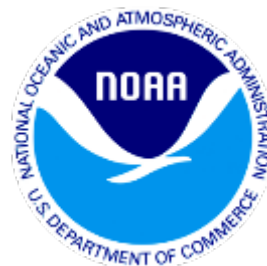


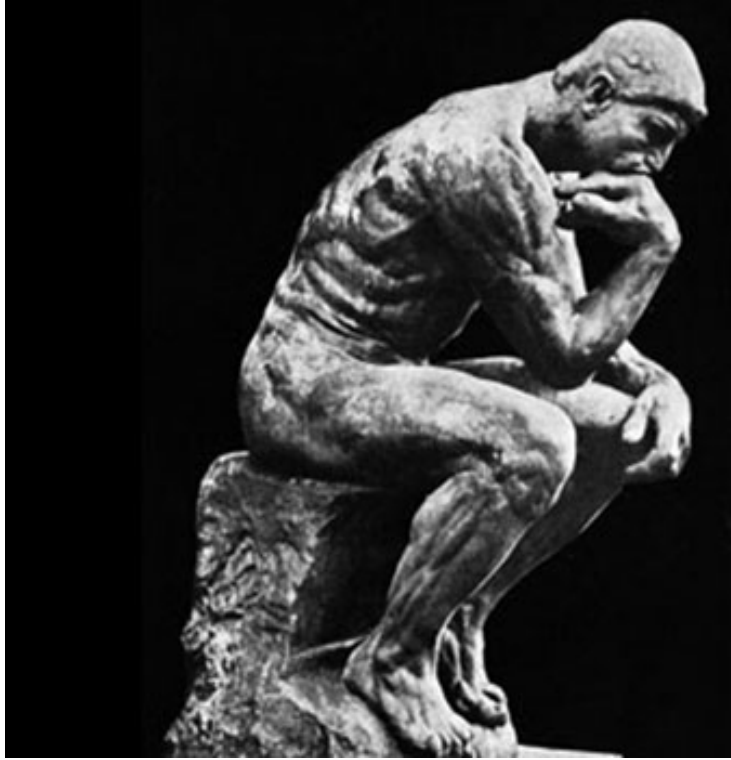
# NOAA's Experience with Green Infrastructure and Flood Impact Reduction: Assessing Green Infrastructure Costs and Benefits

