Community Engagement and Cost Benefit Analyses for Climate Adaptation of Transportation Infrastructure

Samuel Merrill
Joshua Murphy
March 21, 2012

Muskie School of Public Service

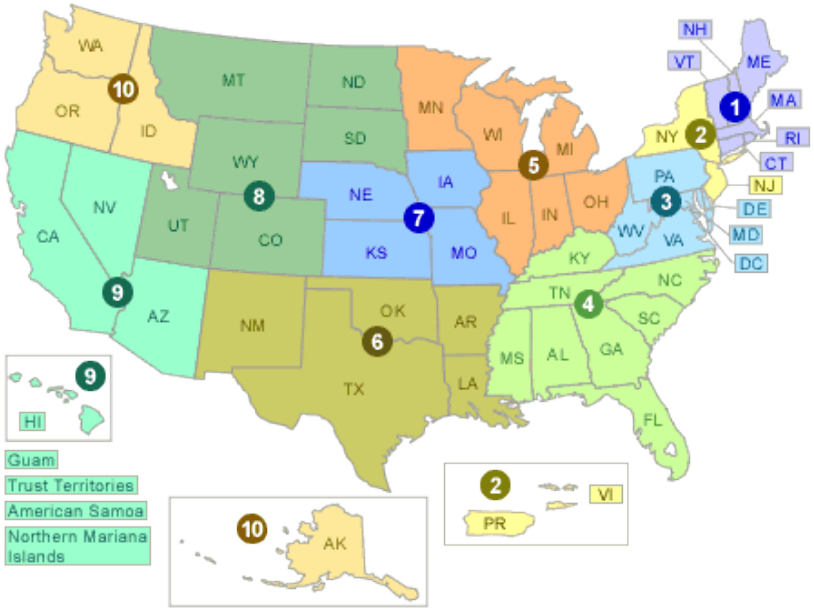
University of Southern Maine
Portland, Maine

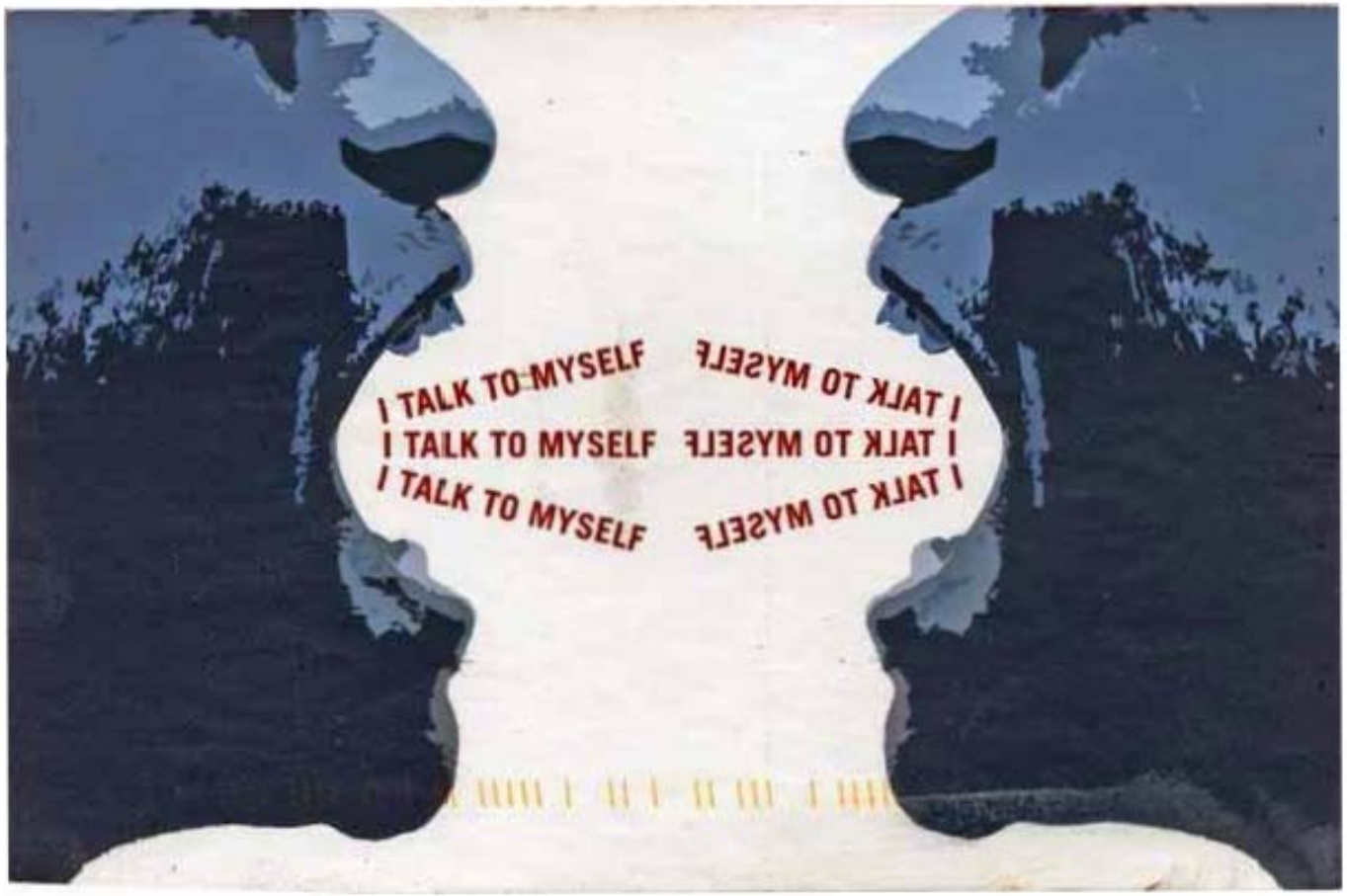
Environmental Finance Center Network

The EFCN is the only university-based organization creating innovative solutions to managing costs of environmental protection and improvement. It consists of ten EFCs serving states within EPA's ten regions. By sharing and integrating information, tools and techniques, the EFCs help address difficult how-to-pay issues of providing environmental services.

http://www.epa.gov/efinpage/efcn.htm.

EFCN
environmental finance center network




I TALK TO MYSELF
I TALK TO MYSELF
I TALK TO MYSELF

United States Environmental Protection Agency | Policy, Planning, And Evaluation (2122) | EPA-230-R-95-900 September 1995

EPA

Anticipatory Planning For Sea-Level Rise Along The Coast of Maine

This report a joint effort in cooperation with State of Maine's State Planning Office.

On the right track…

in 1995!

But it was never <u>brought to the local level</u>

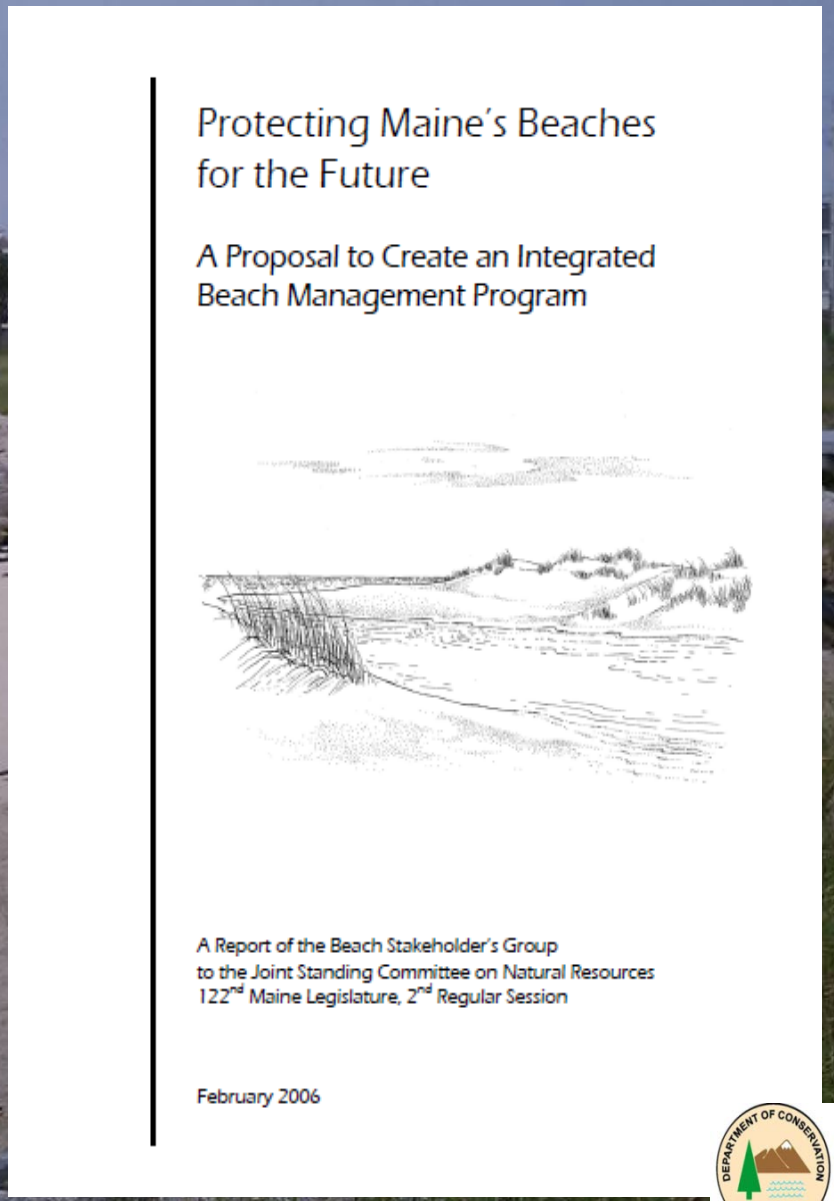
So it was LOST in the archives.

DEPARTMENT OF CONSERVATION MAINE GEOLOGICAL SURVEY

More reports…and updated sea level regulations

2006 - As the result of a 2 year stakeholder process, Maine adopted 2 feet of sea level rise over the next 100 years, which was a "middle-of-the road" prediction for global sea level rise, into its NRPA.

P.A. Slovinsky, MGS



Protecting Maine's Beaches for the Future

A Proposal to Create an Integrated Beach Management Program

A Report of the Beach Stakeholder's Group
to the Joint Standing Committee on Natural Resources
122nd Maine Legislature, 2nd Regular Session

February 2006

DEPARTMENT OF CONSERVATION
MAINE
GEOLOGICAL SURVEY


PRO-COMP
ULTRA-LITE
Auto Meter
RPM
THOUSANDS

A Dutch local resident watches floodwaters through his window, in Dordrecht on Jan. 5. Gale force winds and heavy rains are expected along the Dutch coast. About a quarter of the country sits below sea level.

- More frequent flooding
- More coastal erosion
- Wetland inundation and loss

It's difficult to shift into Action Mode:

1) Consequences appear far off in time.
2) Cost-benefit relationships are ambiguous.
3) Possible actions are complex.
4) Doing nothing is far, far easier.

Adaptation Works

Homeowners in Florida could reduce losses from a severe hurricane by 61 percent, resulting in $51 billion in savings, simply by building to strong construction codes.

Wharton Risk Management and Decision Processes Center, University of Pennsylvania.

