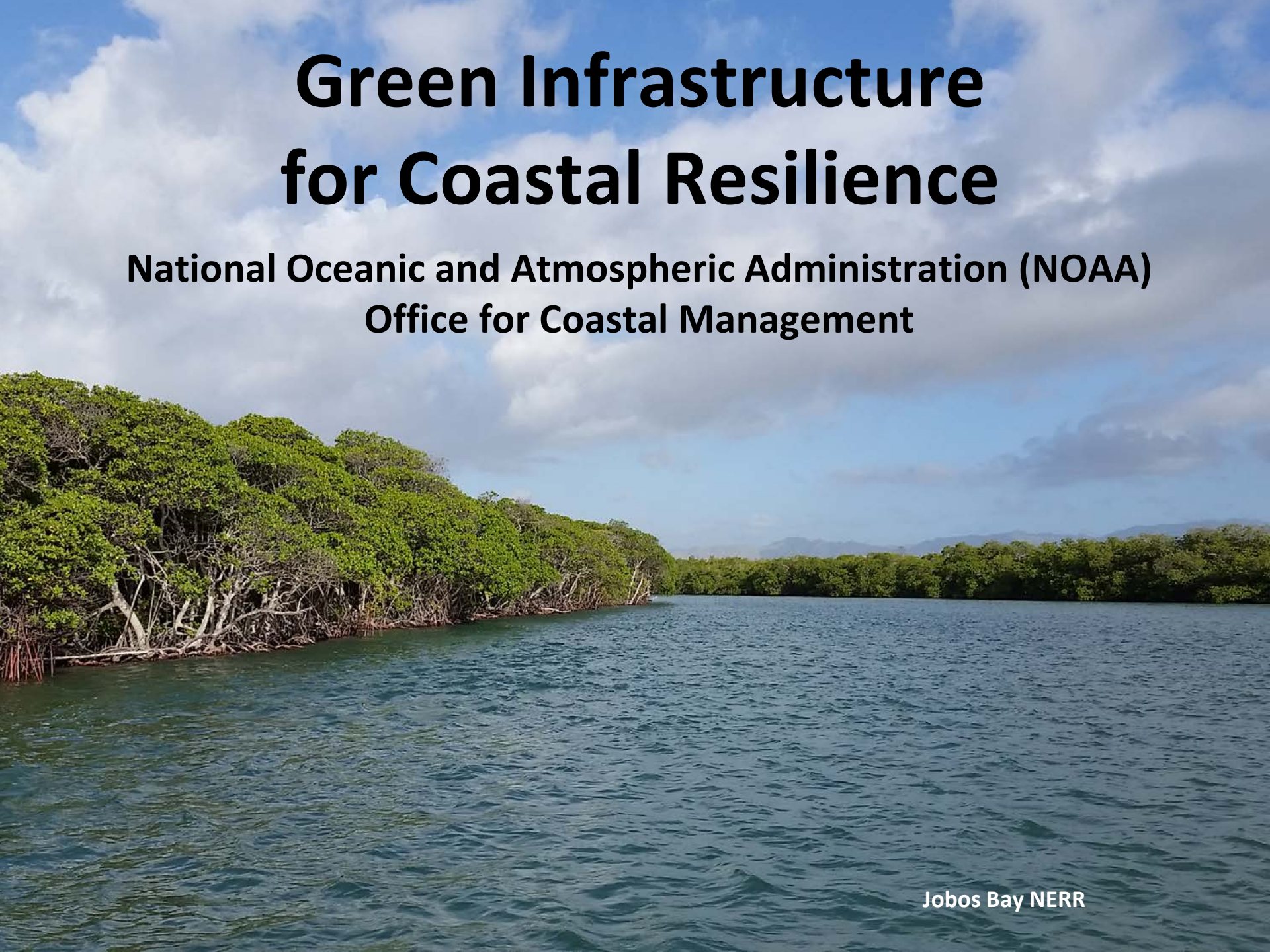
Green Infrastructure for Coastal Resilience

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



Jobos Bay NERR

What Is “Resilience”?

Introducing Green Infrastructure for Coastal Resilience

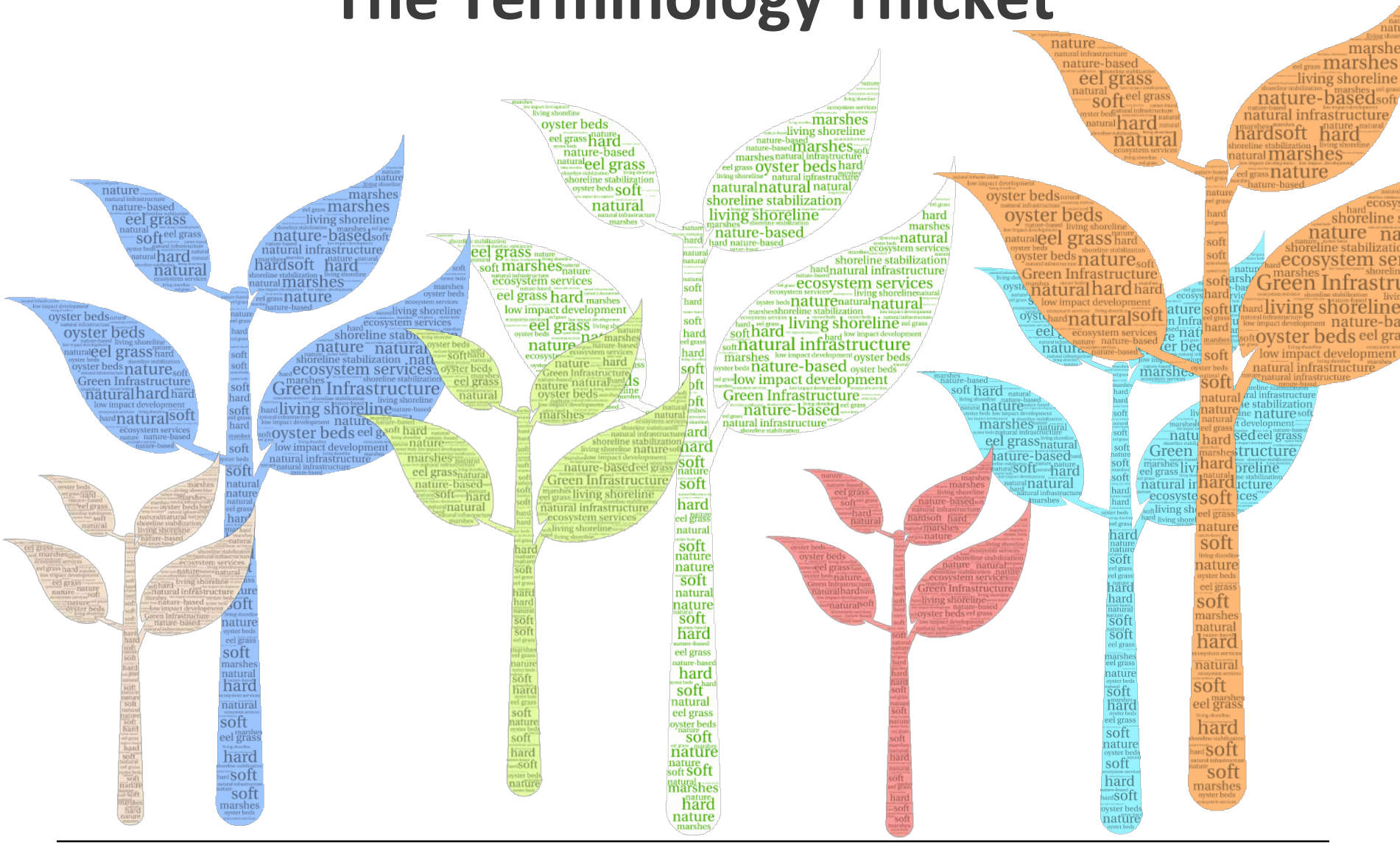
“Resilience is our ability to prevent a short-term hazard event from turning into a long-term community-wide disaster.”

Section 1

Green Infrastructure Concepts and Principles

Departamento de Recursos Naturales Y Ambientales

The Terminology Thicket



Foundations of Green Infrastructure

Green Infrastructure Concepts and Principles

Landscape approach?

Site-level approach?

Applicability across Scales

Landscape and watershed

Community and site

Shore and coastal zone

Green Infrastructure Concepts and Principles

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

Why Green Infrastructure?

Green Infrastructure Concepts and Principles

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.

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."