Lori Cary-Kothera

NOAA's Office for Coastal Management



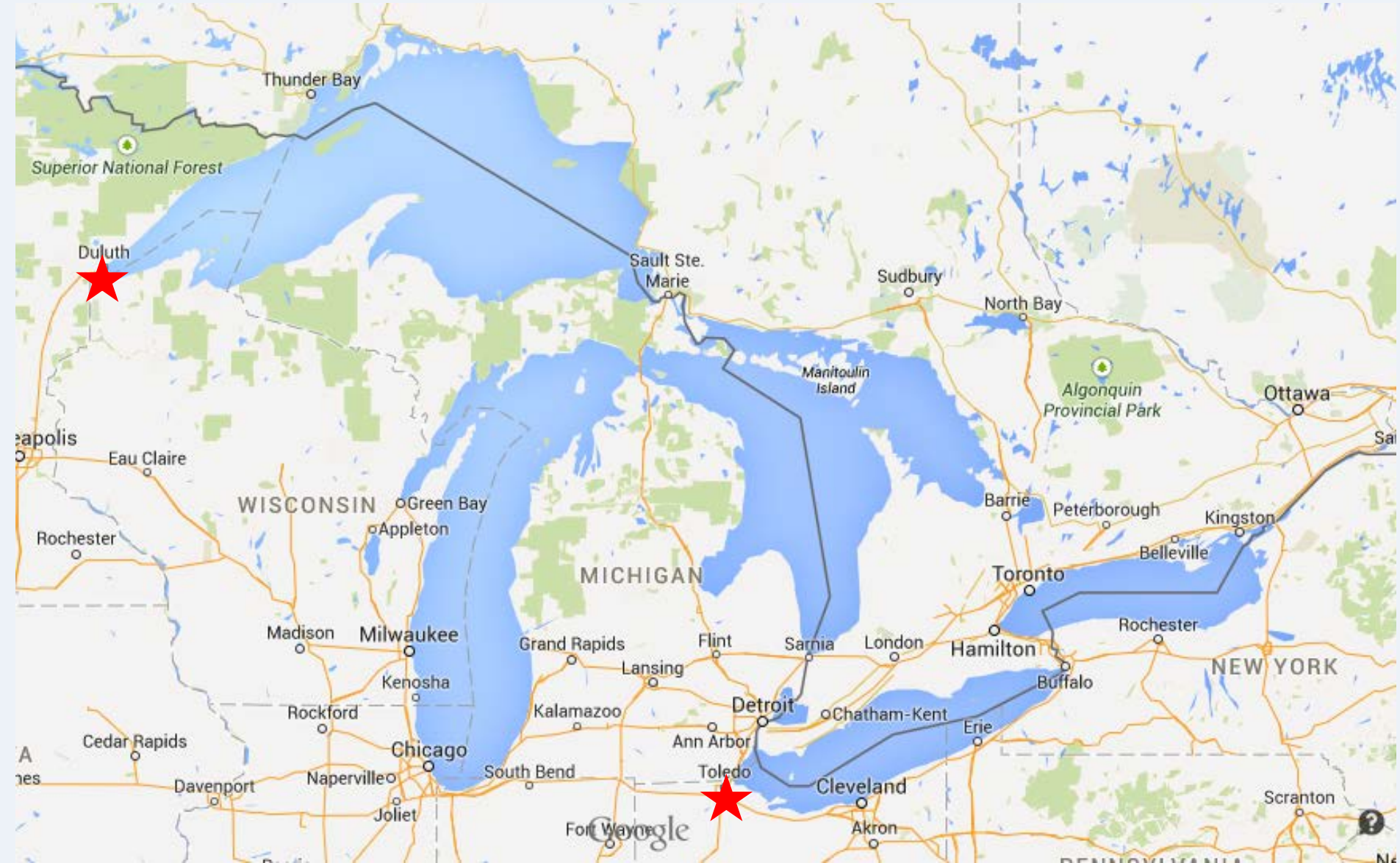




Think Nationally, Act Locally



# Great Lakes Study Sites

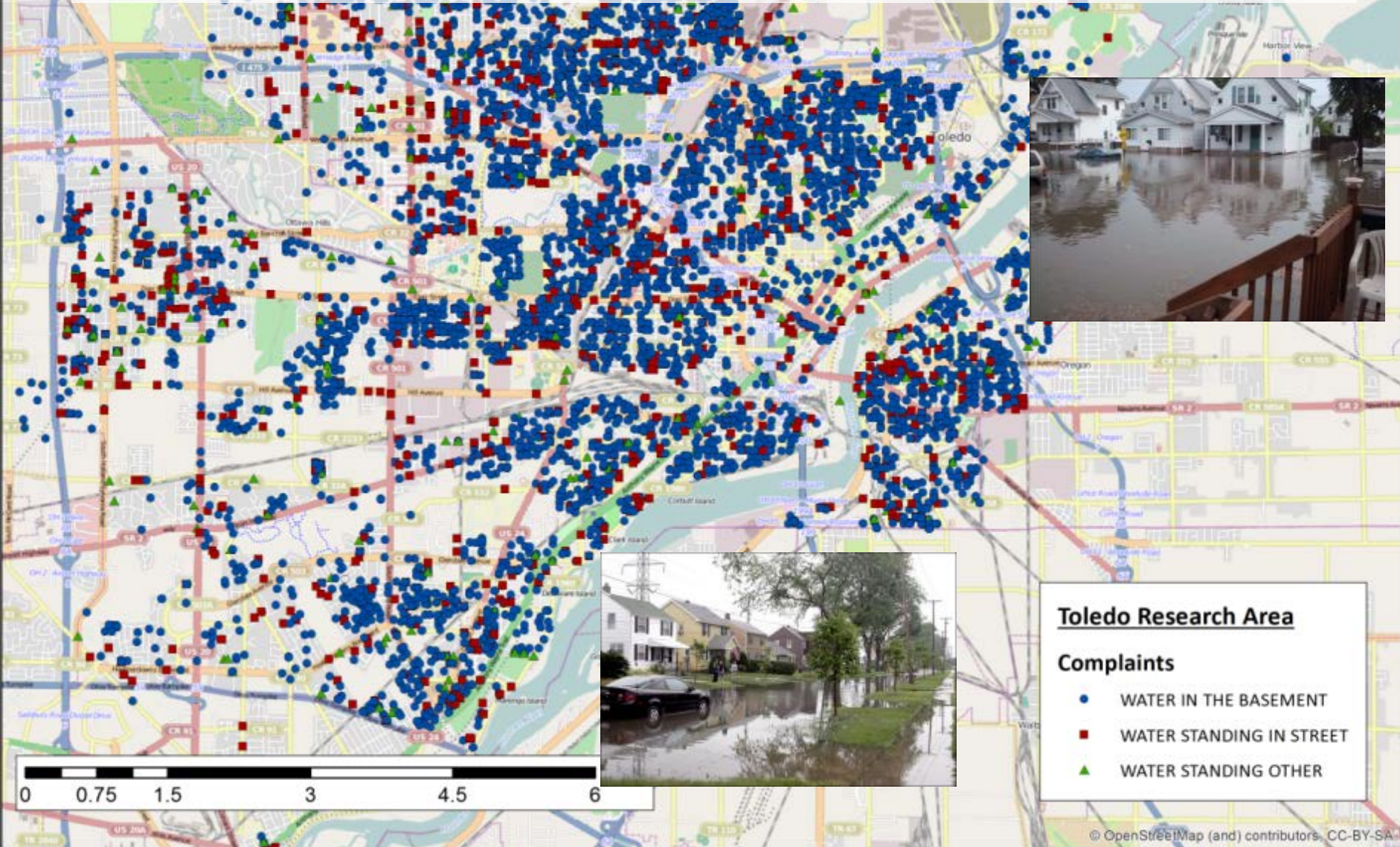








# Basement and Street Flooding Complaints 2007 - 2012



**Toledo Research Area**

**Complaints**

- WATER IN THE BASEMENT
- WATER STANDING IN STREET
- ▲ WATER STANDING OTHER







# Need: Help with long-term planning green infrastructure





But where  
do we start?





My options

Benefits

Costs

Data

Tell us...



# So we worked with...

- Minnesota Sea Grant
- City of Toledo
- U.S. Army Corps of Engineers
- Association of State Floodplain Managers
- Eastern Research Group, Inc.
- American Rivers
- Old Woman Creek NERR

# Economic Assessment

1. Define flood problem
2. Assess current and future flooding
3. Identify flood reduction options using GI
4. Assess flood scenarios with GI options
5. Compare benefits and costs



# Step 1: Define flood problem



# Scale of Study



Site



Neighborhood



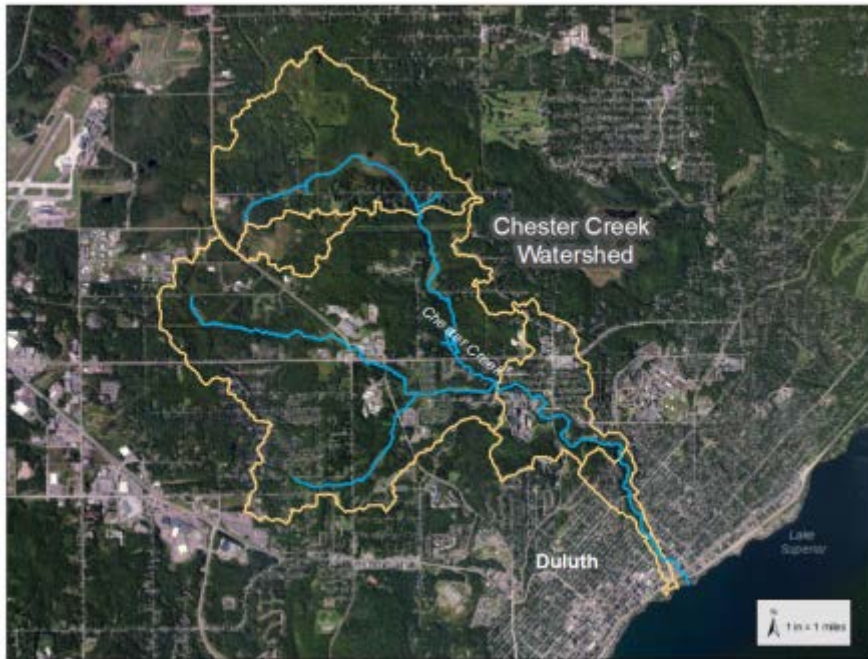
Watershed





# Pilot Communities

## Duluth, Minnesota



## Toledo, Ohio



An aerial photograph of a residential neighborhood where many houses are surrounded by floodwater. The water is a light blue color, and the houses are mostly white with dark roofs. The text "Step 2. Assess current and future flooding" is overlaid in white with a blue shadow on the bottom right of the image.