“Managing Large Scale Risks in a New Era of Catastrophe.” 2007

There are only four options:

1) Do nothing (usually = remain in denial)
2) Fortify assets
3) Relocate assets
4) Accommodate higher water levels

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Fight, Flee, or Freeze

There are only four options:

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Fight, Flee, or Freeze => Fortify, Flee, or Flood

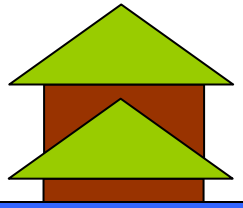
There are only four options:

1) Do nothing (usually = remain in denial)
2) Fortify assets
3) Relocate assets
4) Accommodate higher water levels

>> COAST is a tool and approach to help evaluate between these options.

Framing the Sea Level Rise Issue

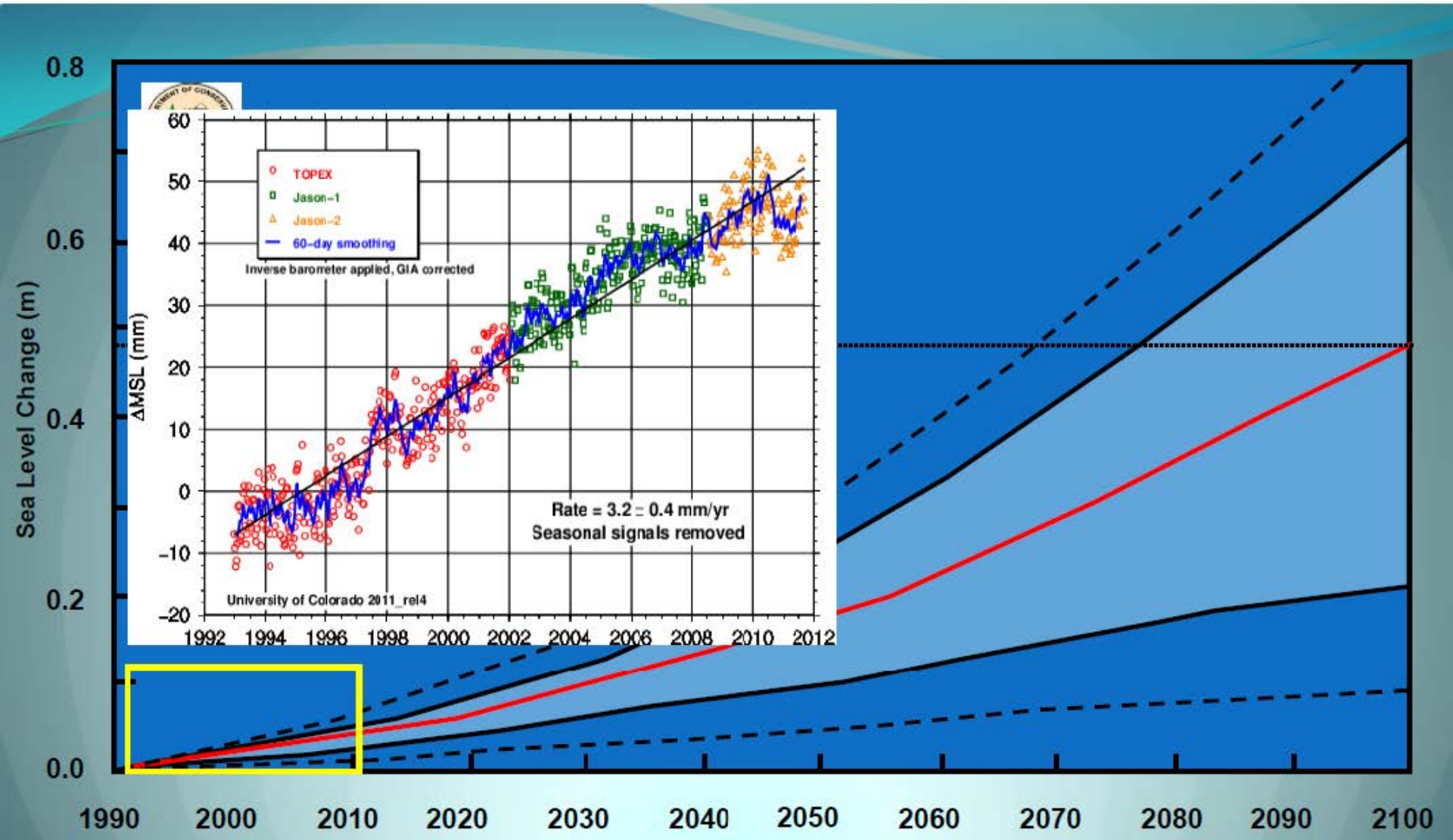
How will local communities respond?



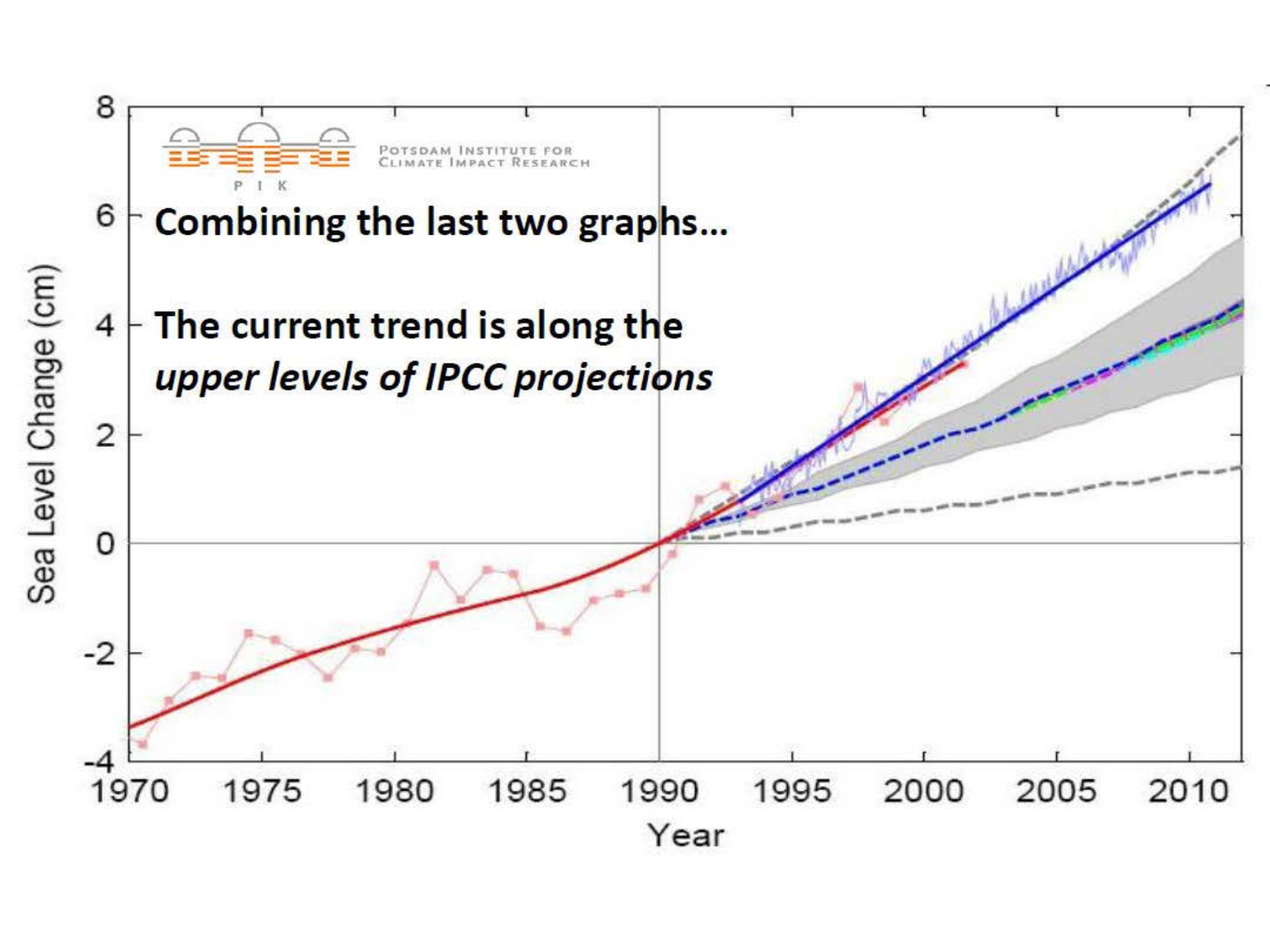
By how much? What will the potential impacts be to the built and natural environments?

Sea Level is RISING, regardless of the cause

DEPARTMENT OF CONSERVATION
MAINE
GEOLOGICAL SURVEY

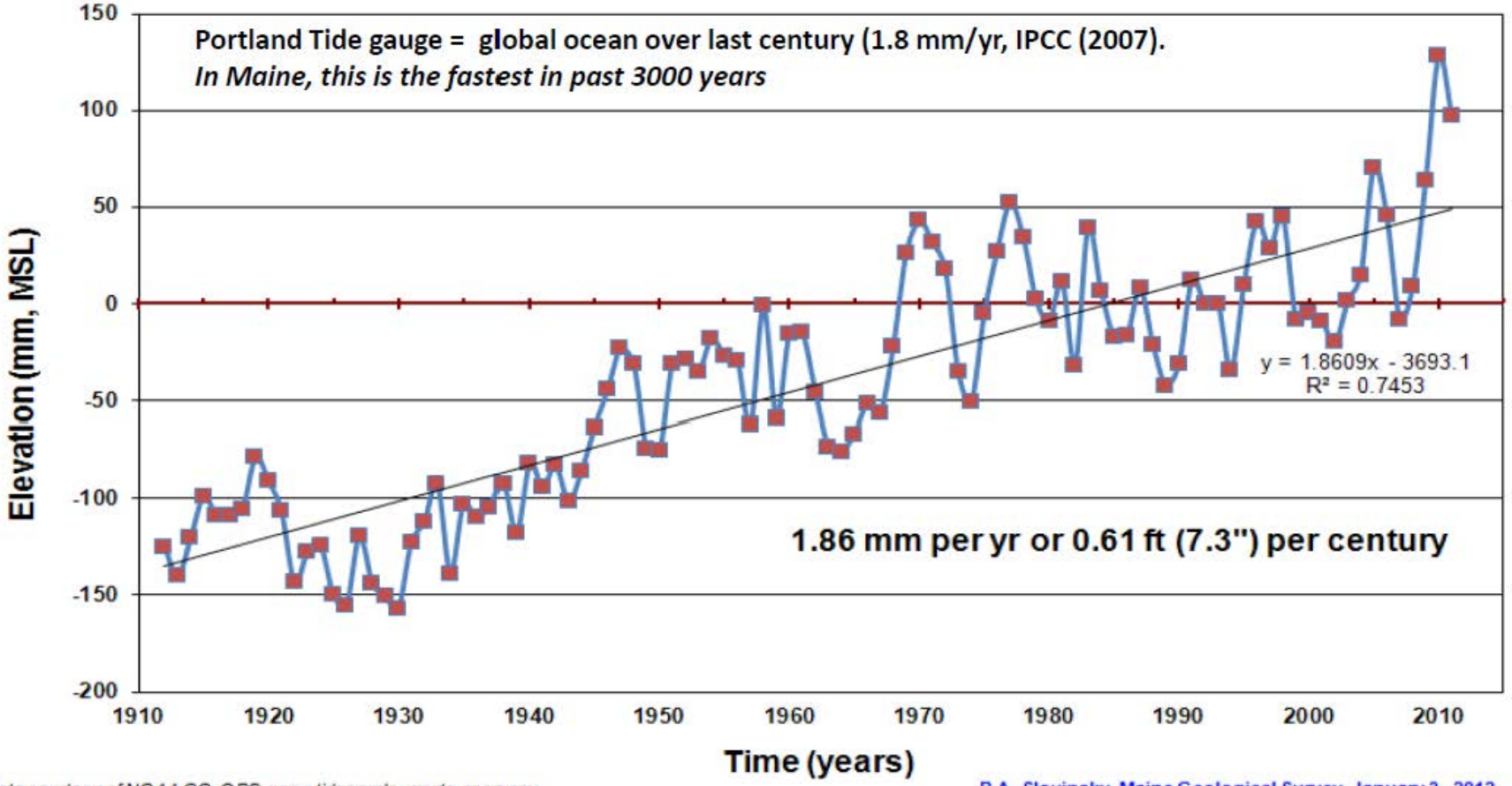


Adapted from the IPCC 3rd Assessment (Tech. Summary of Working Group I Report, Fig. 24, p. 74., 2001)