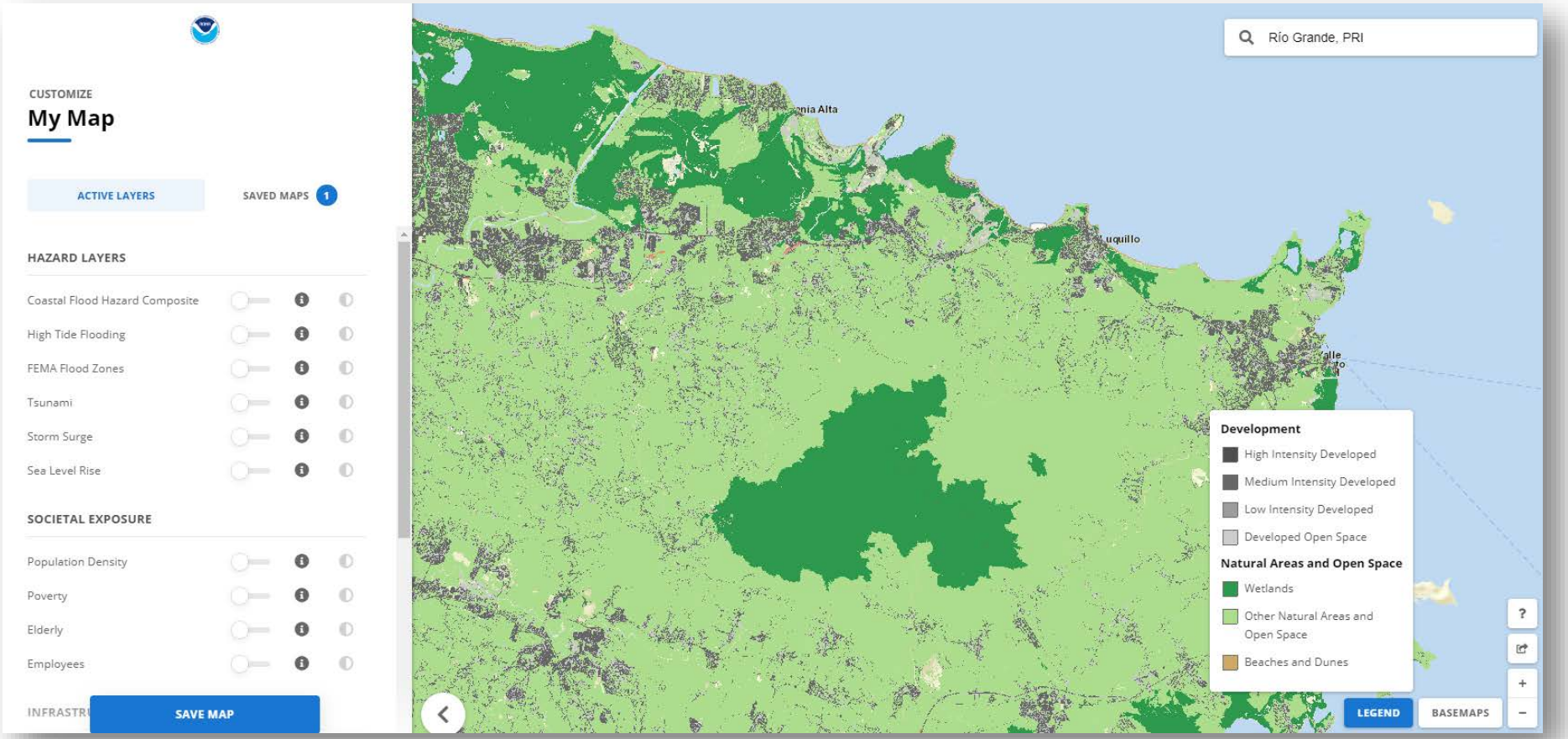
Still, while the violence of the storm may not have shown itself in the destruction of their homes, their dunes were a much different story. A quick survey revealed how much sand and vegetation Sandy scoured away from dunes that had – before the storm – been 25 feet tall and 125-feet wide. It was a sobering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

Exposure to Coastal Hazards

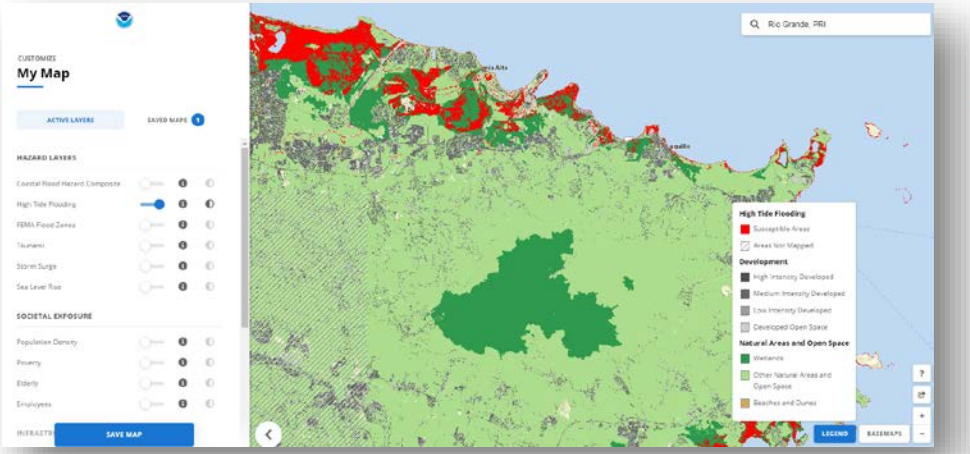
Green Infrastructure Concepts and Principles



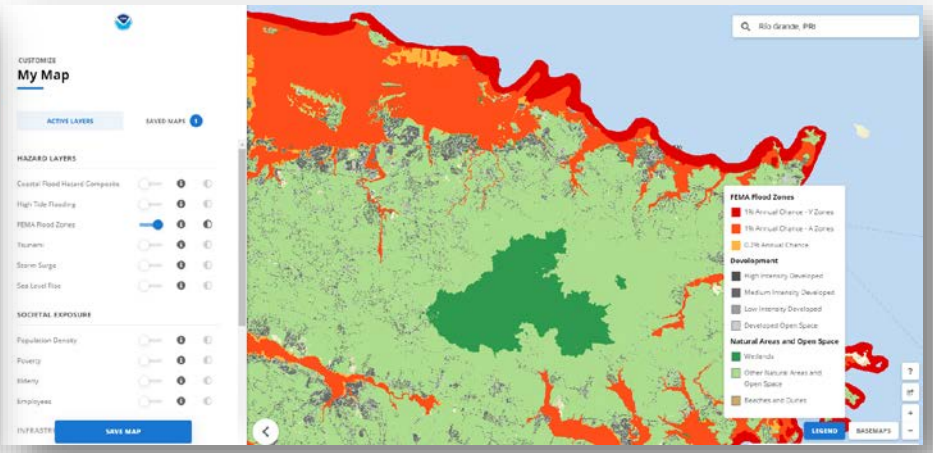
coast.noaa.gov/digitalcoast/tools/flood-exposure

Exposure to Coastal Hazards

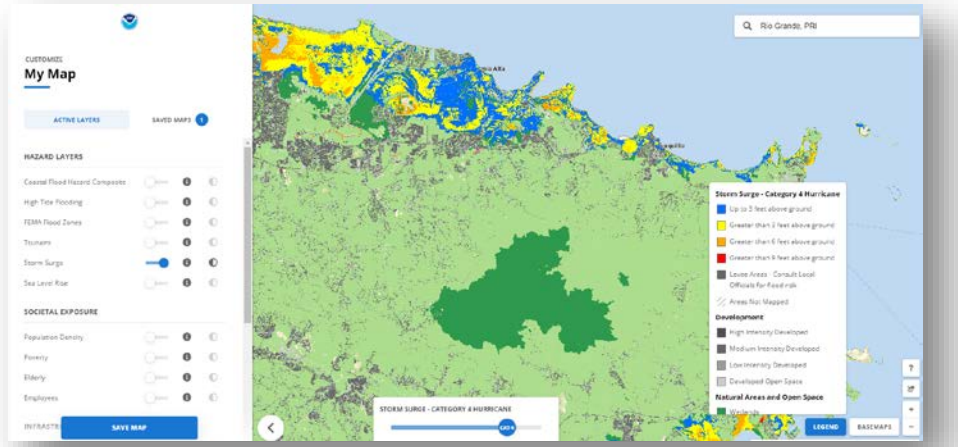
Green Infrastructure Concepts and Principles



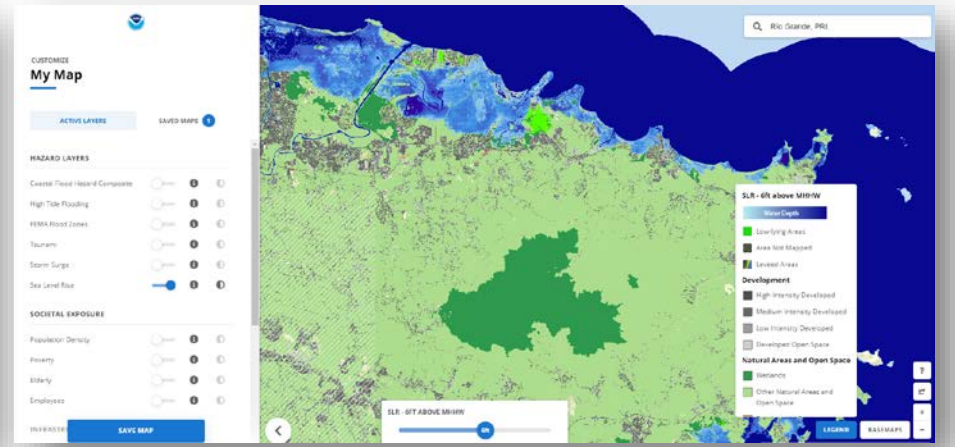
High Tide Flooding



FEMA Flood Zones



Storm Surge



Sea Level Rise

coast.noaa.gov/digitalcoast/tools/flood-exposure

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.