**Step 2. Assess current  
and future flooding**

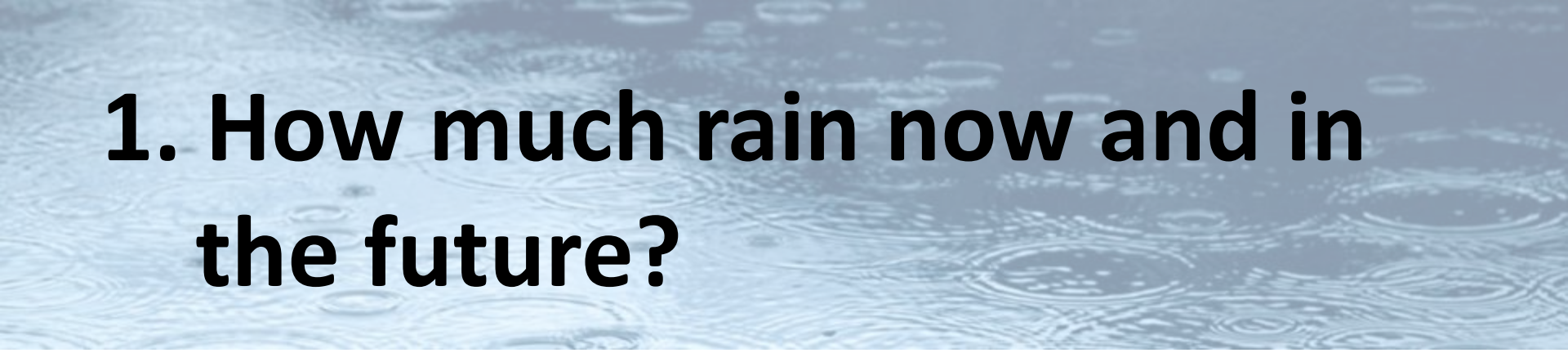


# Flood Impact Scenarios


1. Current precipitation and current land use
2. Future precipitation (2035) and future land use

# Flood Reduction Scenarios

3. Current precipitation and current land use using GI
4. Future precipitation (2035) and future land use using GI



**1. How much rain now and in the future?**



**2. How much water could cause flooding?**



**3. Where could flooding occur?**

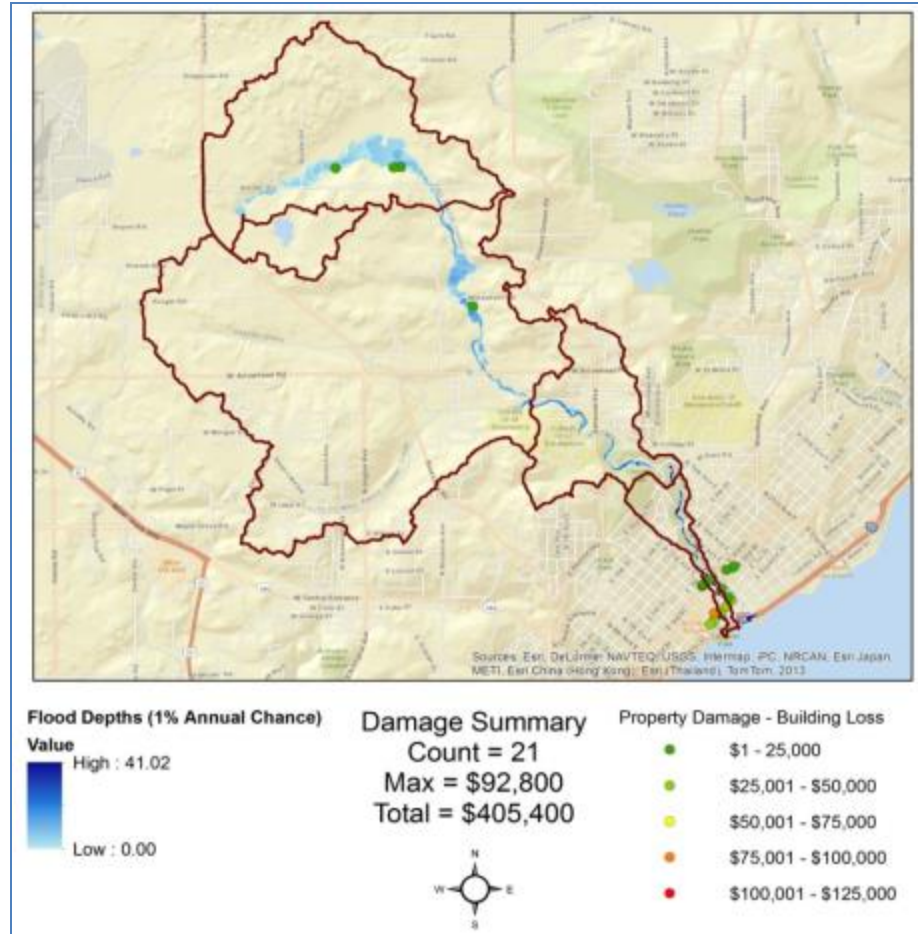


# Toledo Flood Damage Costs



**Flood damage to buildings = \$740K**

# Duluth Flood Damage Costs



**Flood damage to buildings = \$400K**

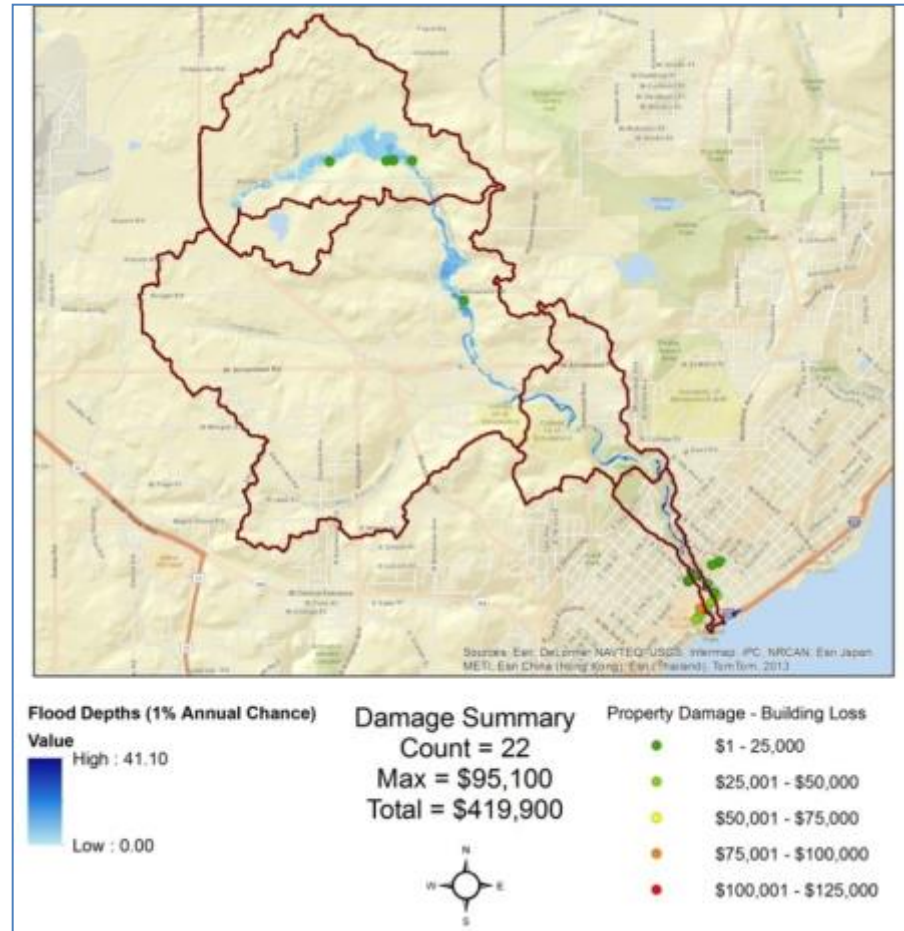


# Toledo Flood Damage Costs



**Flood damage to buildings = \$930K**

# Duluth Flood Damage Costs



**Flood damage to buildings = \$420K**



A close-up photograph of vibrant green grass blades, likely from a species like Paspalum, showing their characteristic long, narrow shape and pointed tips. The blades are densely packed and fill the entire frame, creating a textured, natural background. The lighting is bright, highlighting the varying shades of green and some slight yellowing at the tips of the blades.