Potsdam Institute for Climate Impact Research
P I K
Combining the last two graphs…
The current trend is along the
upper levels of IPCC projections
Sea Level Change (cm)
8
6
4
2
0
-2
-4
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

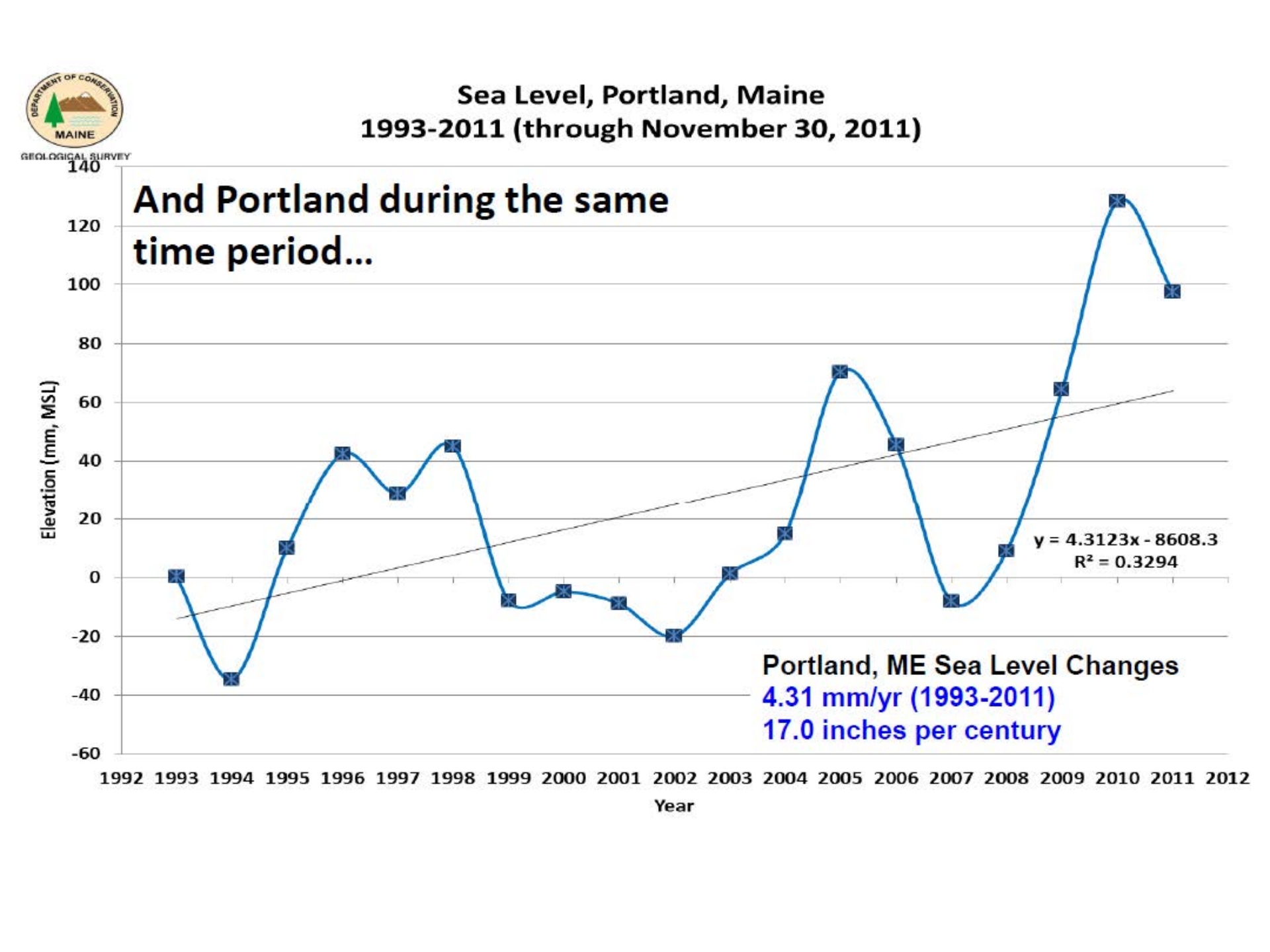
Sea Level, Portland, Maine

1912-2011 (through November 30, 2011)



Data courtesy of NOAA CO-OPS, www.tidesandcurrents.noaa.gov

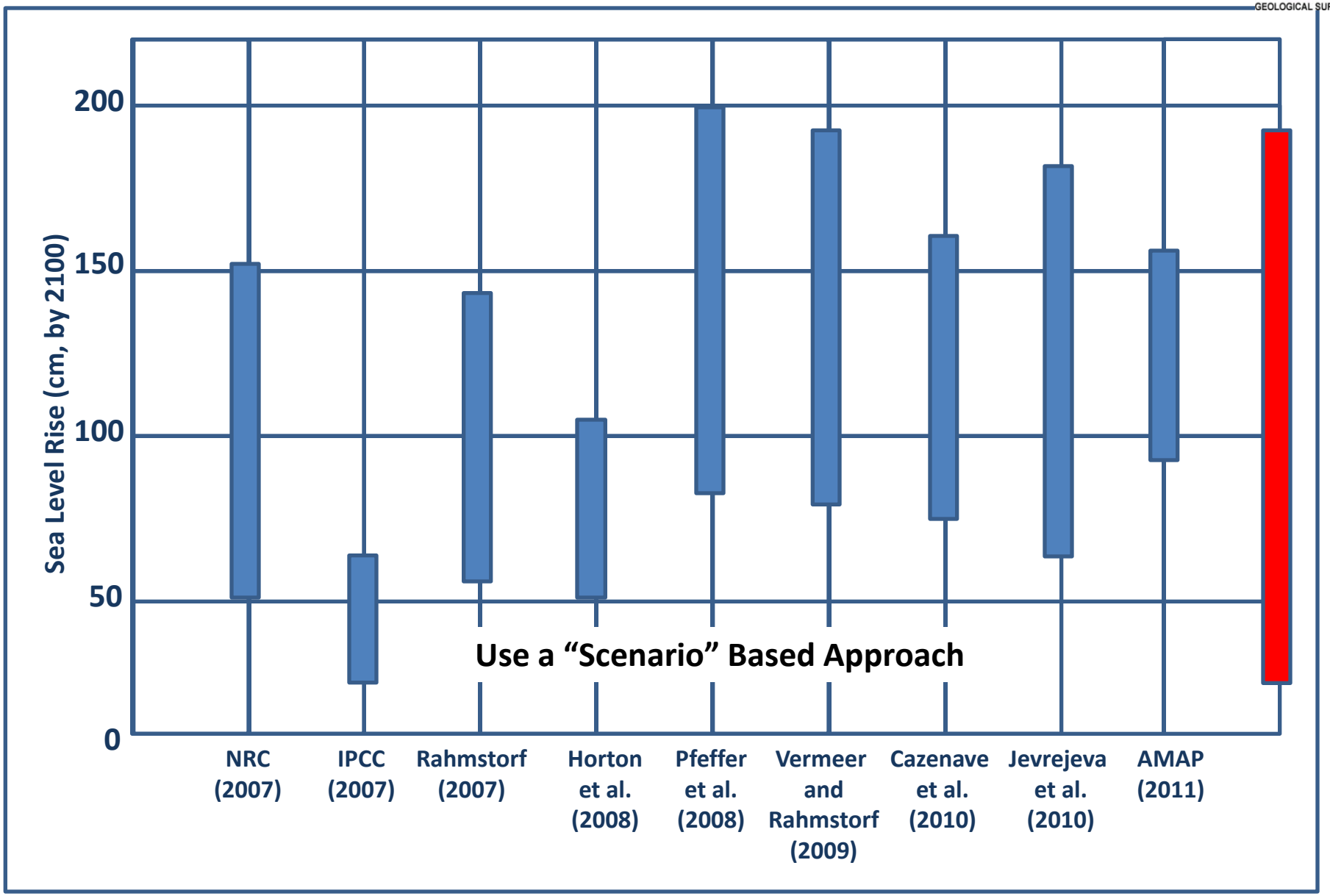
P.A. Slovinsky, Maine Geological Survey, January 3, 2012


Sea Level, Portland, Maine
1993-2011 (through November 30, 2011)
MAINE
GEOLOGICAL SURVEY
And Portland during the same time period…
Elevation (mm, MSL)
140
120
100
80
60
40
20
0
-20
-40
-60
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
Year
y = 4.3123x - 8608.3
R² = 0.3294
Portland, ME Sea Level Changes
4.31 mm/yr (1993-2011)
17.0 inches per century

Summary: Our Strategy (Part 1)

1) Don’t discuss climate change
2) Focus on observed, local data
3) Use visualization and a scenario based approach

For a Range of Scenarios…



Adapted from Rahmstorf (2010); and Williams (2012)

Summary: Our Strategy (Part 1)

1) Don’t discuss climate change.
2) Focus on observed, local data.
3) Use visualization and a scenario based approach.
4) Empower then get out of the way.