Multiple Benefits

- Environmental
- Societal
- Economic

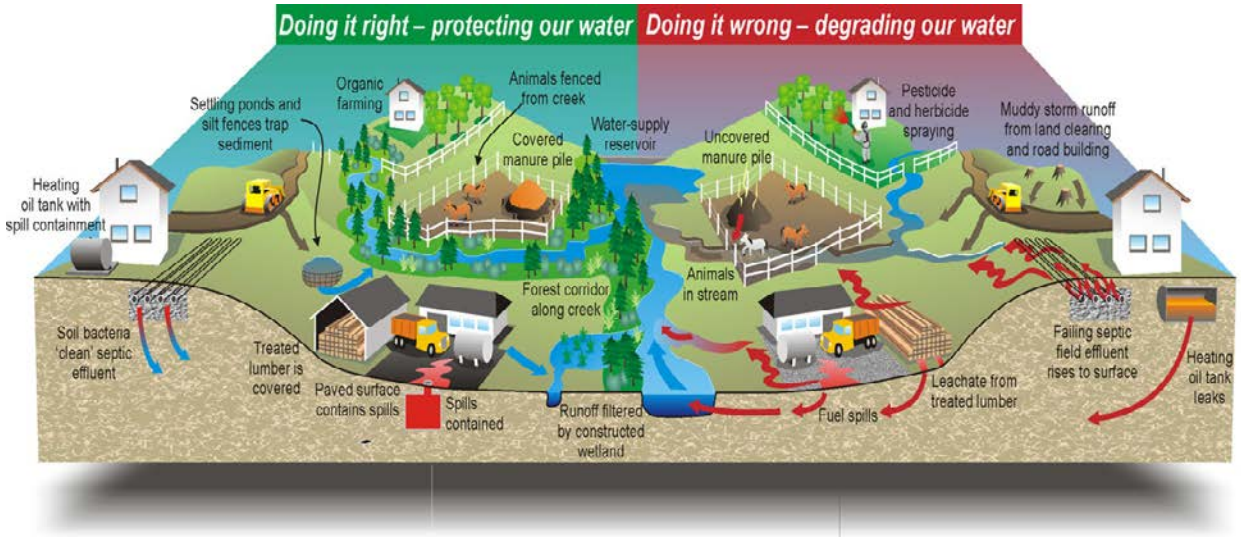
Section 2
The Practice of Green Infrastructure

Jobos Bay NERR

Planning Concepts

The Practice of Green Infrastructure

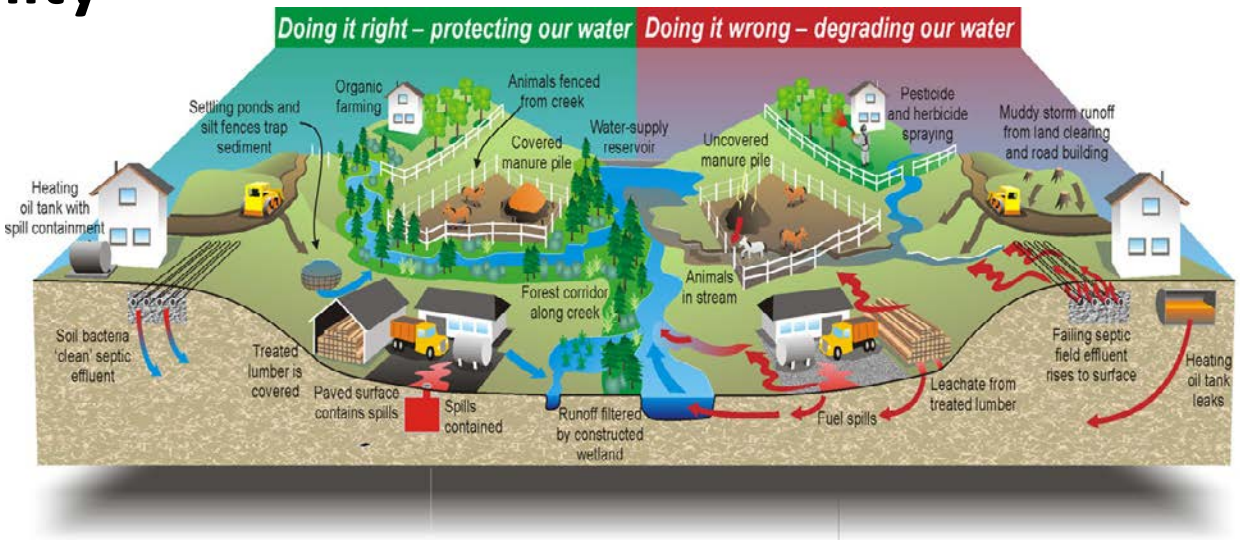
- **Scale**
- **Service**
- **Science**



Design Concepts

The Practice of Green Infrastructure

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



Green Infrastructure in Practice

Landscape and watershed

Community and site

Shore and coastal zone

The Practice of Green Infrastructure

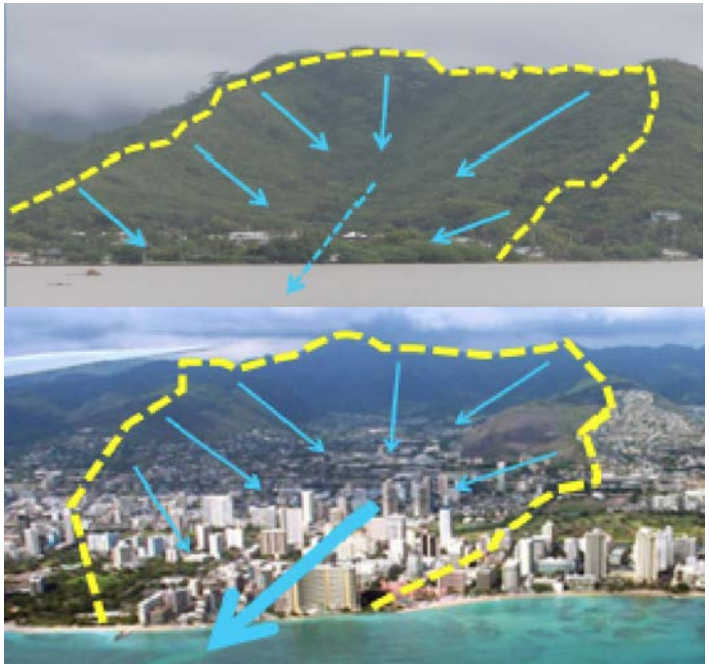
Landscape Design Concepts

The Practice of Green Infrastructure

	BETTER	WORSE
Area		
Proximity		
Connectivity		

Watershed Design Concepts

The Practice of Green Infrastructure

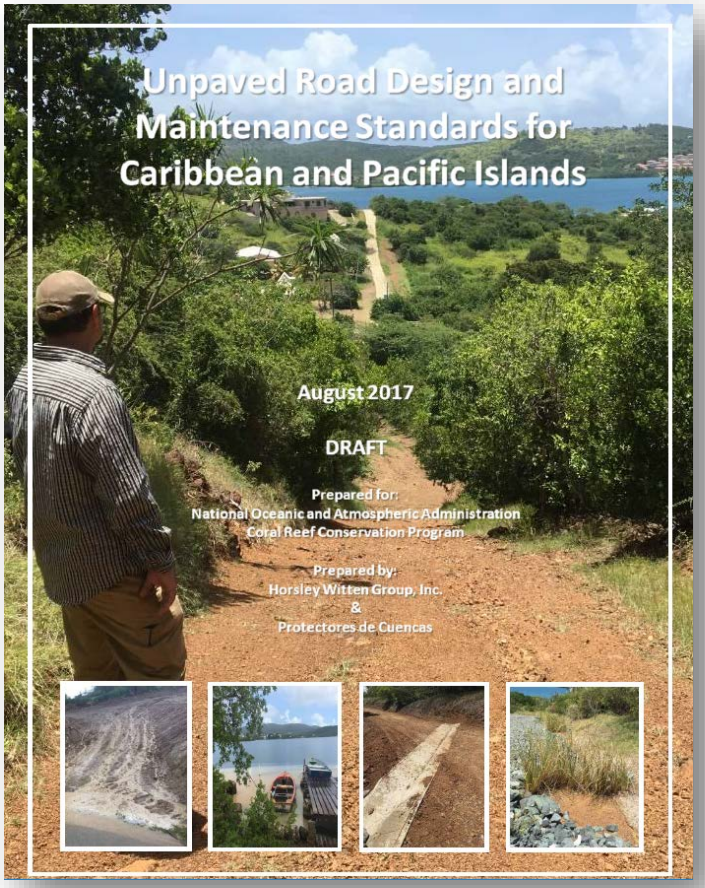


Source: Horsley Witten Group; Center for Watershed Protection

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

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

Landscape 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 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.