# Step 3. Identify Flood Reduction GI Options



# Many Options





**Target: reduce peak discharge by**

DULUTH

**20%**

TOLEDO

**10%**



# How much green infrastructure storage is needed to reach this target?

## DULUTH

**76** acre-feet  
(current conditions)

**86** acre-feet  
(future conditions)

## TOLEDO

**30** acre-feet  
(current conditions)

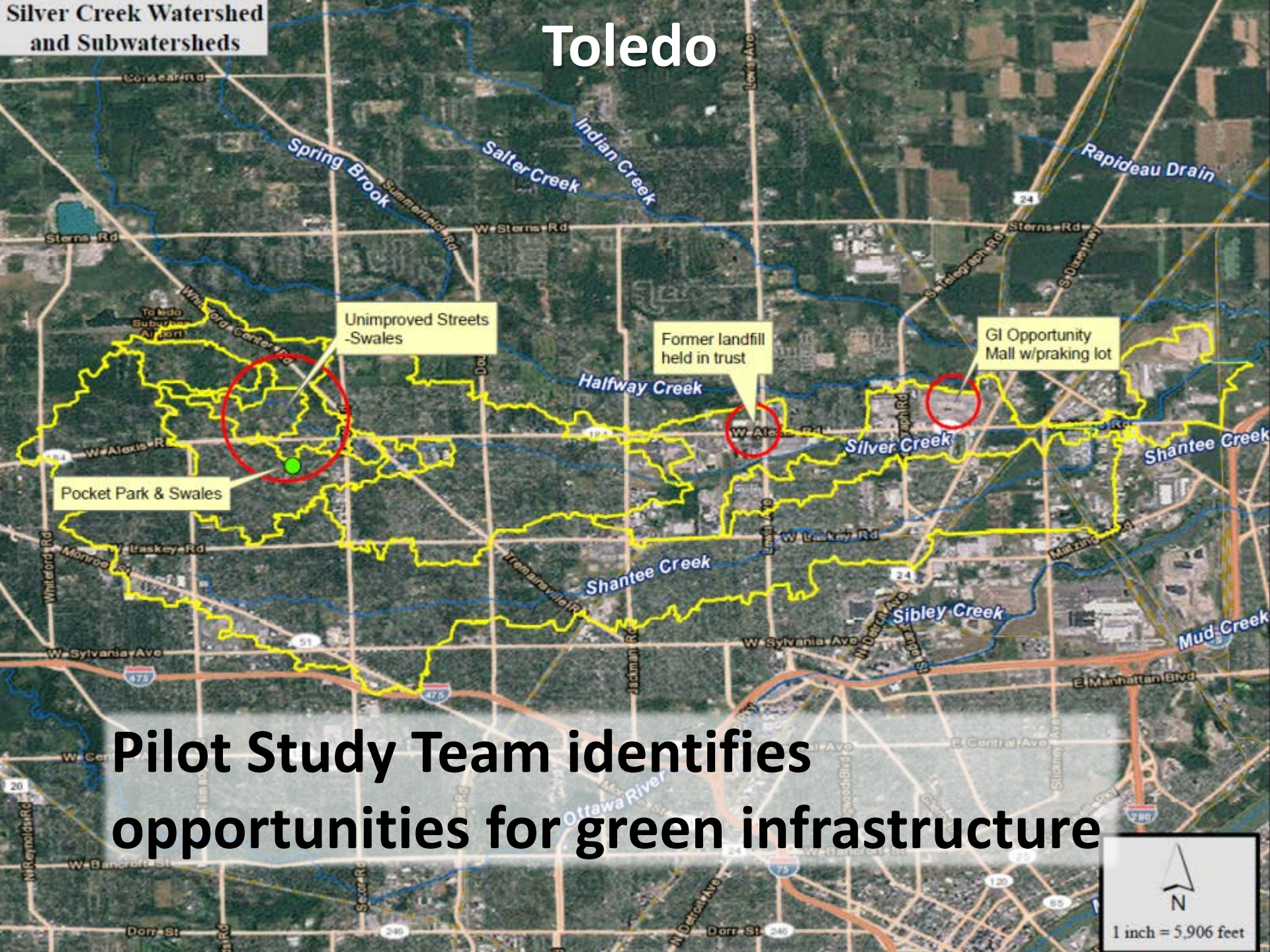
**32** acre-feet  
(future conditions)