Sea Level Rise and Coastal Flooding Impacts Viewer

State, Regional, and County Needs

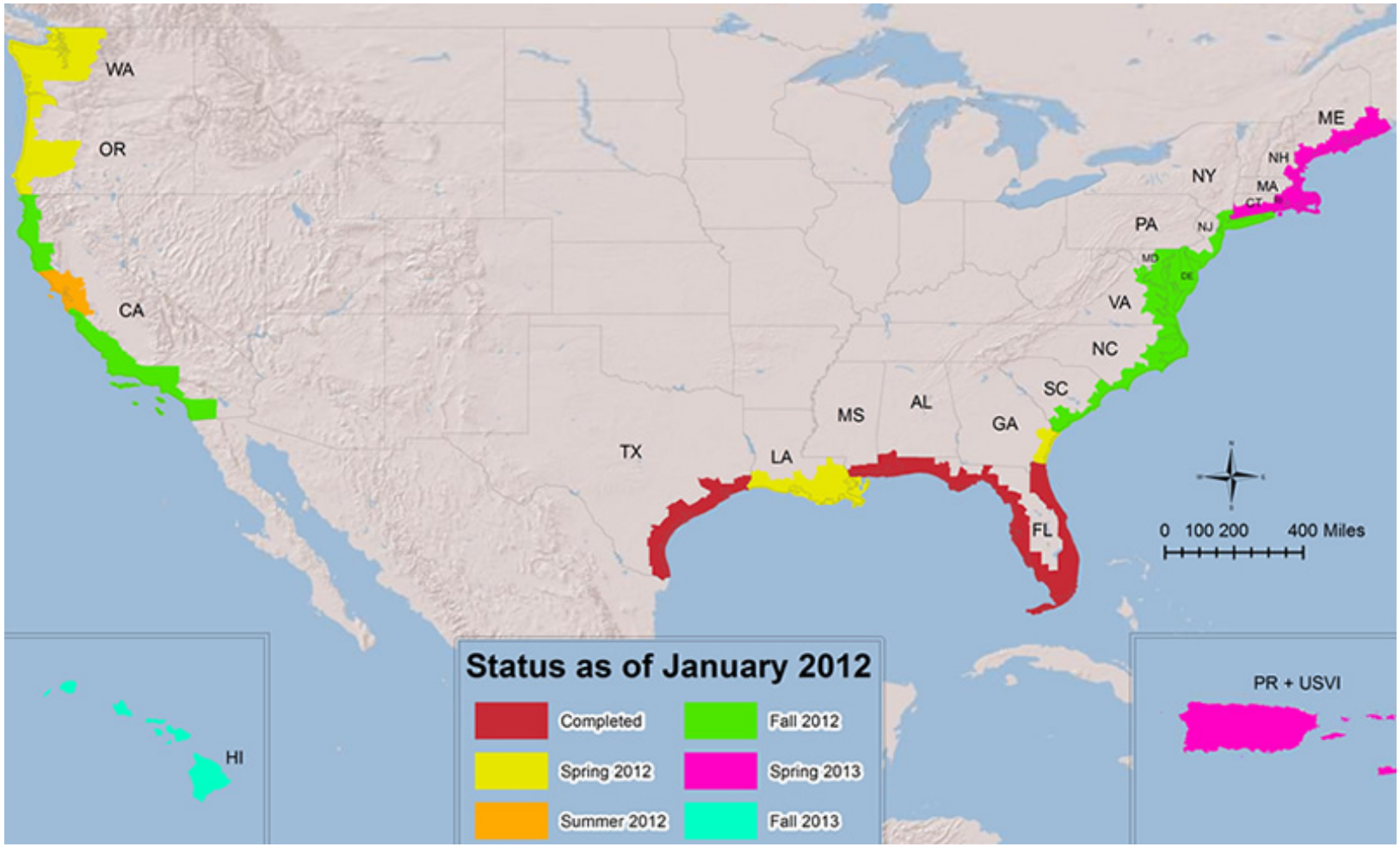
- Assistance with collection of consistent, standardized elevation data and avoidance of duplication
- Federal agency guidance and justification for flood, tide, and storm elevations for coastal areas to use for creating inundation models
- Methods and standards for mapping coastal inundation
- Sea level rise (SLR) visualization tools that show high-risk areas with possible future flooding problems so that land acquisition and adaptation planning can start now

State, Regional, and County Needs

- Simple-to-understand visualization tools
- Show potential impacts of SLR scenarios
- Show how everyday tidal flooding will become worse and more frequent

Building on local pilot studies and recommendations from communities of practice

Current Geographies



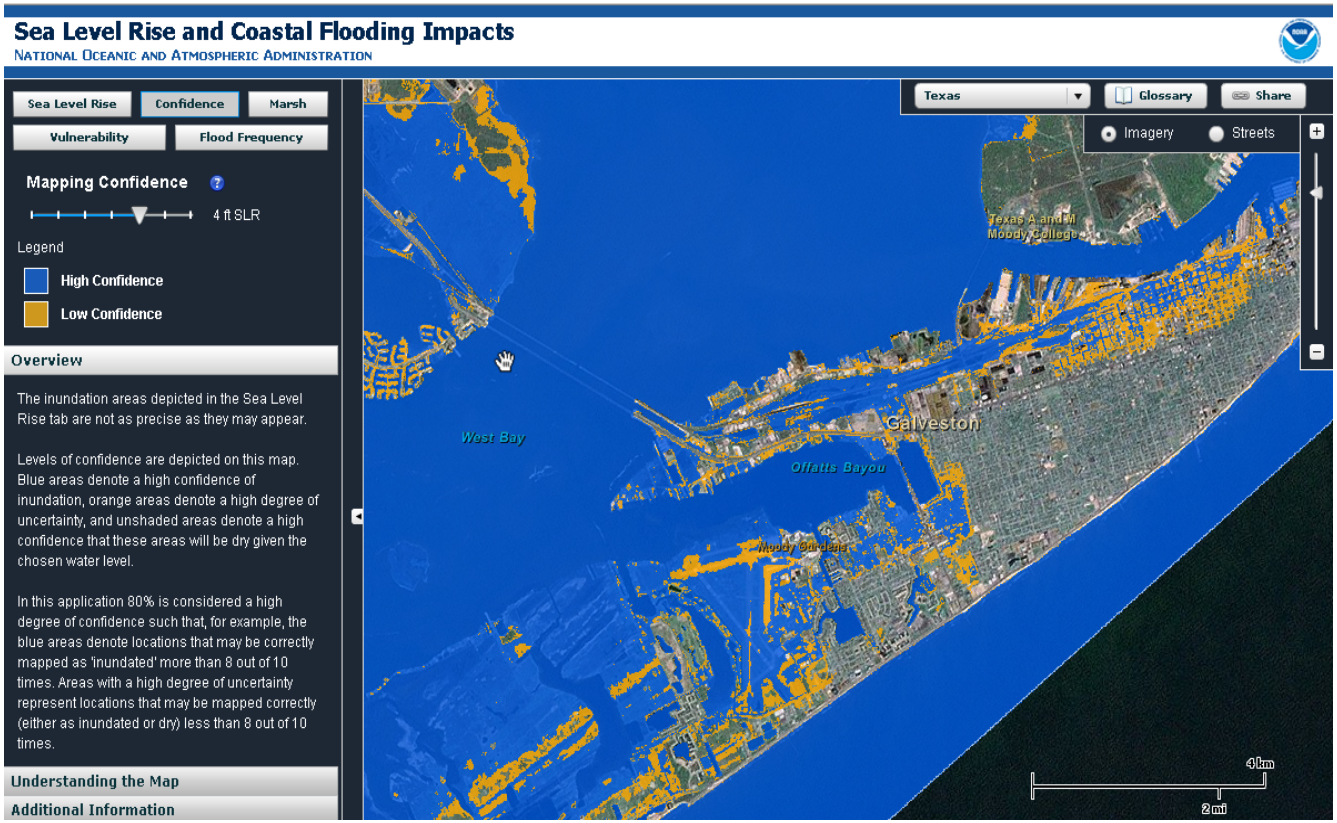
Components

- Impacts of Sea Level Rise
  - Visualize impacts for mean higher high water (MHHW) 6-foot SLR scenarios overlaid on aerial imagery, street map, and terrain map. Photos of SLR on individual structures will illustrate site-specific impacts.

Low-Lying Areas

Components

- Communicate Mapping Confidence
  - ➢ Visualize the mapping confidence of inundation area based on uncertainty of elevation data and MHHW tidal surface.



Zone of Uncertainty

Components

Coastal Flood Frequency

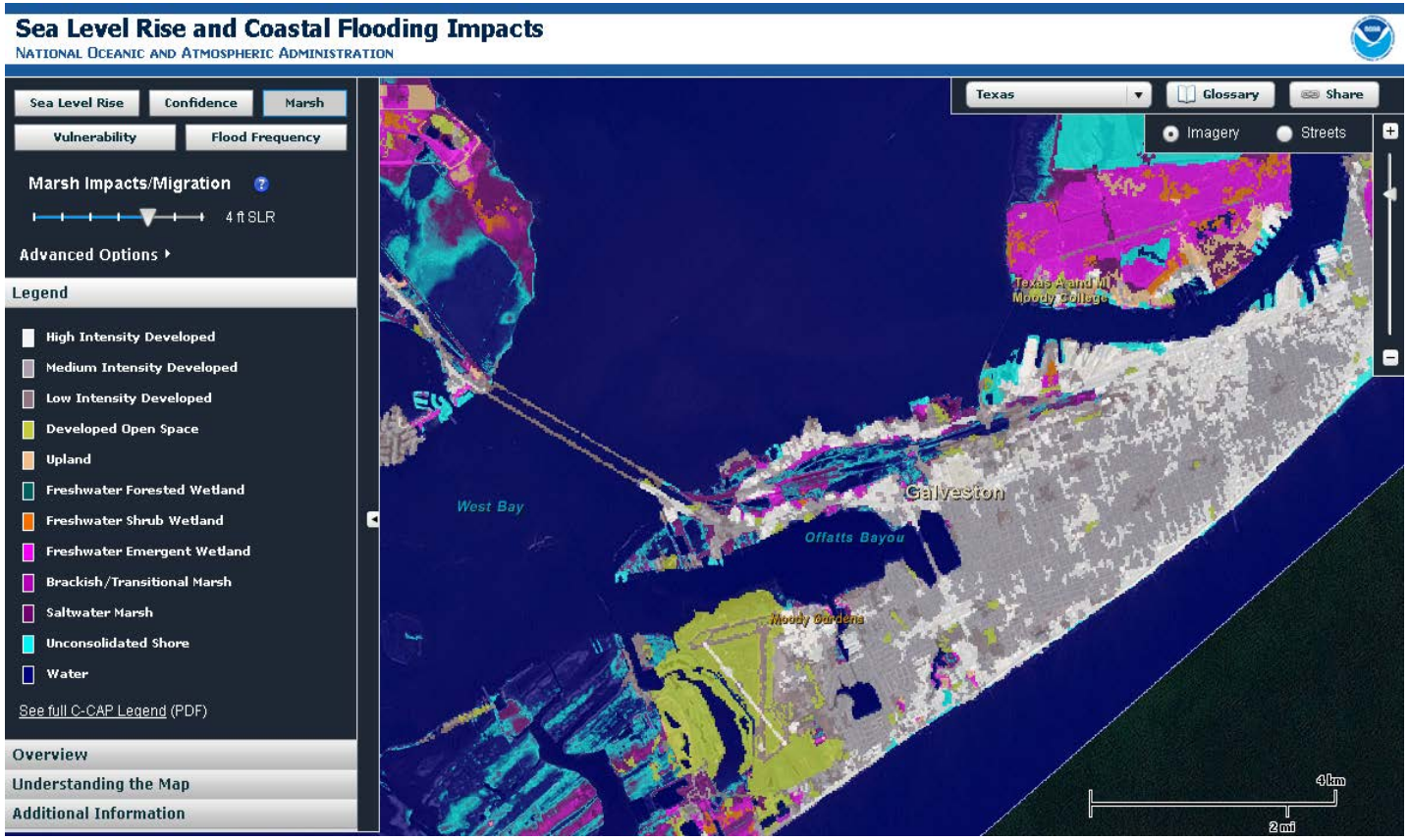
- Communicate that today's flood is tomorrow's high tide. Use three years of observed water level data at National Ocean Service National Water Level Observation Network (NWLON) stations to show increased frequency of everyday flooding.