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

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

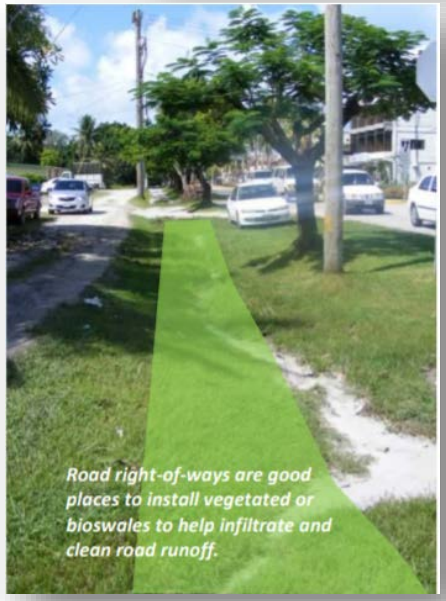
Community and Site Approaches

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

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

Community and Site Approaches

The Practice of Green Infrastructure

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

The Practice of Green Infrastructure

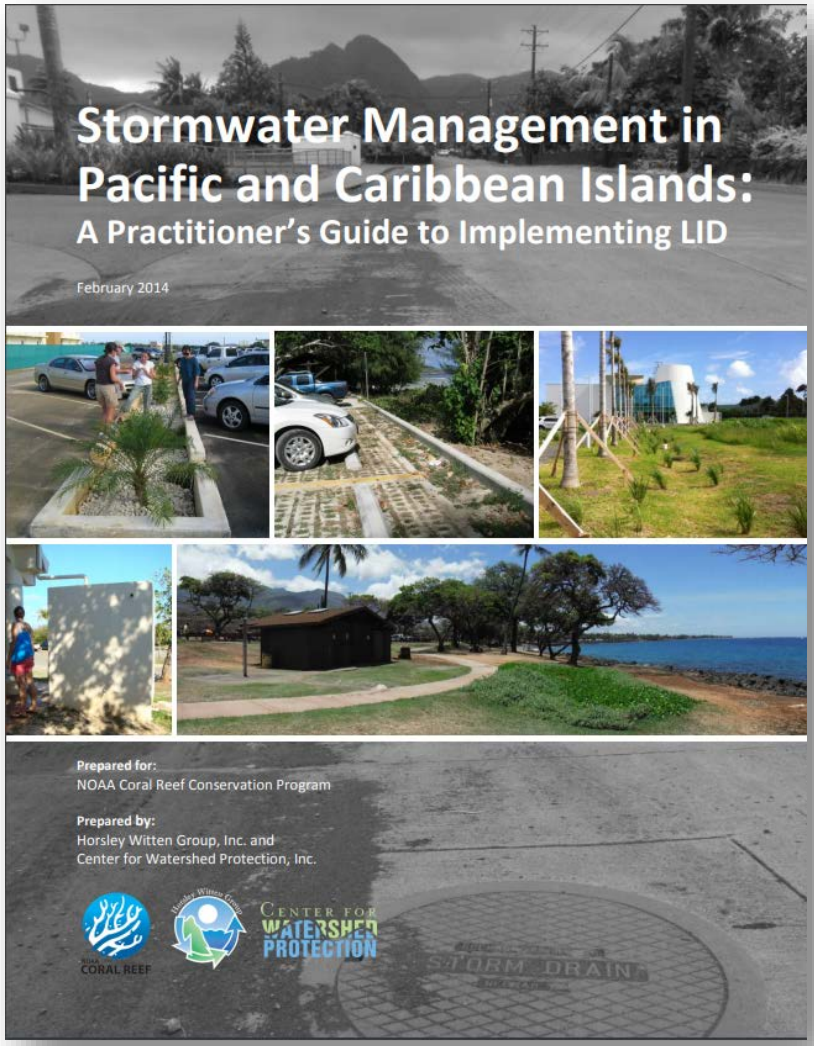
Culebra, Puerto Rico

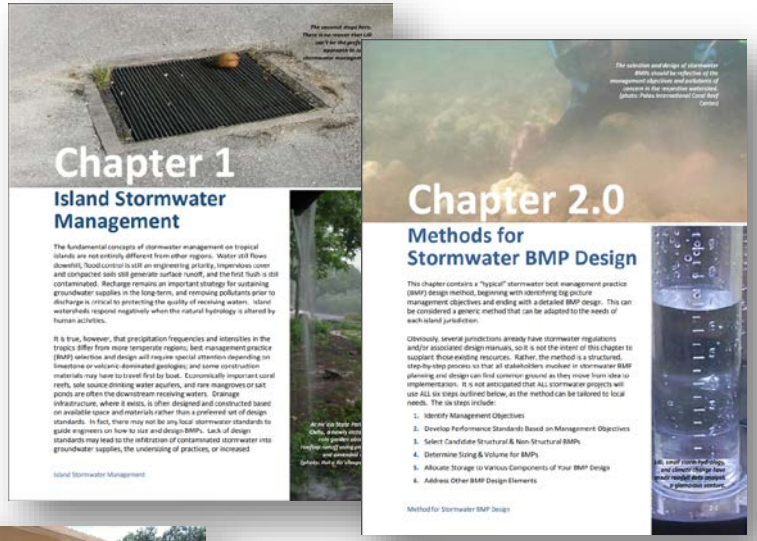
Stormwater runoff damaging coral reefs

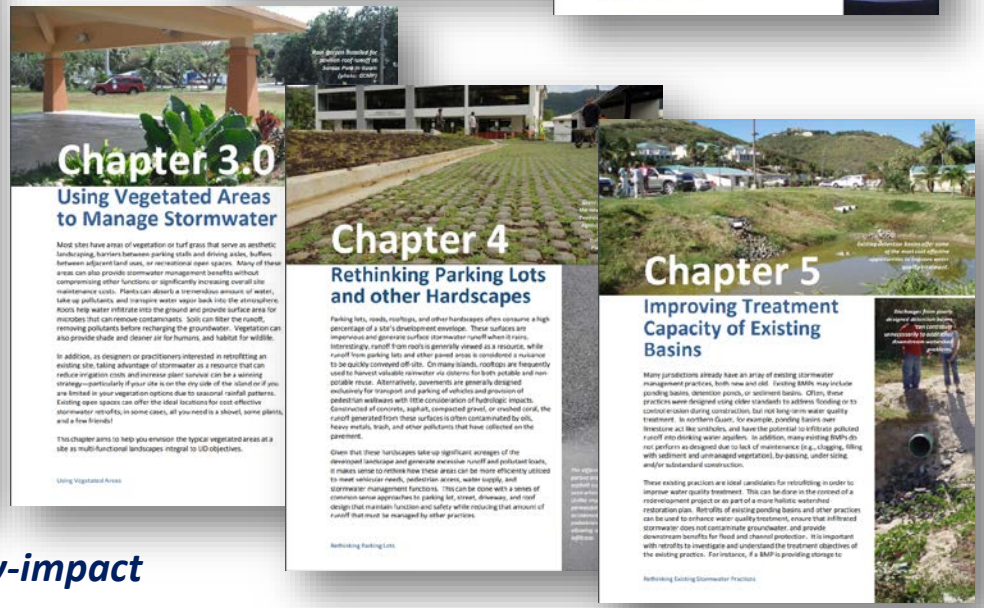
https://oceanservice.noaa.gov/news/feb16/reef-to-ridge-conservation.html

Community and Site Approaches

The Practice of Green Infrastructure







www.coast.noaa.gov/digitalcoast/training/low-impact

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

The Practice of Green Infrastructure

- 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, Mangroves, SAV

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

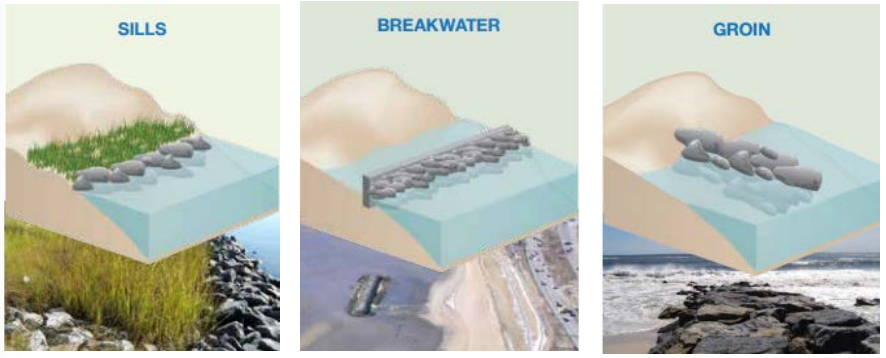
Oyster and Coral Reefs

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

Shoreline Approaches

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

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.**

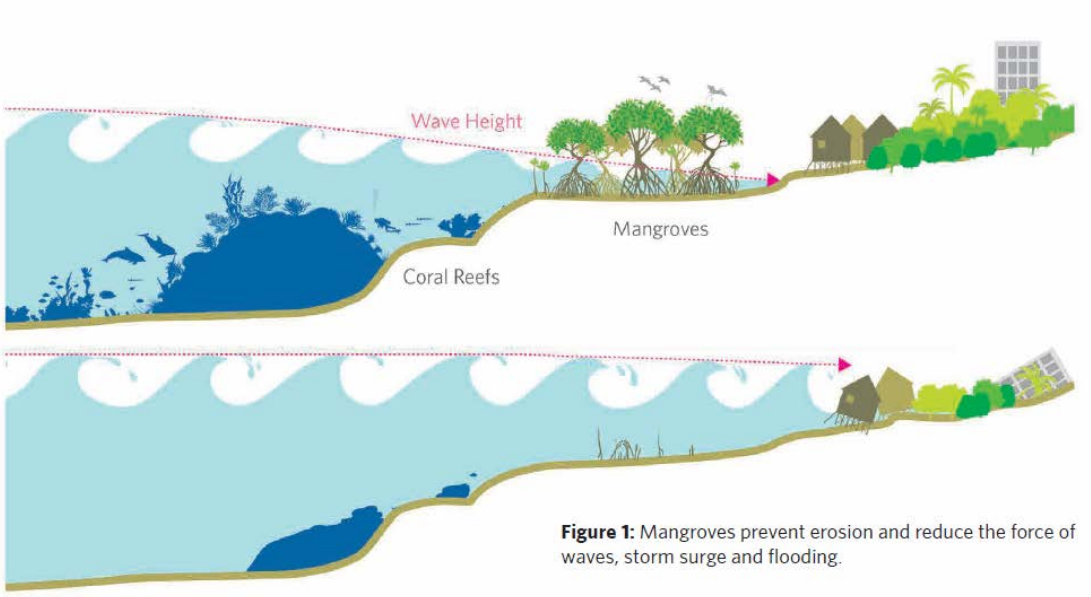


Figure 1: Mangroves prevent erosion and reduce the force of waves, storm surge and flooding.