# What and how much of each?

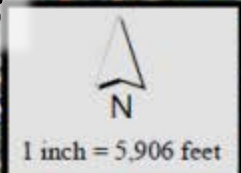




# Toledo

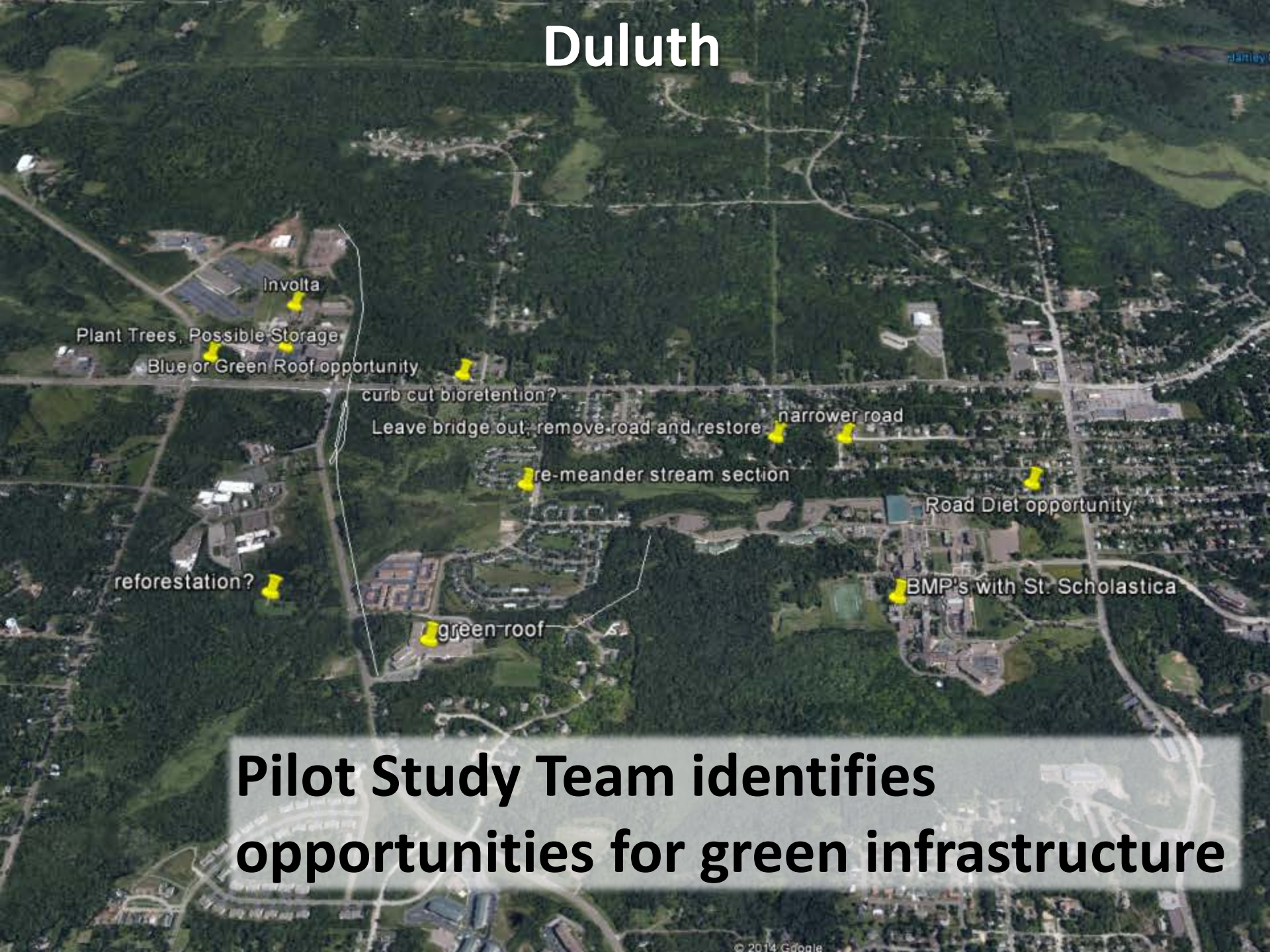


**Pilot Study Team identifies opportunities for green infrastructure**





# Duluth



**Pilot Study Team identifies opportunities for green infrastructure**

# GI Options of Interest

- Bioretention/bioswales along unimproved roads
- Blue Roofs
- Permeable Pavement (Unimproved Roads)
- Permeable Pavement (Sidewalk)
- Underground Storage
- Parcel Buy-outs (for on site detention)







**Step 4.  
Assess how  
much flood  
damages are  
reduced  
using GI**





## Flood Reduction Scenarios

3. Current precipitation and current land use using GI
4. Future precipitation and future land use using GI

Toledo

# How much are flood damages reduced using GI?

Toledo Flood Hazard Visualizer ( beta )

Flood Scenario:  
3. Current Precipitation with Green Infrastructure

Flood Event

- 50% Annual Chance 2 year flood
- 20% Annual Chance 5 year flood
- 10% Annual Chance 10 year flood
- 4% Annual Chance 25 year flood
- 2% Annual Chance 50 year flood
- 1% Annual Chance 100 year flood

Display Layers

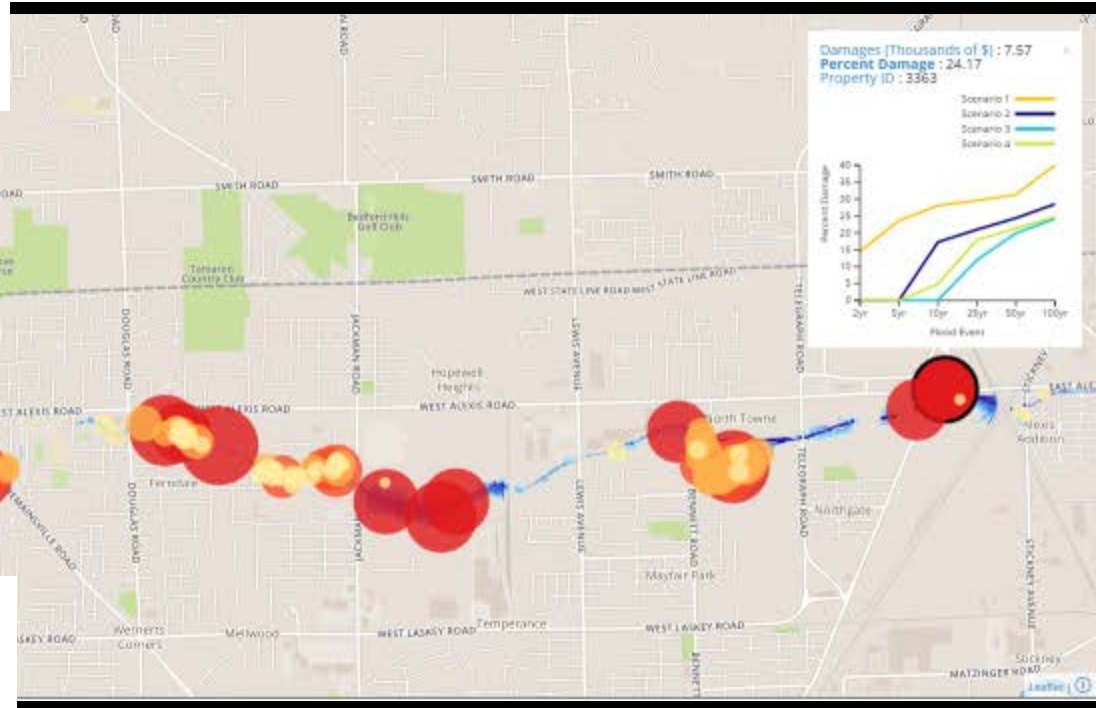
- Flood Losses
- Depth Grid
- Flood Photos
- Green Infrastructure
- Future Land Use
- FEMA National Flood Hazard Layer visible at closer zoom levels

Basemap

- Street Map
- Satellite

**\$740K\***

**\$453K\***



\*Flood damage to buildings

Toledo

# How much are flood damages reduced using GI?

Toledo Flood Hazard Visualizer ( beta )

Flood Scenario:  
4. Future 2035 Precipitation with Green Infrastructure

Flood Event

- 50% Annual Chance 2 year flood
- 20% Annual Chance 5 year flood
- 10% Annual Chance 10 year flood
- 4% Annual Chance 25 year flood
- 2% Annual Chance 50 year flood
- 1% Annual Chance 100 year flood

Display Layers

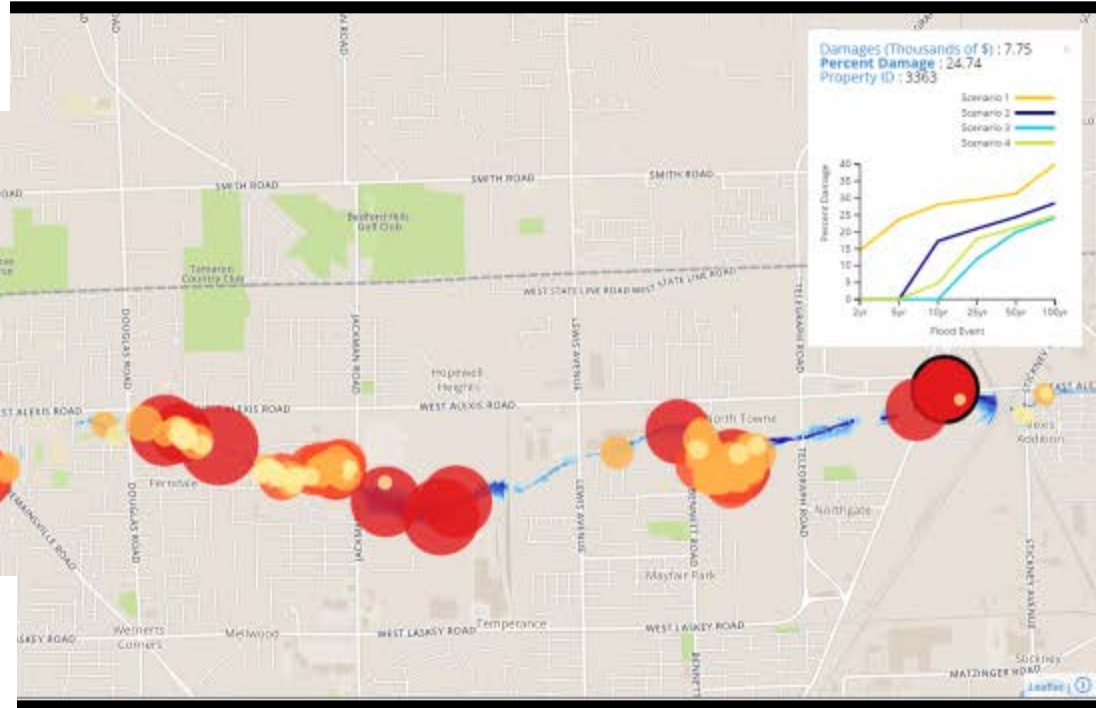
- Flood Losses
- Depth Grid
- Flood Photos
- Green Infrastructure
- Future Land Use
- FEMA National Flood Hazard Layer visible at closer zoom levels