National Weather Service Coastal Flood Warning Areas

Components

Visualize Marsh Impacts

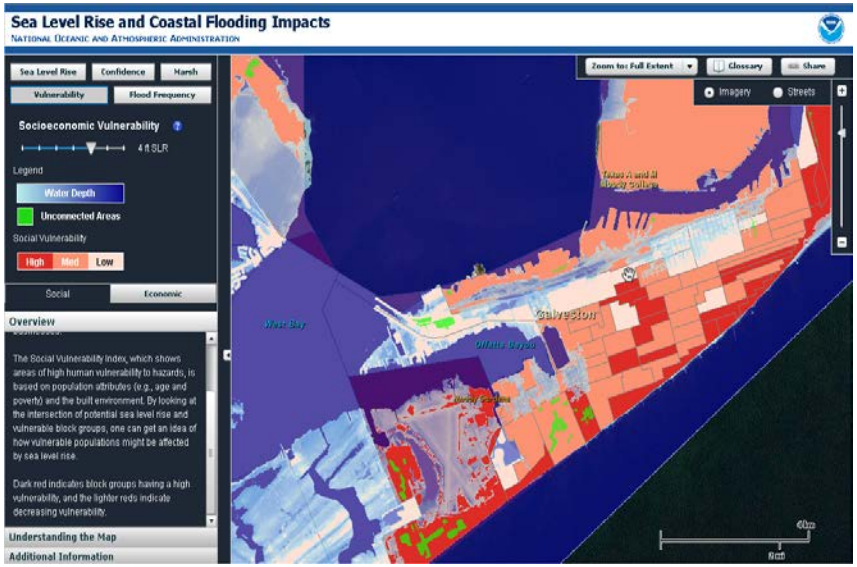
- Visualize the impacts of SLR scenarios on marshes using Coastal Change Analysis Program (C-CAP) data.



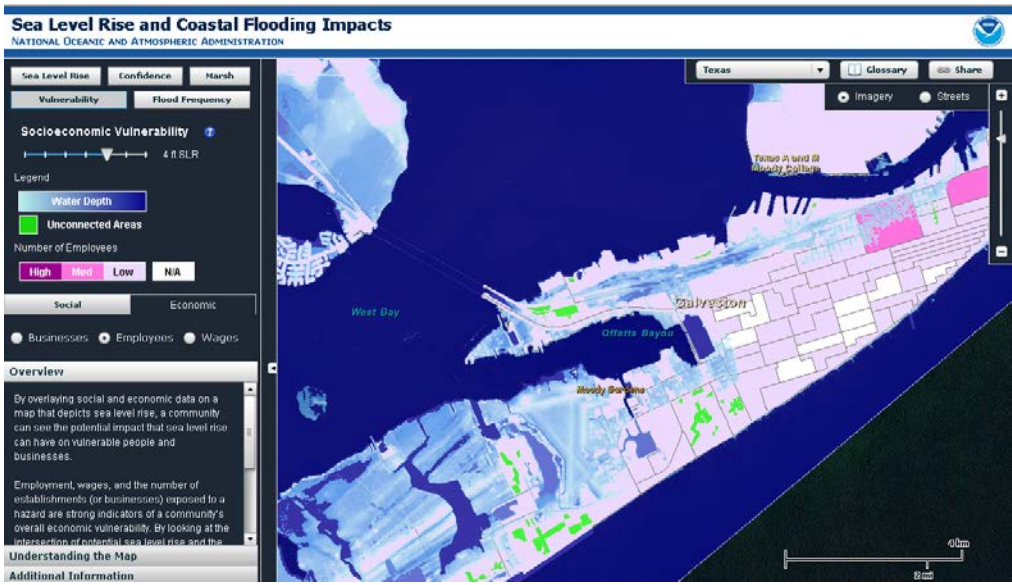
Components

Economic Vulnerability

- Includes Social Vulnerability Index (SOVI) from USC and data from Bureau of Labor Statistics (BLS) showing impacts on society and economy.



Social Vulnerability Index (Cutter)



Bureau of Labor Statistics (Department of Labor)

- *Businesses*
- *Employees*
- *Wages*

Future: Increase Geography and Regional Implementation

- Georgia
- Louisiana
- CA, OR, WA
- Mid-Atlantic
- Pacific
- NC, SC
- Northeast
- Great Lakes

- San Francisco Bay – Adapting to Rising Tides
- New Jersey – Rutgers
- South Florida Climate Compact
- Nature Conservancy and U. of Southern MS Gulf of Mexico Coastal Resilience Project
- U. of Florida and Tampa Bay Regional Planning Council Adaptation Project
- National Park Service Coastal Parks Assessment
- U.S. Army Corps Projects Evaluation
- HI Sea Grant and U. of Hawaii School of Ocean and Earth Sci. (NOAA Coastal Storms Program)
- NCCOS N. Gulf Ecological Effects of SLR project

Data Distribution

A Wealth of Data

- Conditioned DEMs
- SLR layers
- Marsh migration layers
- Uncertainty layers
- Shallow coastal flooding layer
- SOVI data
- BLS data

Many Ways to Access

- Raster geodatabases via FTP
- Representational State Transfer (REST) page
- Web map service (WMS)
- Web coverage service (WCS)
- Enabling mash-up applications

Available via NOAA Digital Coast Tools

www.csc.noaa.gov/digitalcoast/

DIGITAL COAST
NOAA Coastal Services Center

Home Data Tools Training Approaches In Action

Tools

Welcome to the new Digital Coast. If you have questions or comments, please take a video tour or contact us.

The tools on this page support coastal decision-making by transforming Digital Coast data into information tailored for specific issues. Some tools are Web-based, providing direct online analysis and viewing, while others are downloadable extensions that provide new functionality for desktop geographic information systems. Have an idea for a tool you would like to see in the Digital Coast? Make a tool suggestion to the Digital Coast.

Filter by Category: Data Visualization Tools Filter by Issue: Hazards

Data Visualization Tools

Present dynamic views of spatial data. Some may offer data download capabilities

Coastal Resilience Long Island
The Nature Conservancy
Enables users to visualize coastal hazards impacting Long Island, New York
More Info Get It Now

Community Resource Inventory (South Carolina)
Clemson University
Provides an online mapping atlas of the natural and cultural resources in a community
More Info Get It Now

Historical Hurricane Tracks IMS
NOAA
Enables viewers to find tropical cyclone data in the Atlantic and Eastern Pacific Basins

Featured Tool

Multipurpose Marine Cadastre
Provides a framework for marine spatial planning efforts

Tool Resources

Ecosystem-Based Management Tools Network
Supports the implementation of

DIGITAL COAST
NOAA Coastal Services Center

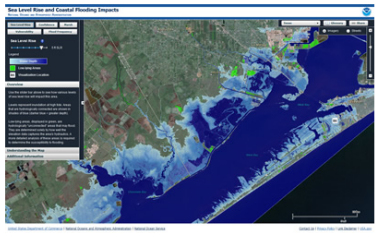
Home Data Tools Training Approaches In Action

Tools

Sea Level Rise Impacts Viewer
NOAA Coastal Services Center

Overview

Being able to visualize potential impacts from sea level rise is a powerful teaching and planning tool, and the Sea Level Rise Viewer brings this capability to coastal communities. A slider bar is used to show how various levels of sea level rise will impact coastal communities. The initial project areas include Texas' Houston and Galveston coasts and Mississippi, with additional coastal counties to be added in the near future. Visuals and the accompanying data and information cover sea level rise inundation, uncertainty, flood frequency, marsh impacts, and socioeconomics.



Launch Now

Features

Displays potential future sea levels

Provides simulations of sea level rise at local landmarks

Communicates the spatial uncertainty of mapped sea levels

Models potential marsh migration due to sea level rise

Overlays social and economic data onto potential sea level rise

Examines how tidal flooding will become more frequent with sea level rise

Acknowledgements

The NOAA Coastal Services Center would like to acknowledge those organizations that provided direct content used in this tool or feedback, ideas, and reviews over the course of the tool's development. Specifically the Center would like to acknowledge the following groups.

Part of the Coastal Inundation Toolkit

www.csc.noaa.gov/inundation/

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NOAA Coastal Services Center

Home About Data Tools Training Approaches In Action

Approaches

Coastal Inundation Toolkit

Home About Glossary Resources

Tweet 10

Understand
What is coastal inundation, its causes, and impacts?

Identify
How do I recognize community risks?

Visualize
How can visualizations improve understanding of inundation?

Communicate
What are the best ways to communicate risk and vulnerability information?

Discover
What are others doing to address coastal inundation?

About The Toolkit
Provides the tools and information communities need to understand and address coastal flooding.

Highlighted Resources

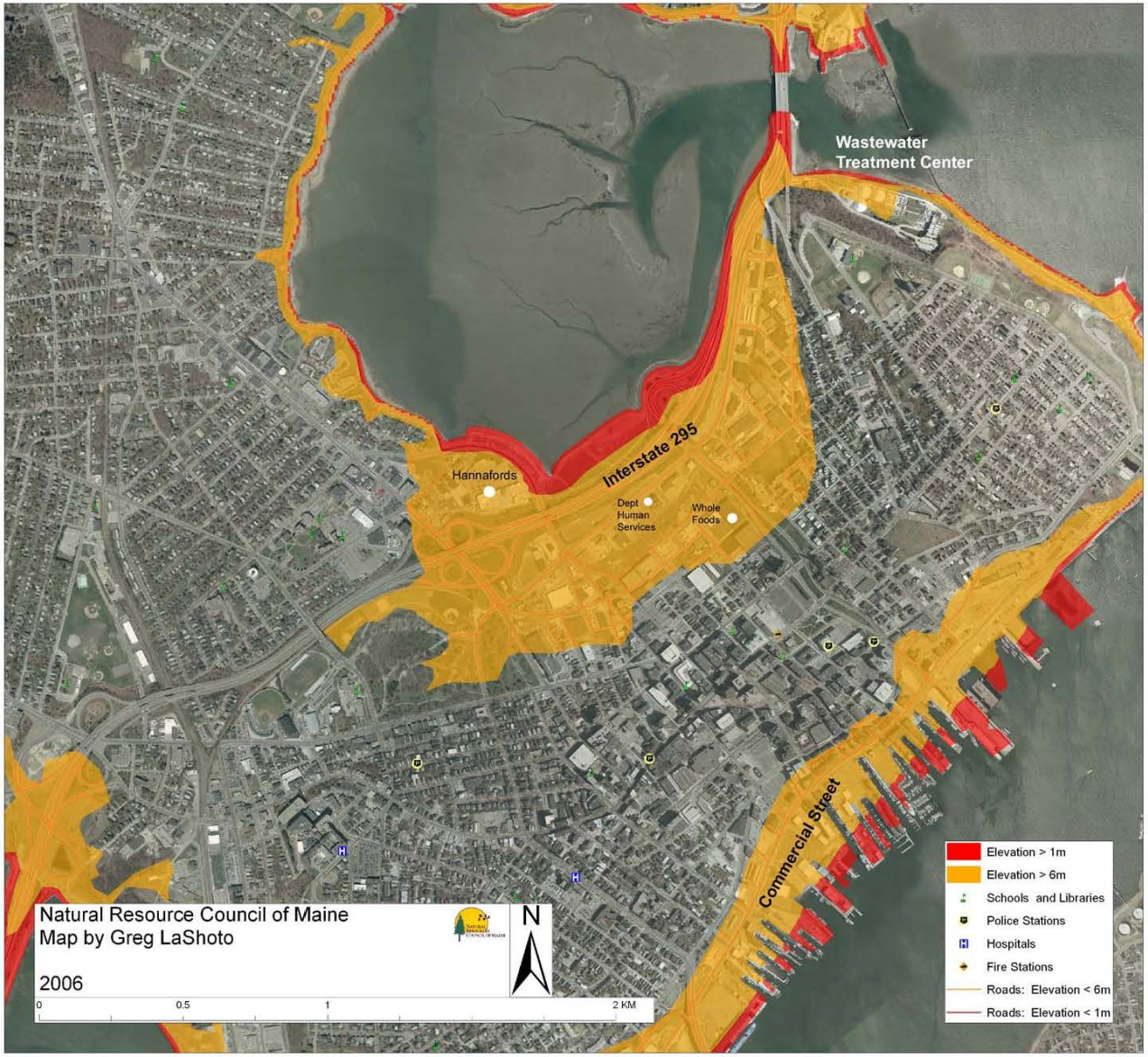
Sea Level Rise and Coastal Flooding Impacts Viewer
Visualize potential community impacts from sea level rise. Accompanying information includes uncertainty, flood frequency, marsh impacts, and socioeconomics.