nature.org/GlobalMangrovesRiskReductionSummaryReport **and** ***nature.org/GlobalMangrovesRiskReductionTechnicalReport***

Landscape Approaches and Resilience

The Practice of Green Infrastructure

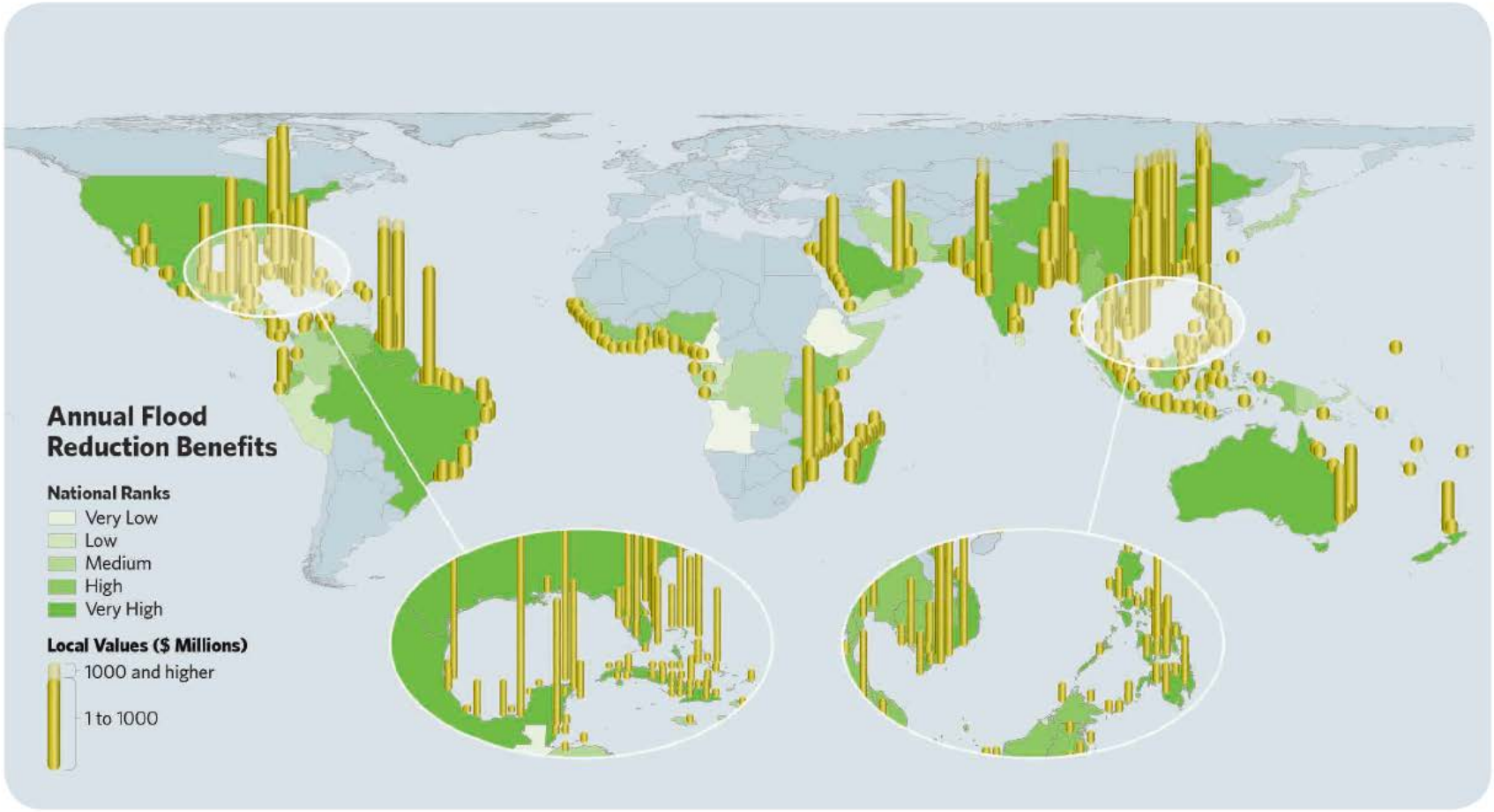


Figure 4: The map shows where mangroves provide the greatest flood reduction benefits for property. The values represent the difference in annual expected damages in US $ millions with and without mangroves per 100 km of coast.

nature.org/GlobalMangrovesRiskReductionSummaryReport and
nature.org/GlobalMangrovesRiskReductionTechnicalReport

Shoreline Approaches and Resilience

The Practice of Green Infrastructure

Hurricane Irene, North Carolina

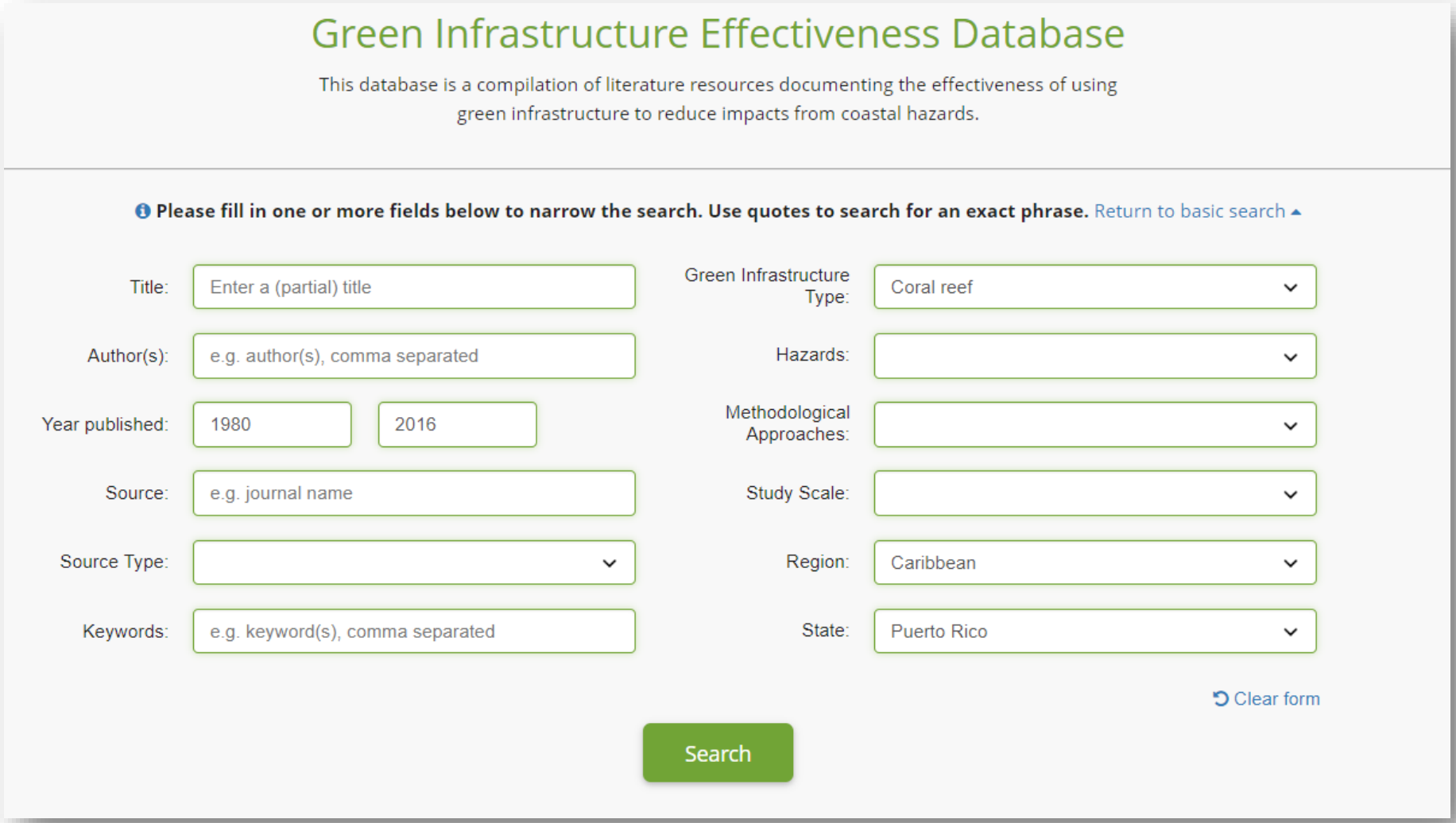
76% of bulkheads were damaged in the storm