Basemap

- Street Map
- Satellite

**\$930K\***

**\$527K\***



**\*Flood damage to buildings**



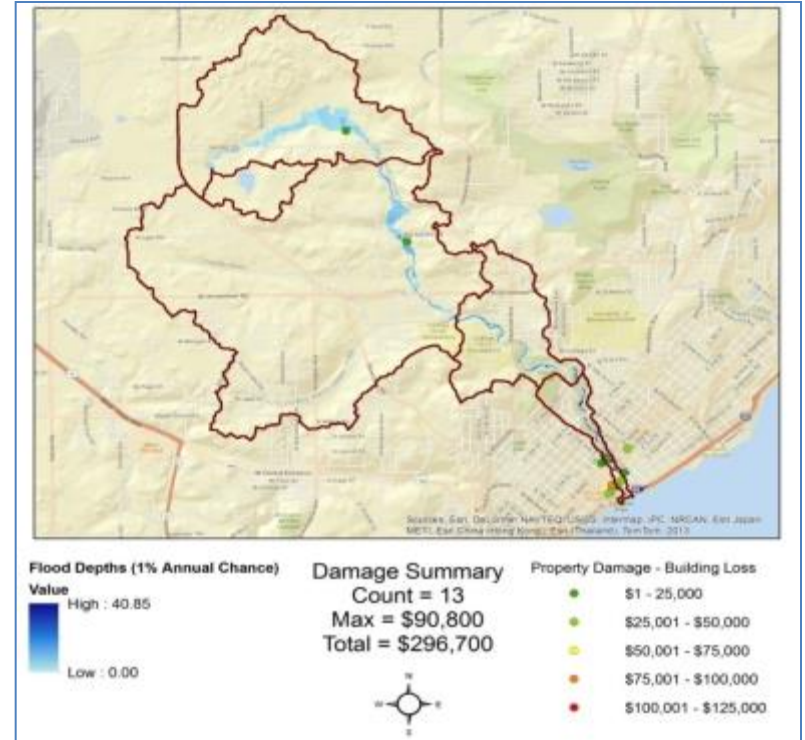
Duluth

# How much are flood damages reduced using GI?

**\$400K\***



**\$296K\***



**\*Flood damage to buildings**

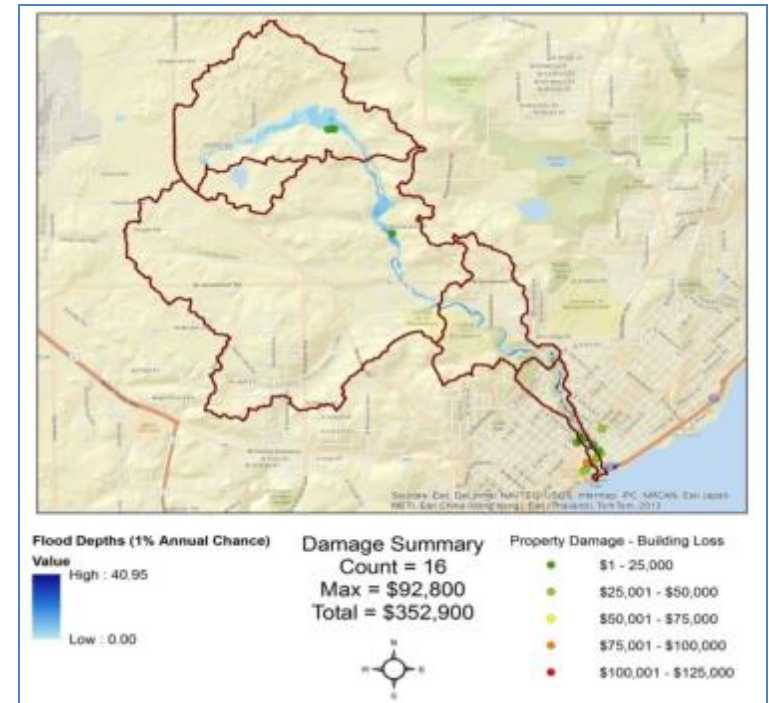
Duluth

# How much are flood damages reduced using GI?

**\$420K\***



**\$352K\***



**\*Flood damage to buildings**

Toledo

# Risk Reduced with GI Storage

## No Green Infrastructure Storage

Current land use/current precipitation: 1%\*

Future land use/future precipitation: 1.45%\*

## With Green Infrastructure Storage

Current with green infrastructure providing flood storage: 0.50%\*

Future with green infrastructure providing flood storage: 0.71%

RISK

\*Percent chance that a storm will occur in a year with peak discharge of 1,255 cfs and cause damages



Duluth

# Risk Reduced with GI Storage

## No Green Infrastructure Storage

Current land use/current precipitation: 1%\*

Future land use/future precipitation: 1.84 %\*

## With Green Infrastructure Storage

Current with green infrastructure providing flood storage: 0.24%\*

Future with green infrastructure providing flood storage: 0.51%\*

RISK

\*Percent chance that a storm will occur in a year with peak discharge of 1,530 cfs and cause damages

# Estimated unit cost of green infrastructure





**Step 5. Compare  
costs and  
benefits**





Costs of green infrastructure to obtain storage using least expensive GI option

Toledo

30 acre-feet of storage with  
least expensive GI = \$1.77M

Duluth

76 acre-feet of storage with  
least expensive GI = \$4.3M



**Benefits = Damages Avoided**





# Toledo's Benefits

- For 20-year period: \$700K not spent on flood damages to buildings (\$1.77M for GI)
- For 50-year period: \$1.77M not spent on flood damages to buildings (\$1.77M for GI)



# Duluth's Benefits

- For 20-year period: \$1.63 million not spent on flood damages (\$4.3M for GI)
- For 50-year period: \$4.6M not spent on flood damages (\$4.3M for GI)