1 2 3 4

The COAST Approach to Climate Change Adaptation Finance

Examples from Portland, Maine

Impact of Sea Level Rise on Portland, ME

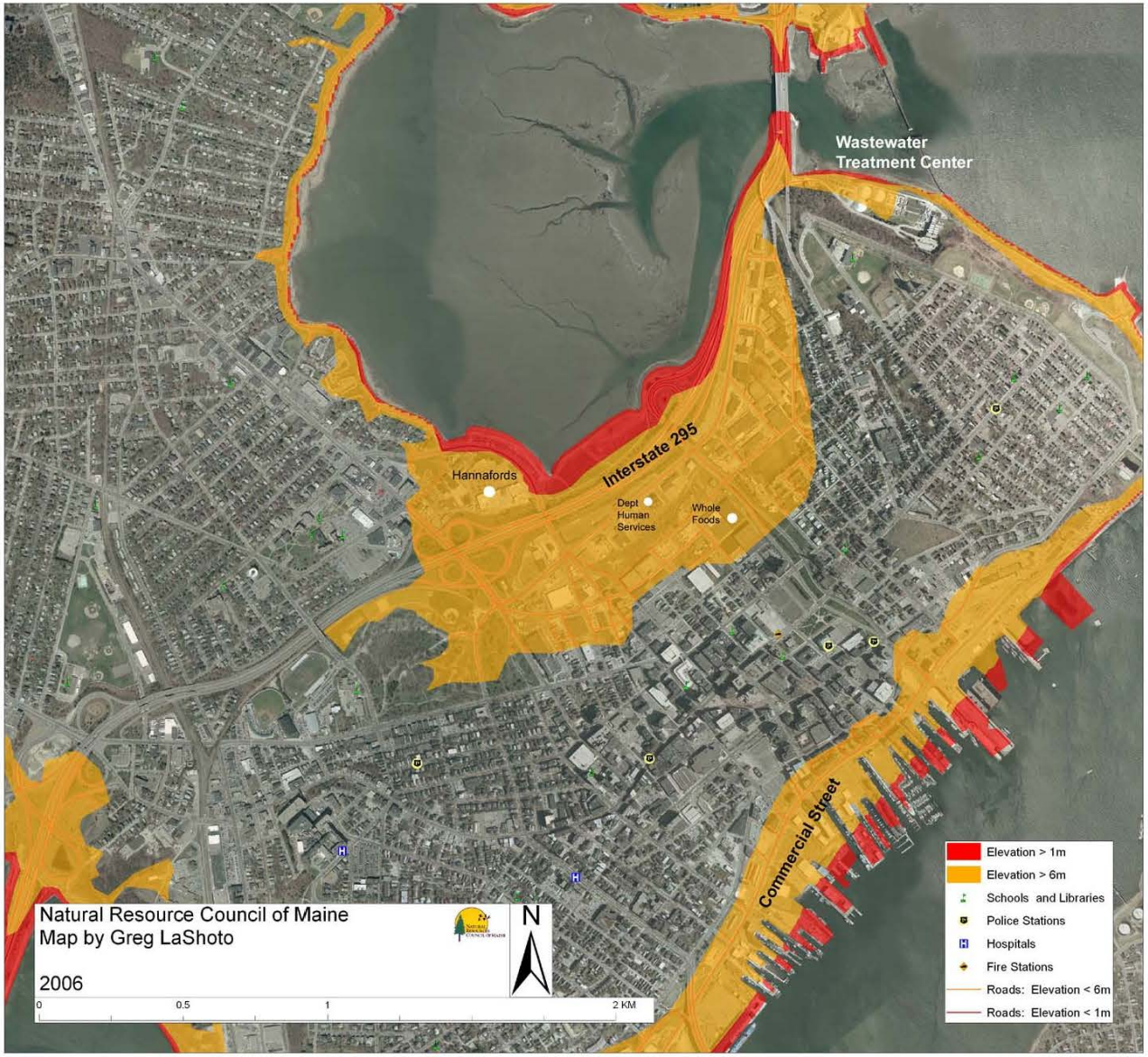


… Sea Level Rise on Portland, ME


Hannaford's
Interstate 295
Dept. Human Services
Whole Foods
Wastewater Treatment Center
Commercial Street


FALMOUTH

Impact of Sea Level Rise on Portland, ME



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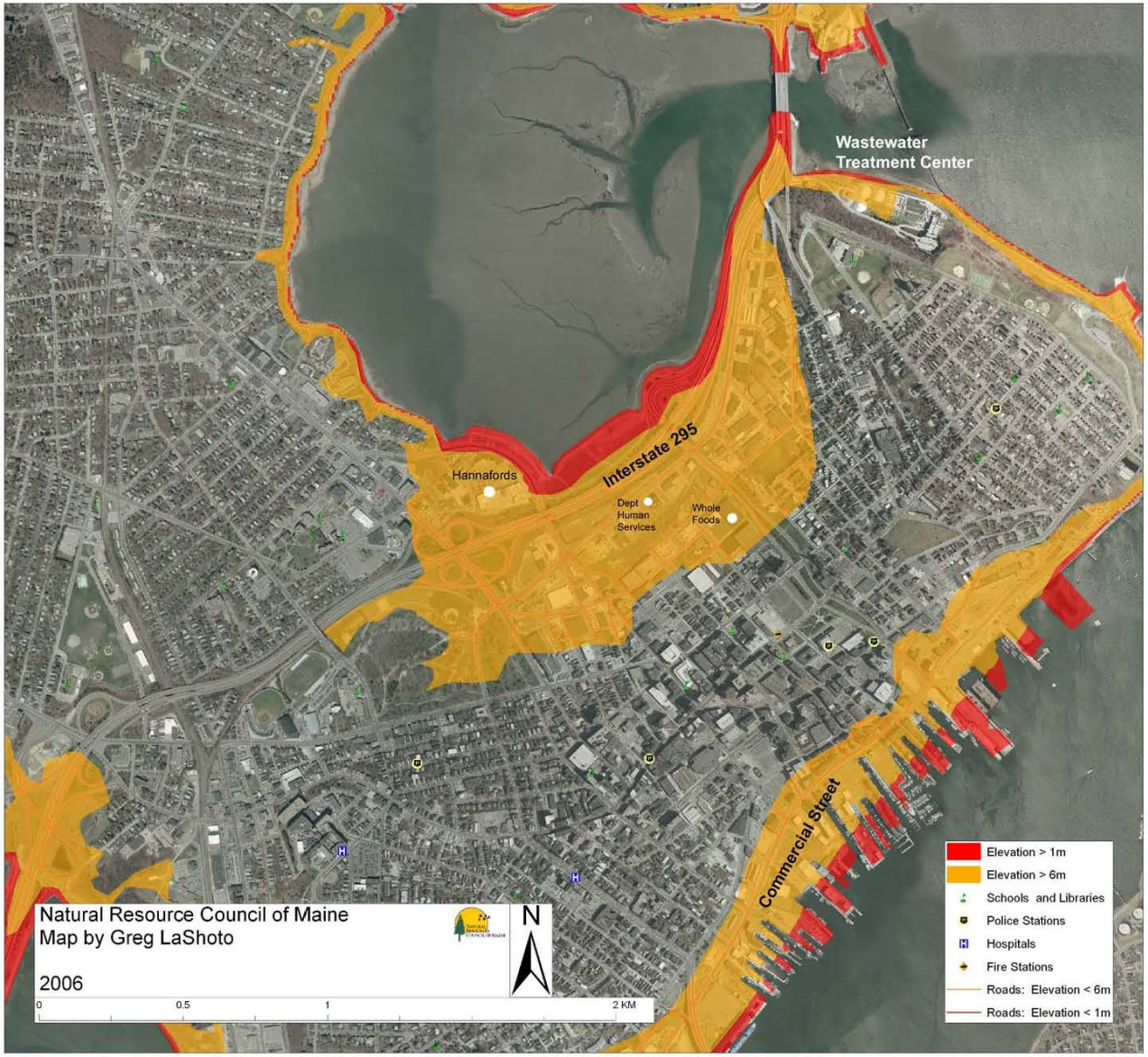


(R. Obrey.)
Whole Foods1/9/10 at high tide

The Old Port, 10/11 at high tide (M. Craig)


NO
THRU
TRAFFIC
RESIDENT
AND
BUSINESS
TRAFFIC
ONLY

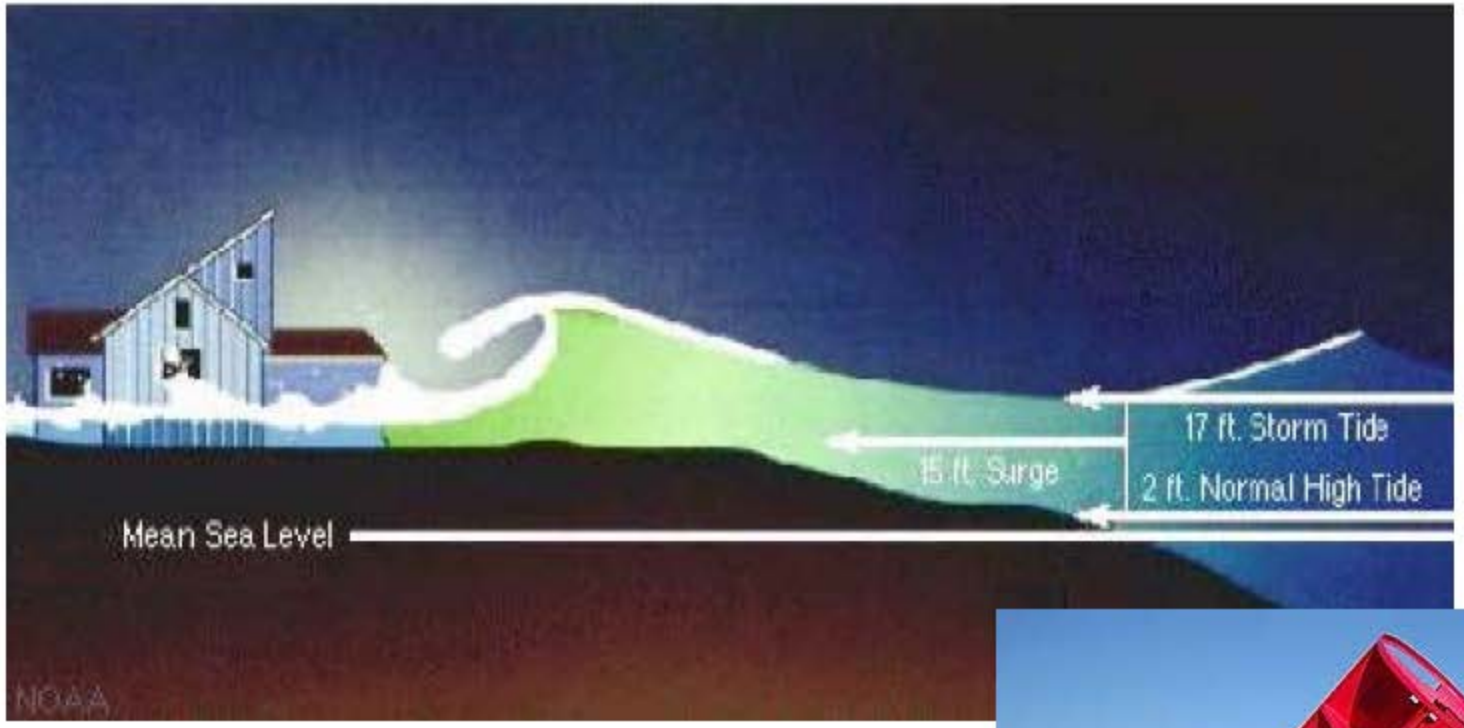

FedEx
4A 2885
RIPPLE
PRIVATE PARKING


The Portland Press Herald
Catch Up On YOUR LOCAL TEAMS
RED CLAWS
TO SUBSCRIBE CALL 791-6000