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

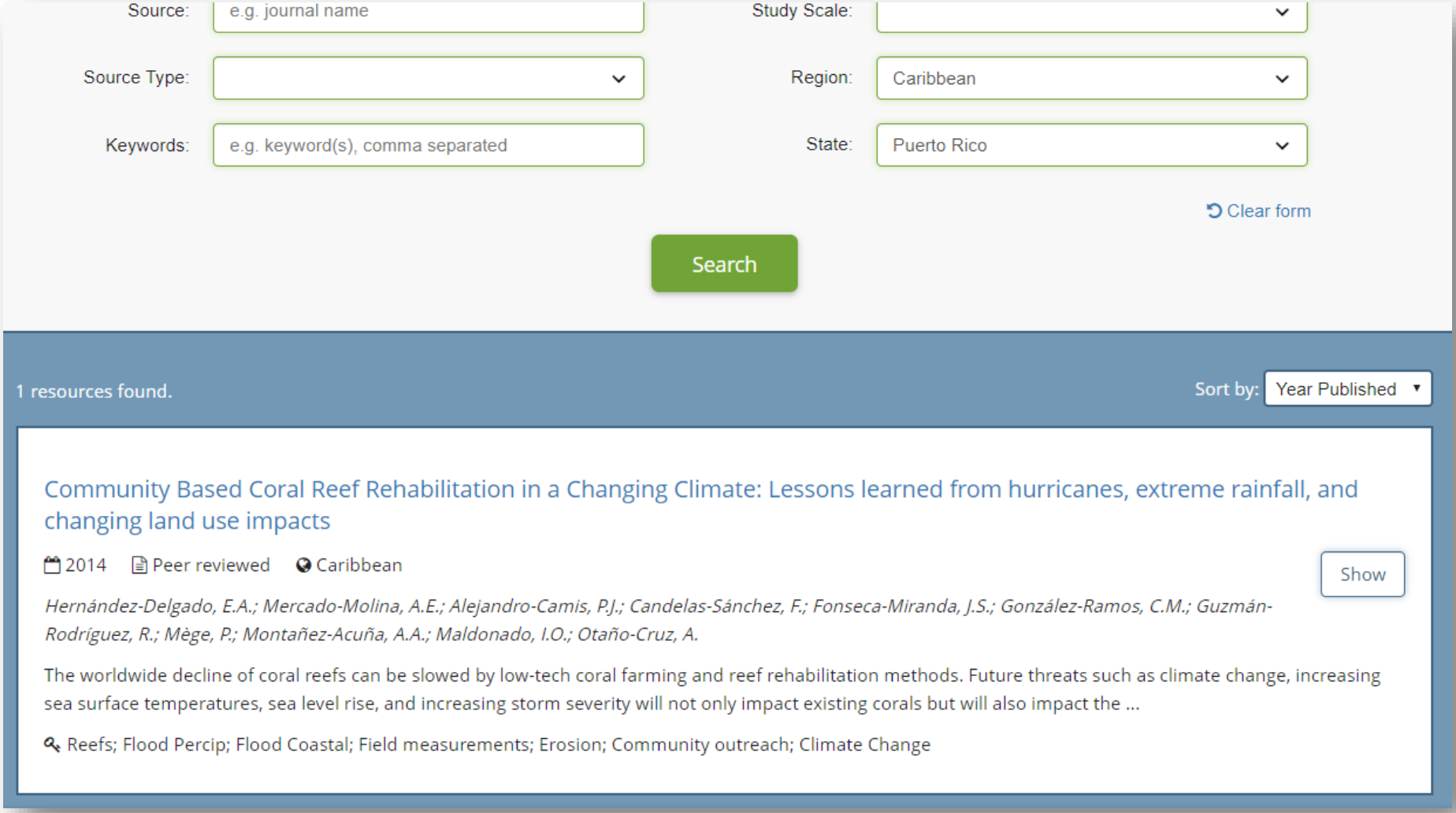
The Practice of Green Infrastructure



coast.noaa.gov/digitalcoast/training/GI-database

Green Infrastructure and Resilience

The Practice of Green Infrastructure



coast.noaa.gov/digitalcoast/training/GI-database

Green Infrastructure and Resilience

The Practice of Green Infrastructure

coast.noaa.gov/digitalcoast/training/GI-database

Section 3
Implementing Green Infrastructure

Green Infrastructure Can Inform Planning

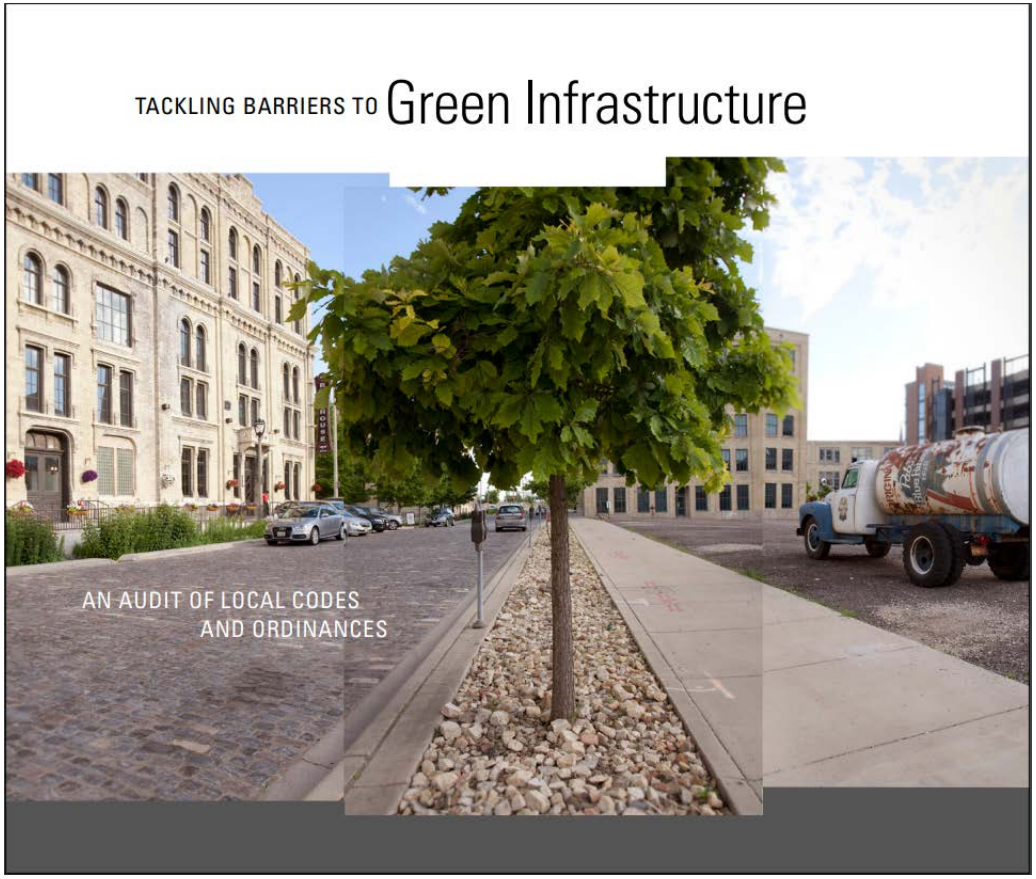
Implementing Green Infrastructure

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



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

i. 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.

ii. Trees and shrubbery appropriate for the development, and according to the plan approved under subsection (a) above. The incorporation of amended soil areas, stormwater trees, and other vegetative stormwater control measures into landscaping plans is encouraged.

(c) Parking Lot Landscaping

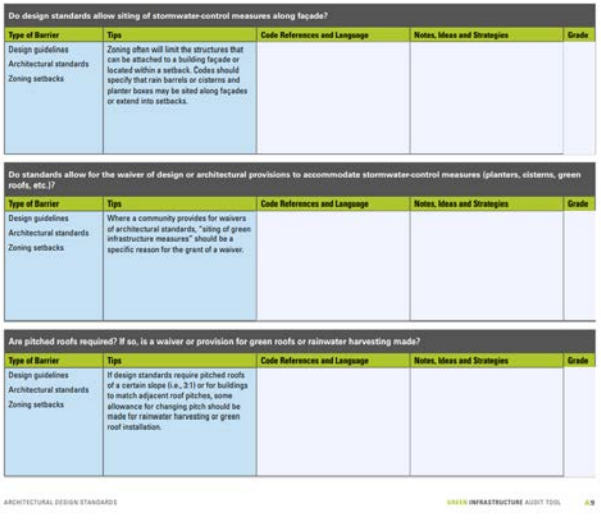
1. Landscaping shall be provided on the perimeter and within the interior of all parking areas to provide screening, canopy cover, and stormwater treatment and control. The integration of vegetated stormwater control measures with parking lot landscaping is strongly encouraged. All landscaped areas shall be mulched or seeded in keeping with the overall landscaping plan. The Village may maintain a list of accepted species of tree and landscaping materials, including plants and trees suitable for use in vegetated stormwater control measures.
2. 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 75 square feet in size.

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

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

Runoff volume reduction: 56%

Total suspended solids reduction: 64%



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

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

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

Type of Barrier	Tips	Code References and Language	Notes, Ideas and Strategies	Grade
Design guidelines Architectural standards Zoning setbacks	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.			