## You may be thinking...

1. Numbers are low
2. Costs outweigh benefits





# You Need Data...

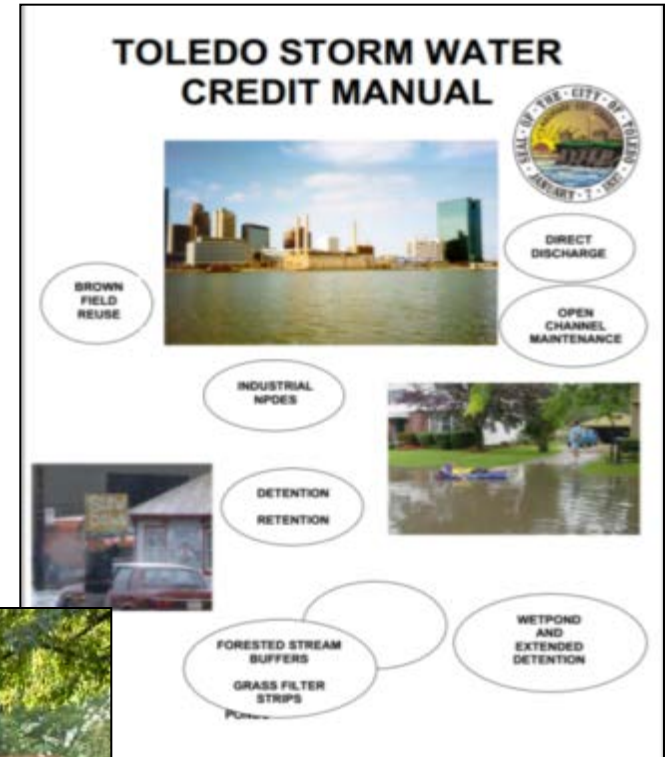
- Buildings
- Roads, bridges
- Stormwater infrastructure
- Recreation
- Wages
- Land damages



# We Had...

- Buildings (*Both communities*)
- ~~Roads, bridges~~
- Stormwater infrastructure (*Duluth only*)
- Recreation (*Duluth only*)
- ~~Wages~~
- Land damages (*Duluth only*)

# How Toledo Is Using Results





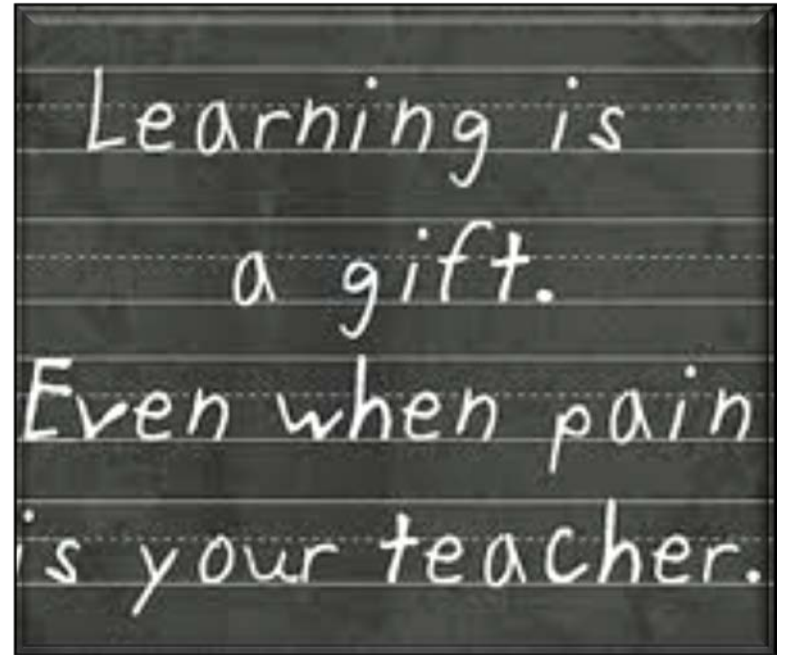
# How Duluth Is Using Results





# Lessons Learned

- Focus on longer term
- Hard to get all the data
- Look to implement GI over time
- Leverage other infrastructure investments
- Get a champion that is not elected or works for the city
- Consider benefits that cannot be monetized in decisions
- Partners are critical



# What's Next for NOAA?

Sharing what we have learned!

- Process Guide
- Data Matrix
- Green Infrastructure Options to Reduce Flooding

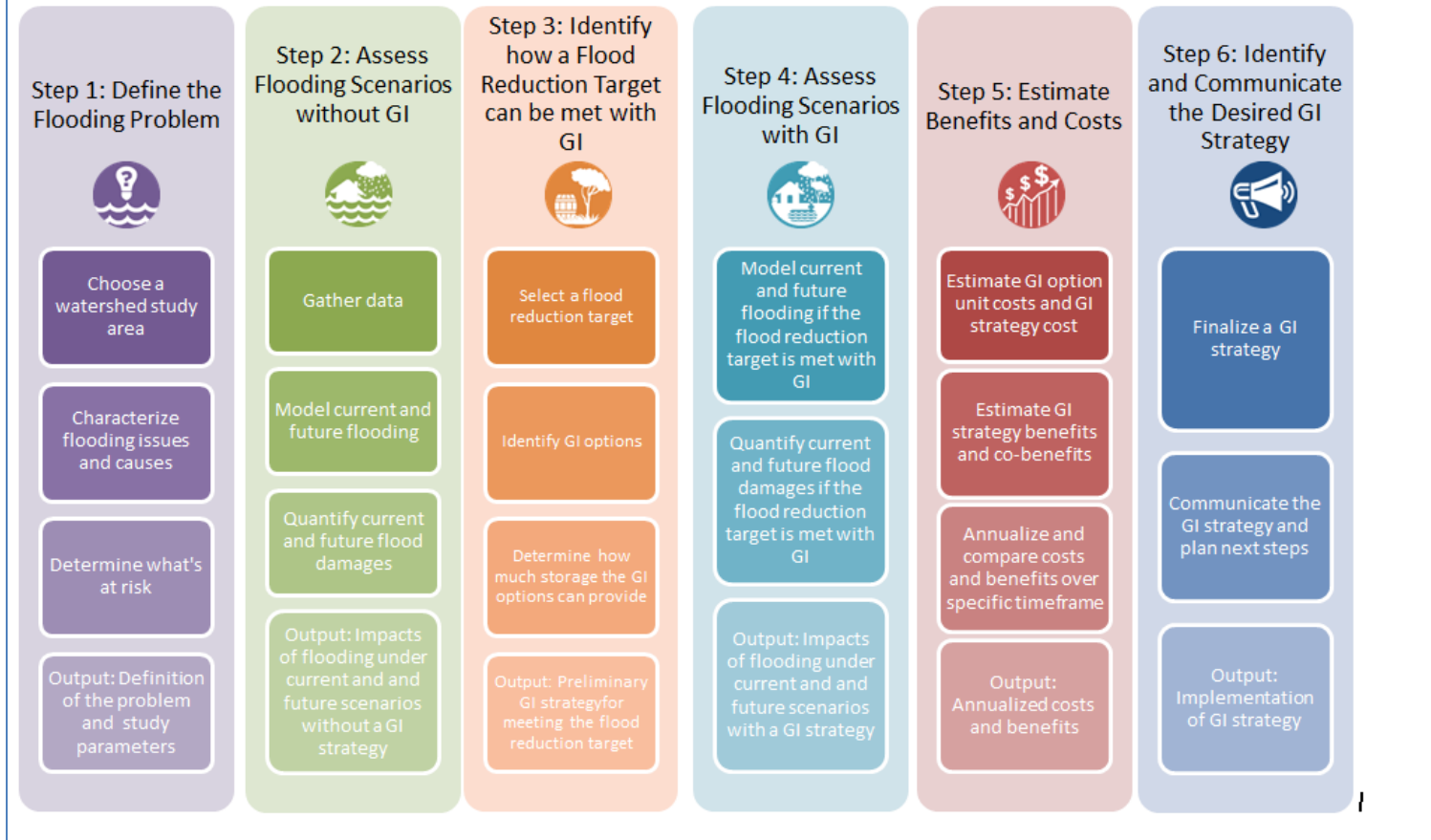
## **Digital Coast**

*[coast.noaa.gov/digitalcoast/](https://coast.noaa.gov/digitalcoast/)*

*[coast.noaa.gov/digitalcoast/publications/climate-change-adaptation-pilot](https://coast.noaa.gov/digitalcoast/publications/climate-change-adaptation-pilot)*