Marginal Way and Cove St., 9/10, New Moon J. Piribeck

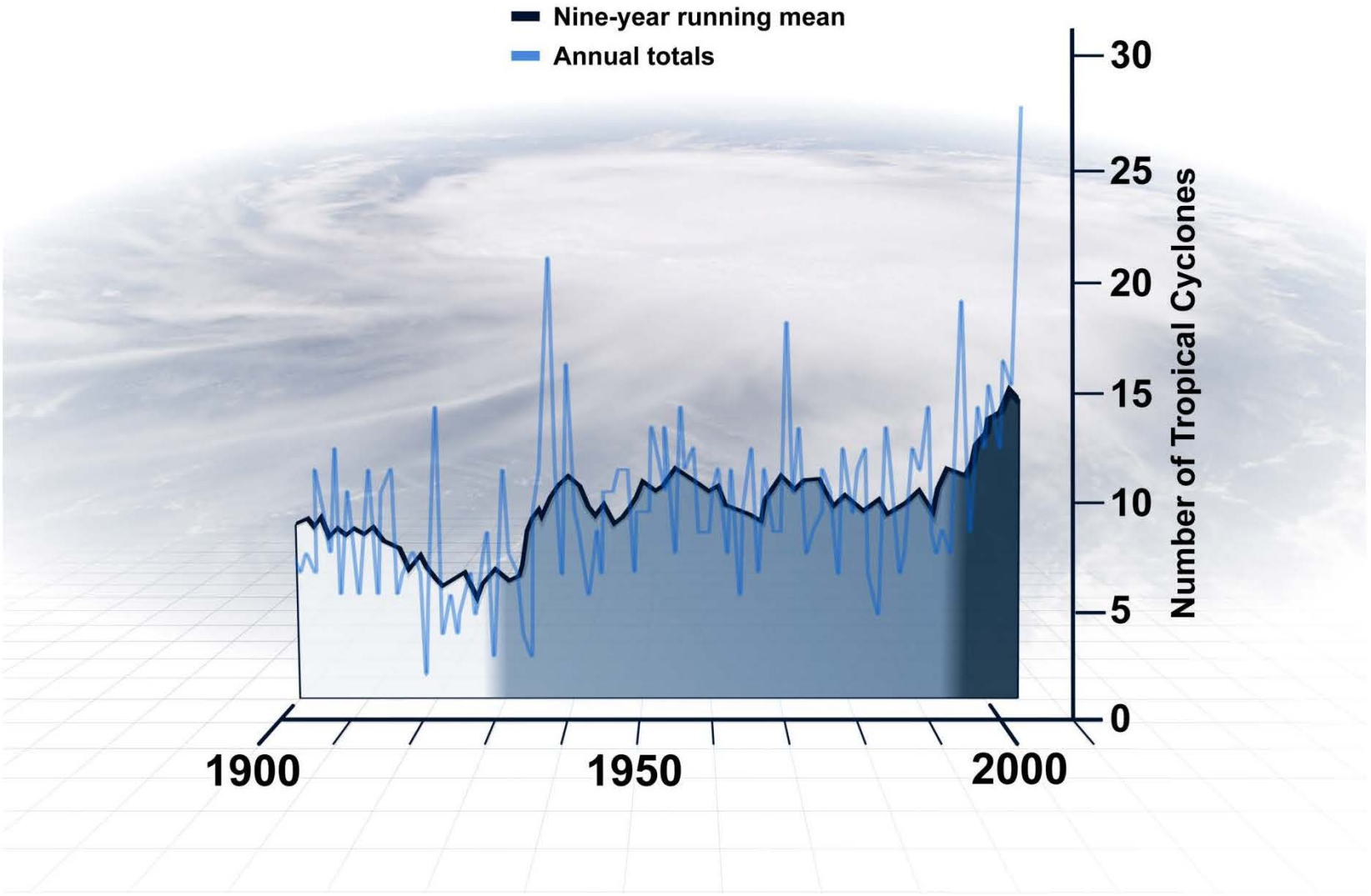
Marginal Way and Cove St., 9/10, New Moon J. Piribeck

Climate Change>>Sea Level Rise>>Storm Surge



Patriot's Day Storm 2007: York Beach

Frequency of Atlantic Storms



The Old Port, 3/10 at high tide (D. Yakovleff)

R. Obrey

R. Obrey

R. Obrey


DUNKIN' DONUTS
DRIVE THRU
MAZZIOTTI MOTOR WORKS
Curves
Kirby CENTERS OF MAINE
SALES · SERVICE · SUPPLIES
797-0700
AROUND BACK
DUNKIN' DONUTS
DUNKIN' DONUTS
FOR LEASE
207 773-7100
NO THRU TRUCKS

R. Obrey

R. Obrey


NO PARKING
On Any Street, April 1 - October 1
No Parking Anytime in Fire Lane

R. Obrey

R. Obrey

The Effects of Climate Change on Economic Activity in Maine:

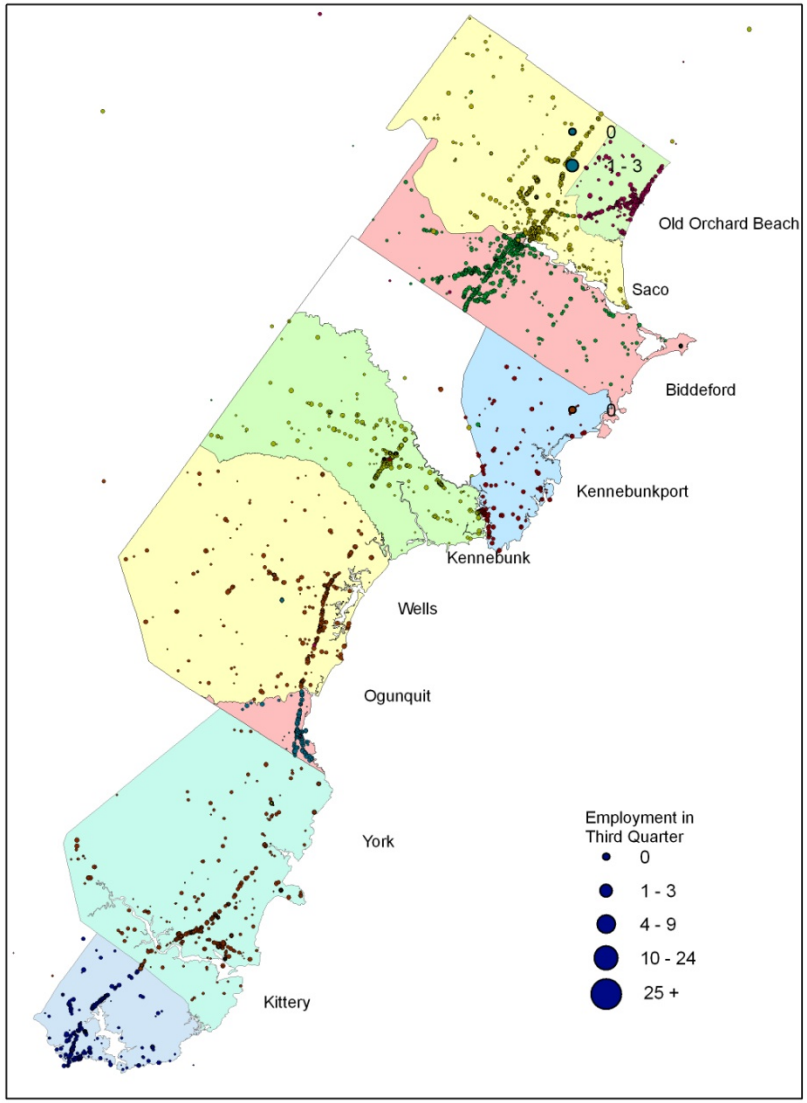
Coastal York County Case Study

by Charles S. Colgan

Samuel B. Merrill

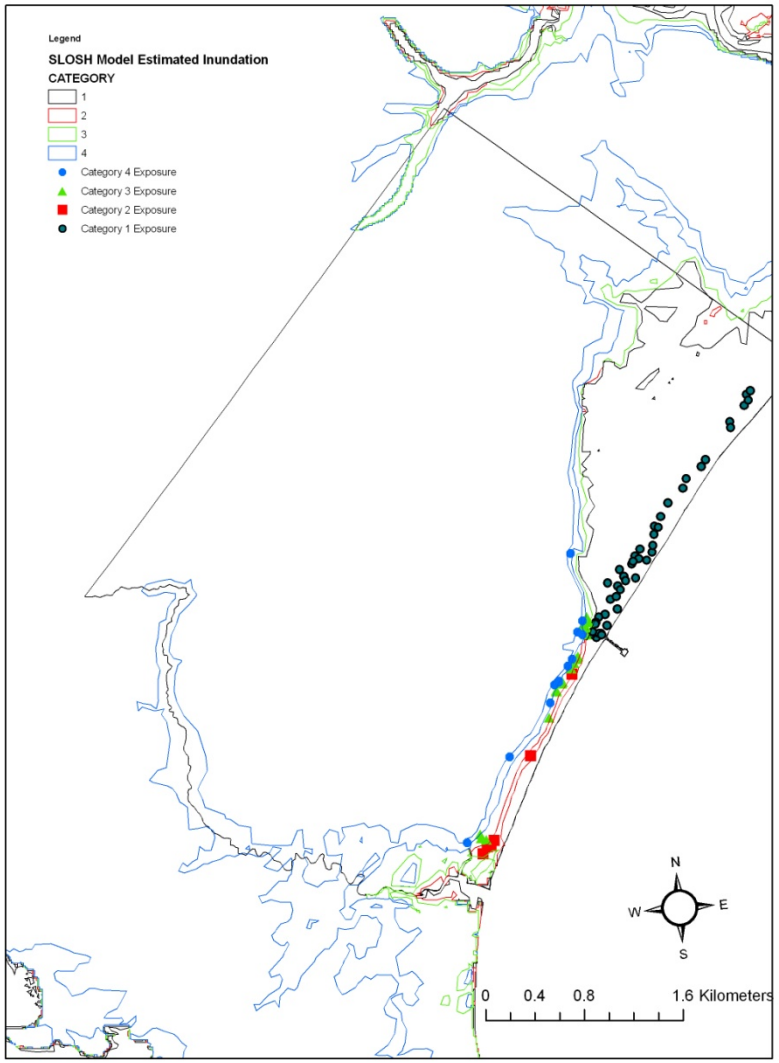
Climate change can have significant ramifications for Maine's economy. If short-term projections for the next century are accurate, at minimum sea level rise will become increasingly noticeable in association with more severe and destructive coastal storms. Charles Colgan and Samuel Merrill evaluate risk estimates by presenting a case study of the projected consequences of sea level rise and coastal storm damage on the economy of the state's most vulnerable area, York County's coastal communities.