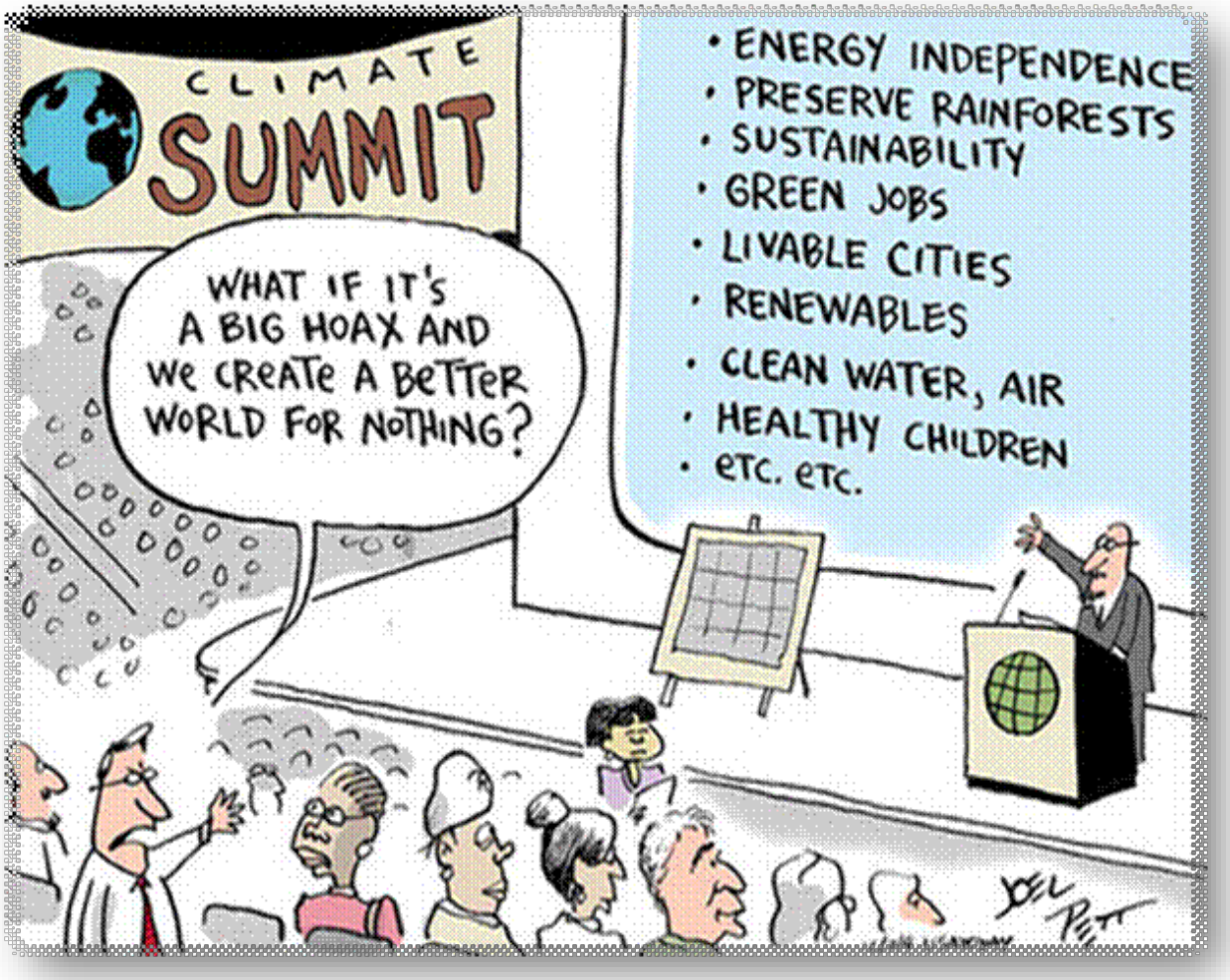
ARCHITECTURAL DESIGN STANDARDS

GREEN INFRASTRUCTURE AUDIT TOOL A-9

seagrant.wisc.edu/home/Portals/0/Files/Coastal%20Communities/Green_Infrastructure/DRAFT_GIworkbook_complete.pdf

Multiple Benefits

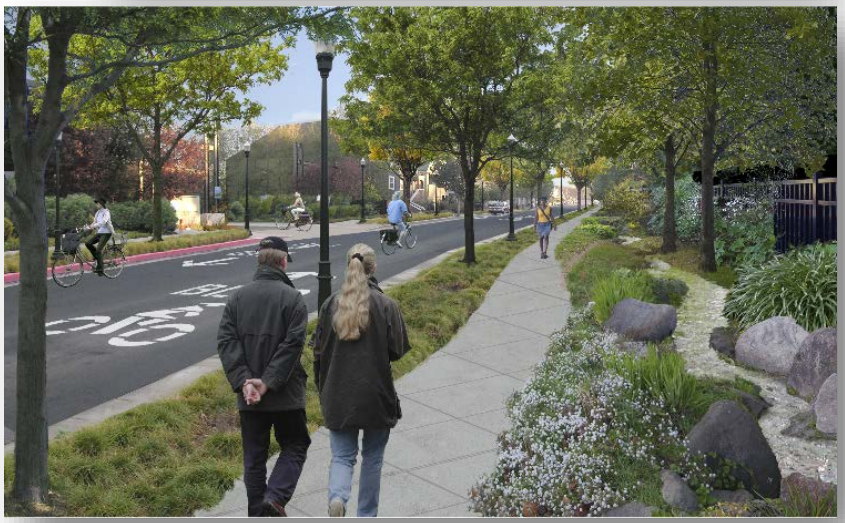
Implementing Green Infrastructure



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

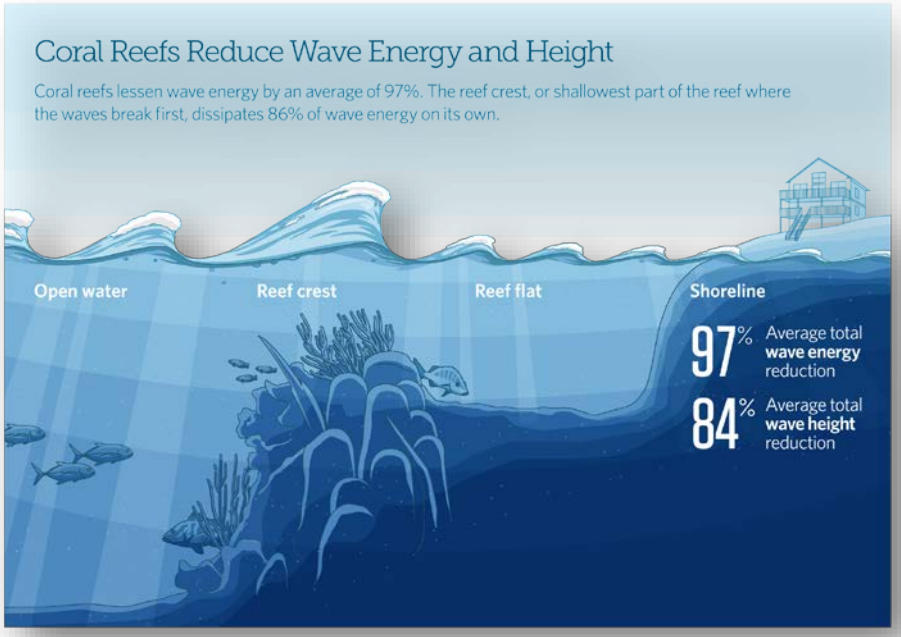
Animations!

https://youtu.be/rtyT_H8hXzE

coast.noaa.gov/digitalcoast/training/gi-animation

Engaging Stakeholders

Implementing Green Infrastructure



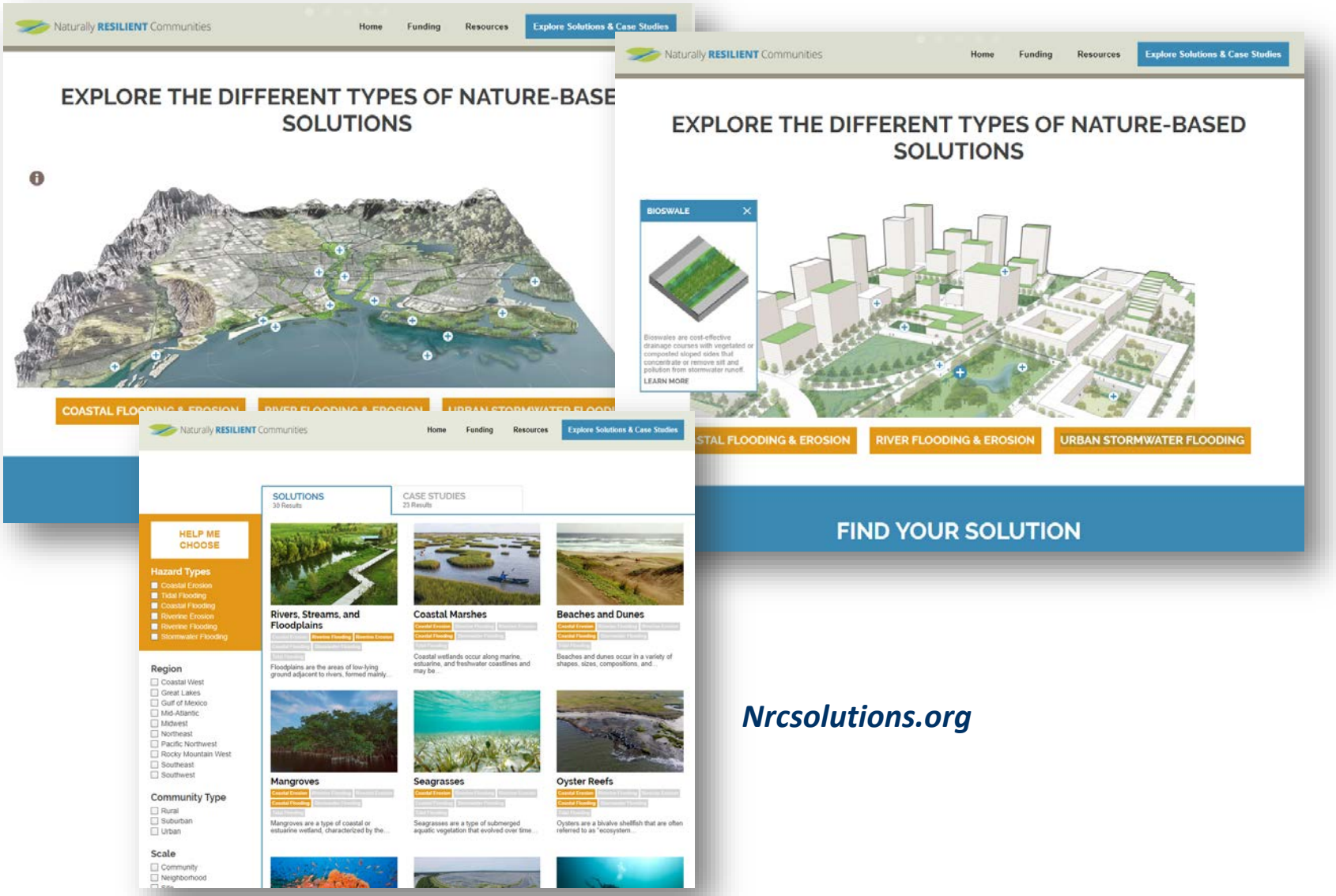
www.pewtrusts.org/en/research-and-analysis/data-visualizations/2014/coral-reefs-reduce-wave-energy-and-height