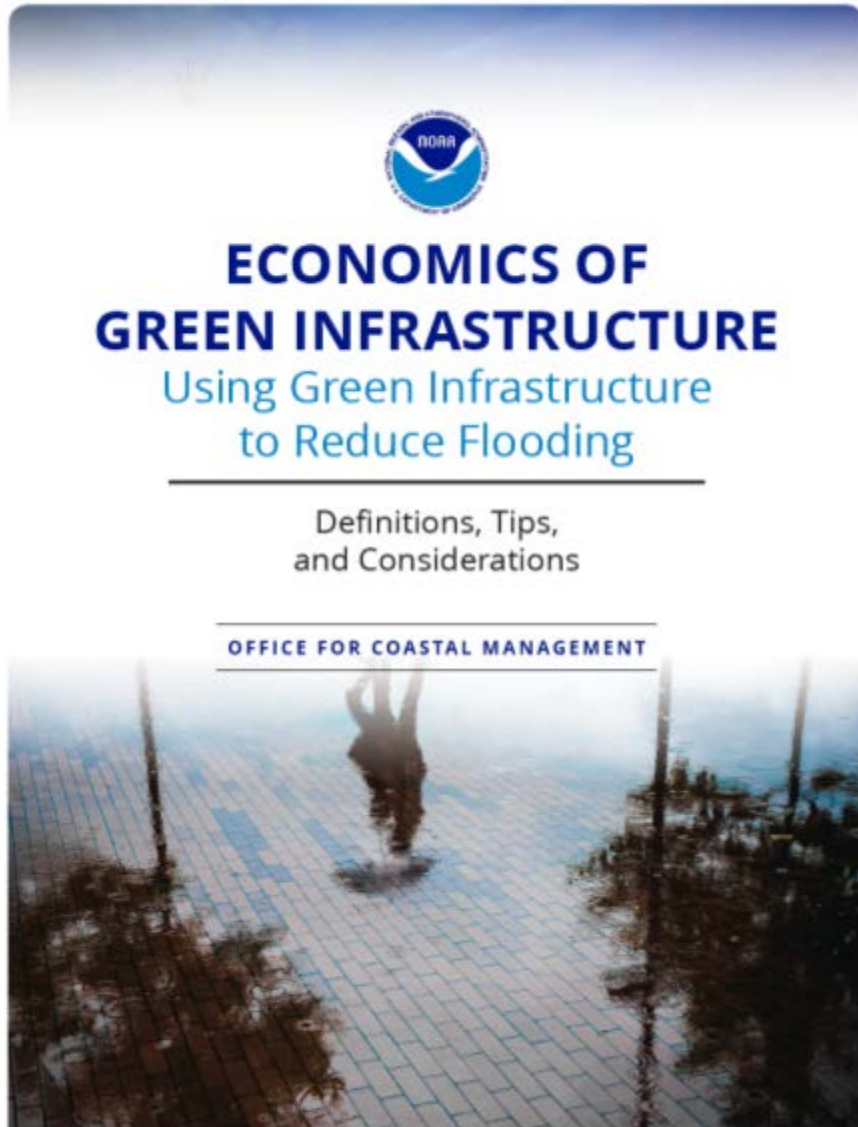
# Assessing Costs and Benefits of Green Infrastructure for Flood Mitigation: A Process Guide for Communities

## Framework for Cost and Benefit Assessment for Flood Mitigation using Green Infrastructure





# Companion Pieces



GI Options

## Green Infrastructure Geospatial Data Needs Matrix

**Assessment Process Steps**  
<https://oai.noaa.gov/records/publications/trade-change-adaptation-pilot>

This matrix provides a list of data used to conduct two pilot projects in the Great Lakes assessing the costs and benefits of using green infrastructure to reduce flooding impacts. These data are the best available from national, state, and municipal data sources and models. They are suitable for watershed-scale studies. Work with your local GIS analyst to discuss the data available for your assessment.

✔ Required: Data that gets you through the process  
○ Optional: Data that helps to improve the process

	Step 1: Define the Flooding Problem	Step 2: Assess Current and Future Flooding Scenarios	Step 3: Identify Flood Reduction Options Using GI	Step 4: Assess Flooding Scenarios with GI Options	Step 5: Compare Benefits and Costs	Step 6: Develop Approaches to Implement Desired Options
<b>Land Data</b>						
Land Use, Current	✔	✔	✔	✔	○	○
Land Use, Future		✔	✔	✔	○	○
Land Cover, Current	○	✔	✔	✔	○	○
Land Cover, Historical	○		○	✔		○
Digital Elevation Models (DEMs)	○	✔	○	✔		
<b>Weather &amp; Climate Data</b>						
Precipitation, Current	○	✔		✔		○
Climate, Current	○	✔	○	✔		○
Precipitation, Future		✔		✔		○
Climate, Future		✔	○	✔		○
<b>Hydrology Data</b>						
Historic Flood Locations	✔		○		○	○
Watershed(s) Delineations	✔	✔	○	✔		
Streams	✔	✔	○	✔		○
Stream Points		✔	○	✔		
FEMA Regulatory Maps	○	✔	○	✔		○
FEMA Digital Flood Insurance Maps (DFIRM)	○	✔	○	✔		○
FEMA Flood Insurance Studies (FIS)	○	✔	○	✔		○
USGS Regression Equations		✔	○	✔		
Basin Storage %		✔	○	✔		
Basin Development Factor		✔		✔		
Main Channel Slope		✔	○	✔		
Rural Peak Discharge		✔		✔		
Inundation Grid(s)		✔	○	✔		○
Flow Direction Grid(s)	○	✔	○	✔		○
Flow Accumulation Grid(s)	○	✔		✔		○
<b>Social &amp; Economic Data</b>						
Social Vulnerability Index	○	○	○		○	○
Bureau of Labor Statistics Employment	○	○			○	○
<b>Infrastructure Data</b>						
Land Parcel / Assessor Database		✔	○	✔	○	○
Stormwater Utilities	○	○	○	○	○	○
Building Structure	○	○		○	○	○
Green Infrastructure Sites, Current	○	○	✔	○	○	✔
Green Infrastructure Sites, Future		○		○	○	○
Impervious Surface %	○	✔	○	✔		

Data Matrix

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843-740-1243



**Digital Coast**

*coast.noaa.gov/digitalcoast/*

*coast.noaa.gov/digitalcoast/publications/climate-change-adaptation-pilot*