Infographics!

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

Engaging Stakeholders

Implementing Green Infrastructure



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.

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.

Photo: Tracy Skrabal, North Carolina Coastal Federation

To learn more, visit *coast.noaa.gov/digitalcoast/topics/green-infrastructure*.

Office for Coastal Management
Digital Coast

coast.noaa.gov/digitalcoast/training/gi-benefits

OFFICE FOR COASTAL MANAGEMENT
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

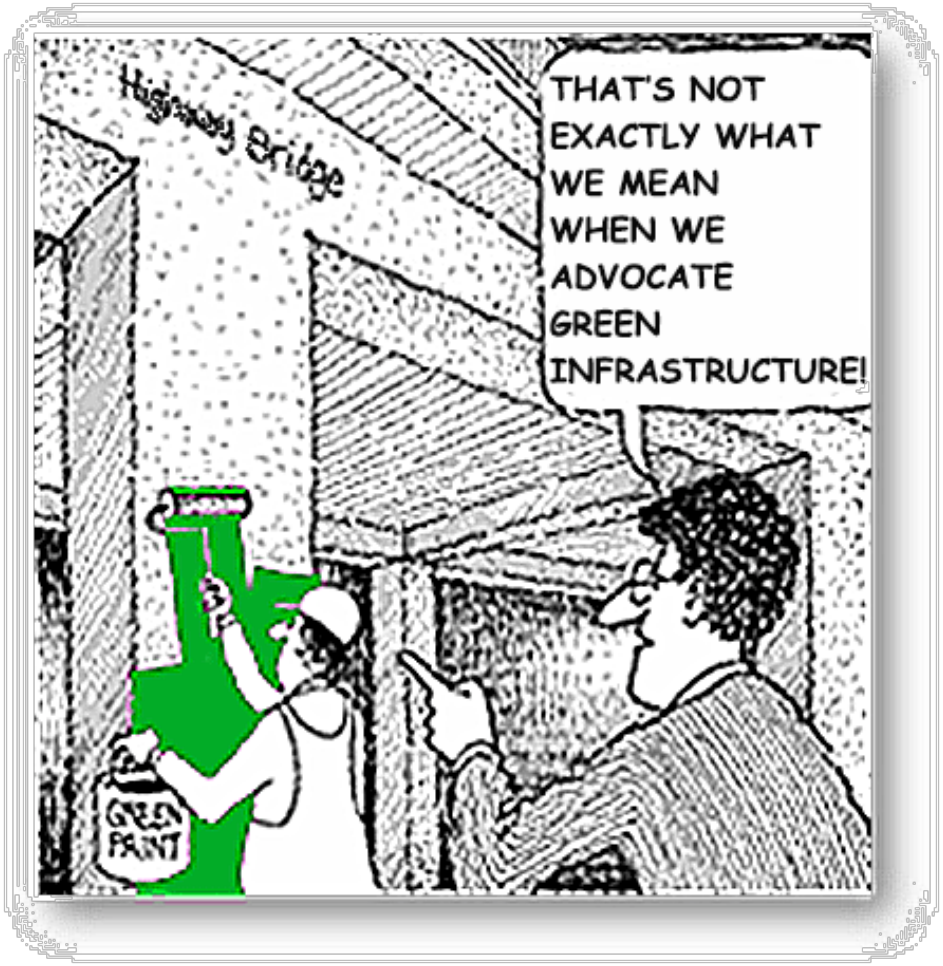
Funding for Green Infrastructure

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



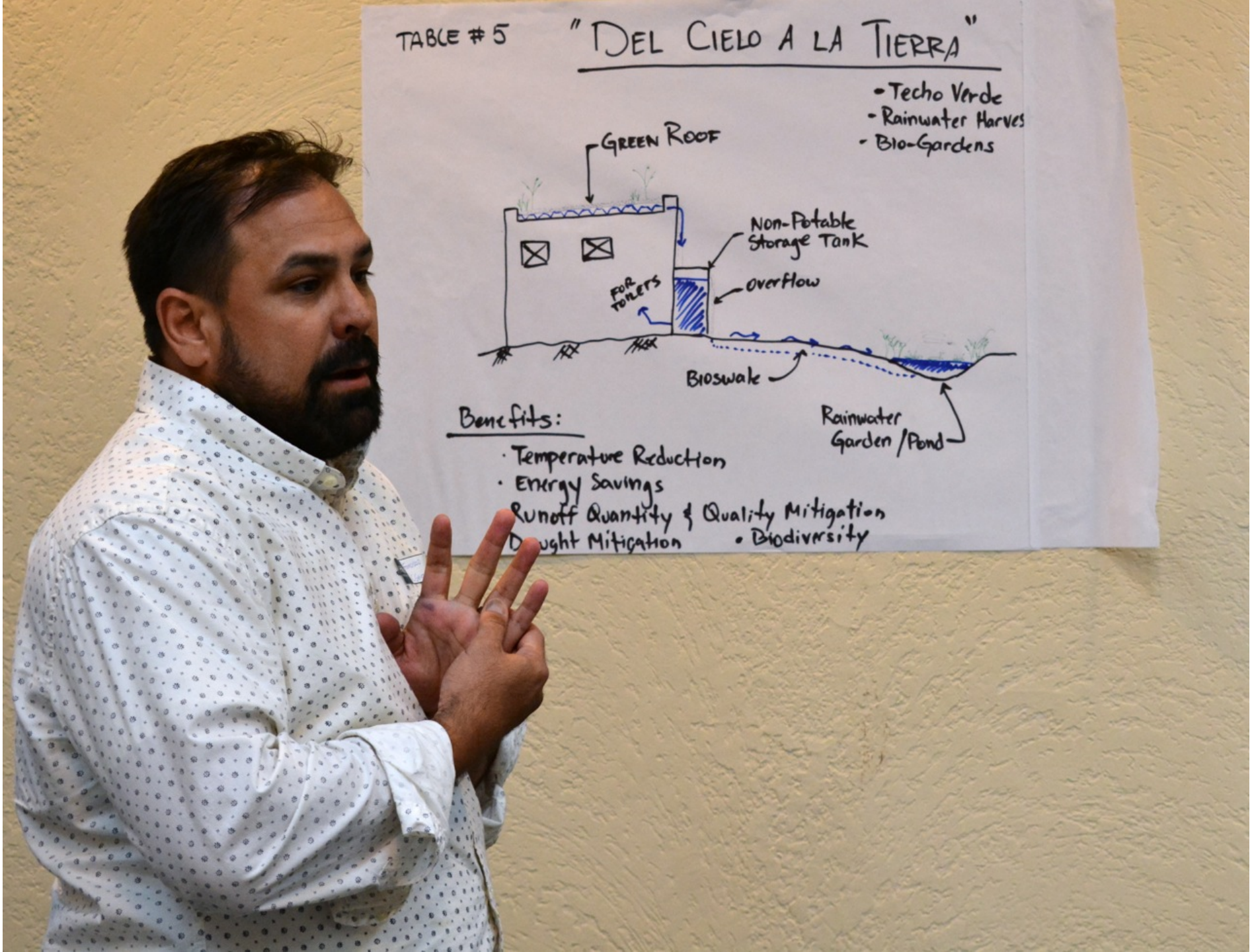


TABLE #5
"DEL CIELO A LA TIERRA"
• Techo Verde
• Rainwater Harves
• Bio-Gardens
GREEN ROOF
Non-Potable Storage Tank
FOR TOILETS
overflow
Bioswale
Rainwater Garden / Pond
Benefits:
· Temperature Reduction
· Energy Savings
Runoff Quantity & Quality Mitigation
ught Mitigation
• Biodiversity


TABLE