Employment Locations in York County Coastal Communities 2007

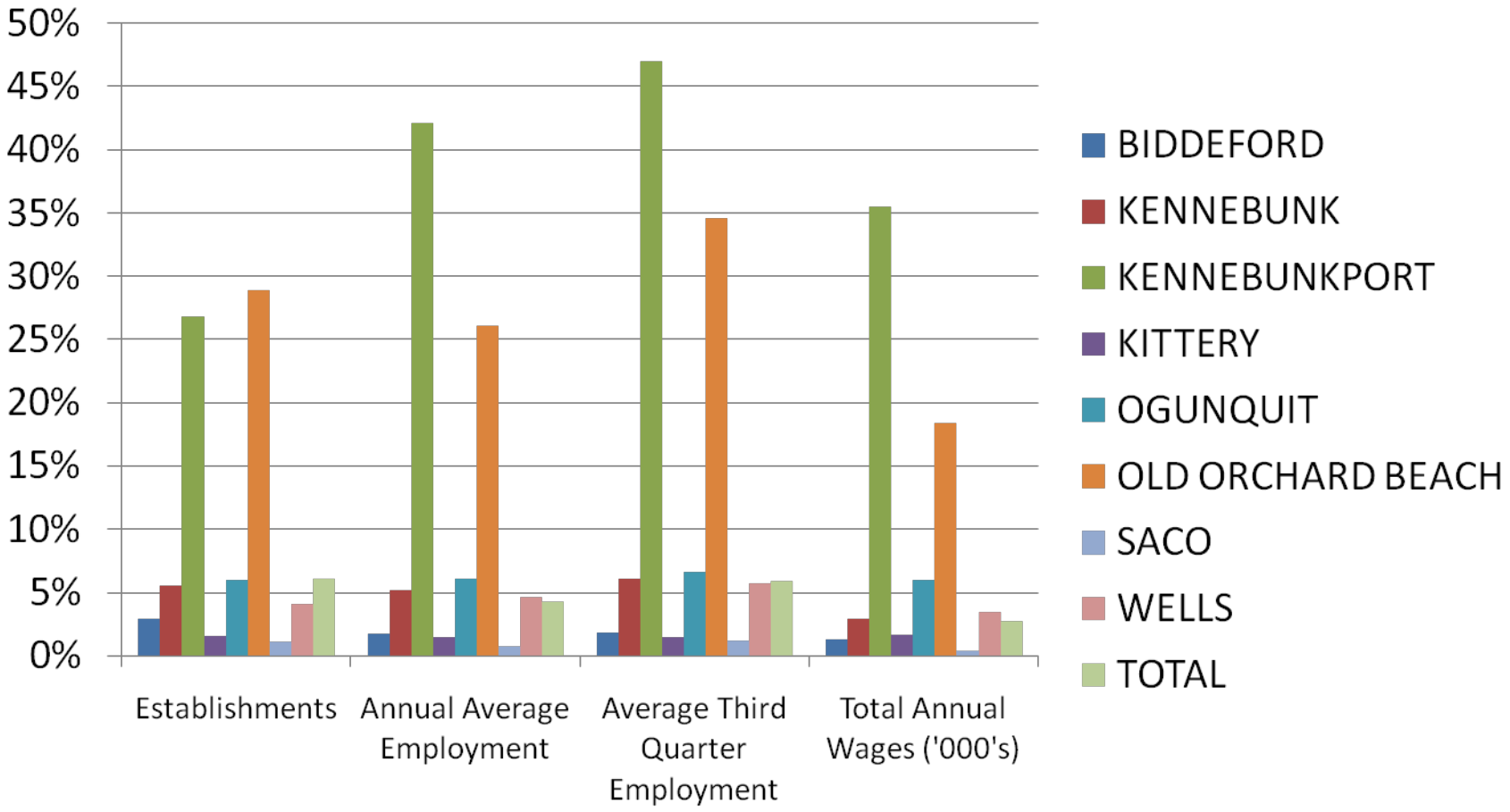


Source: Maine Department of Labor Quarterly Census of Employment and Wages

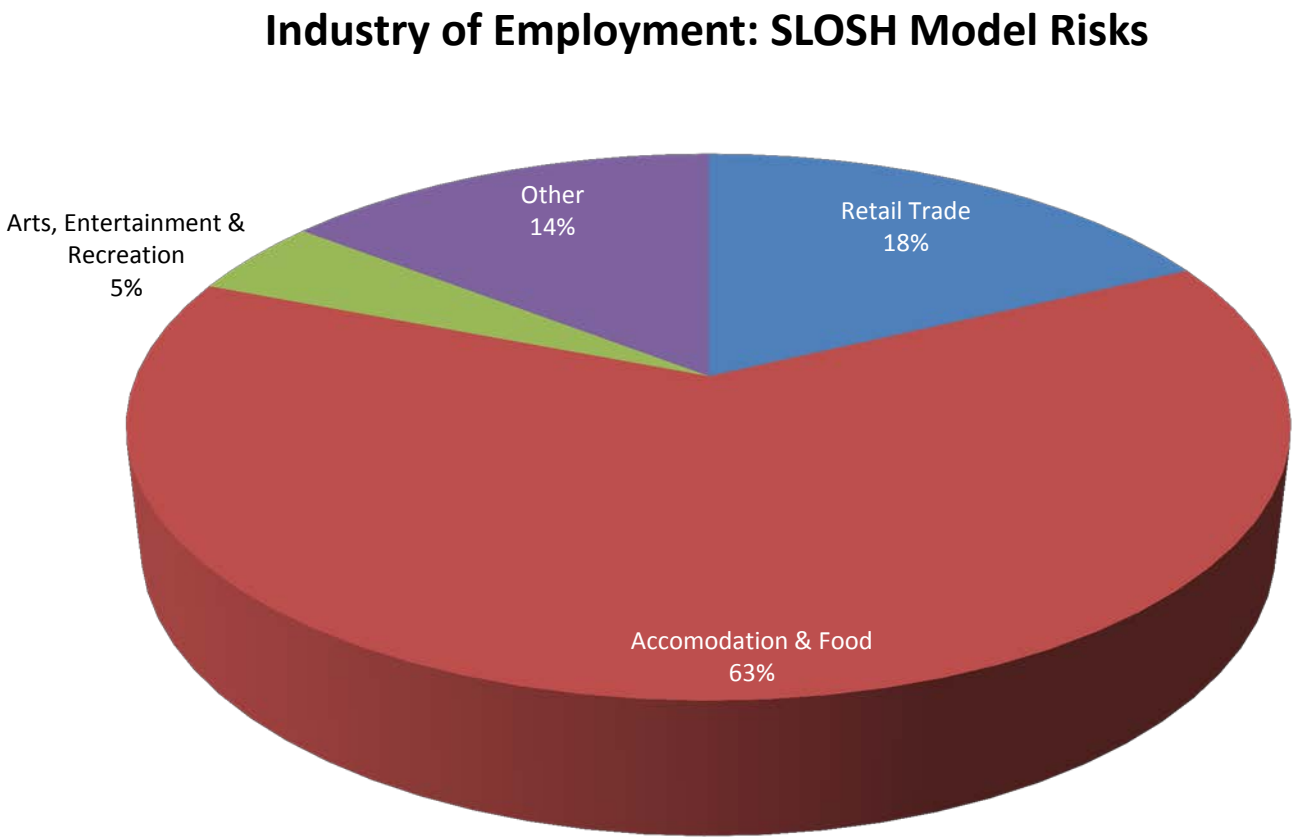
Old Orchard Beach: Employment At Risk by Different Size Storms



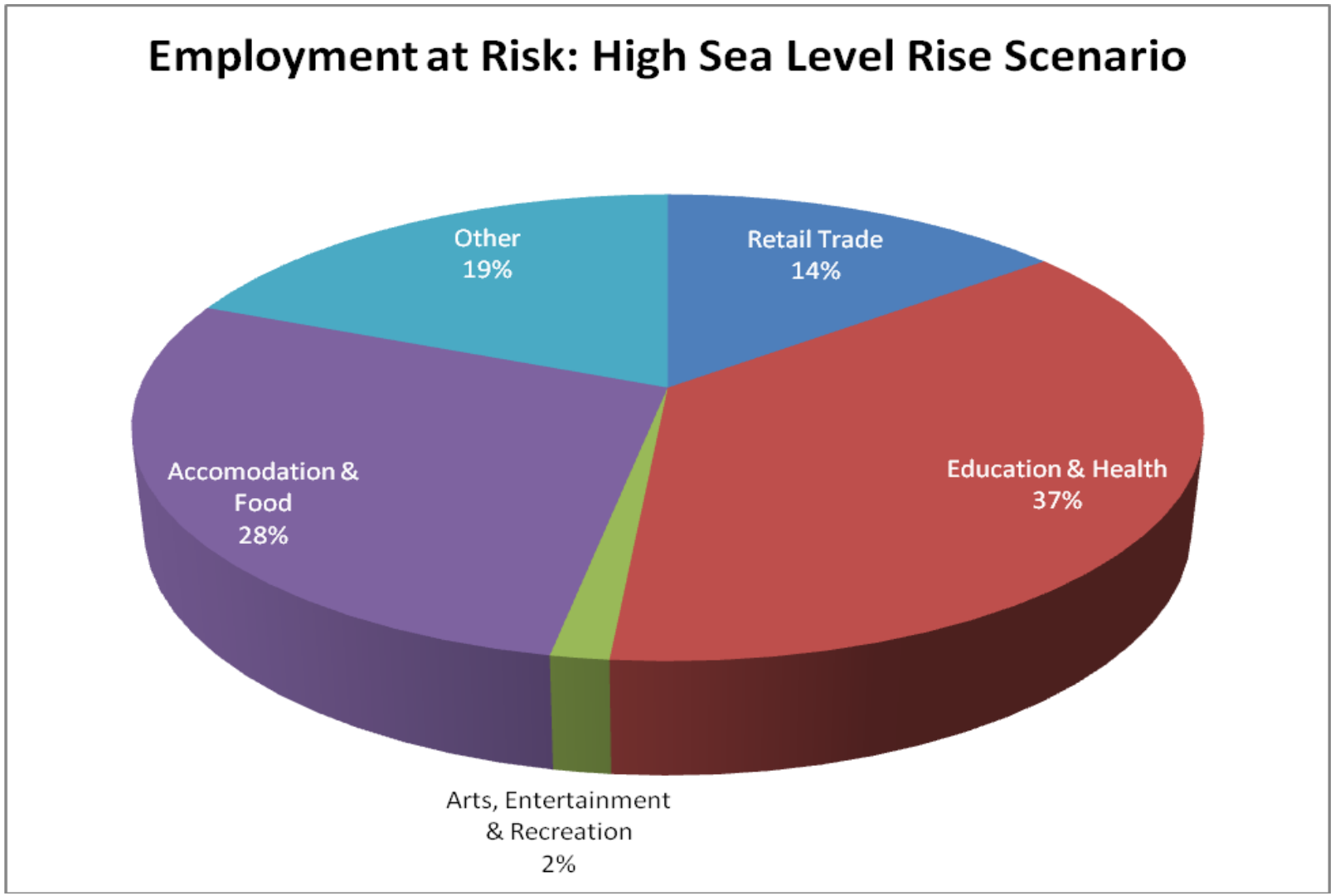
Percent of Town Economy in At Risk Employers



Within the SLOSH Model Zone, the biggest threat is to Establishments Related to Tourism



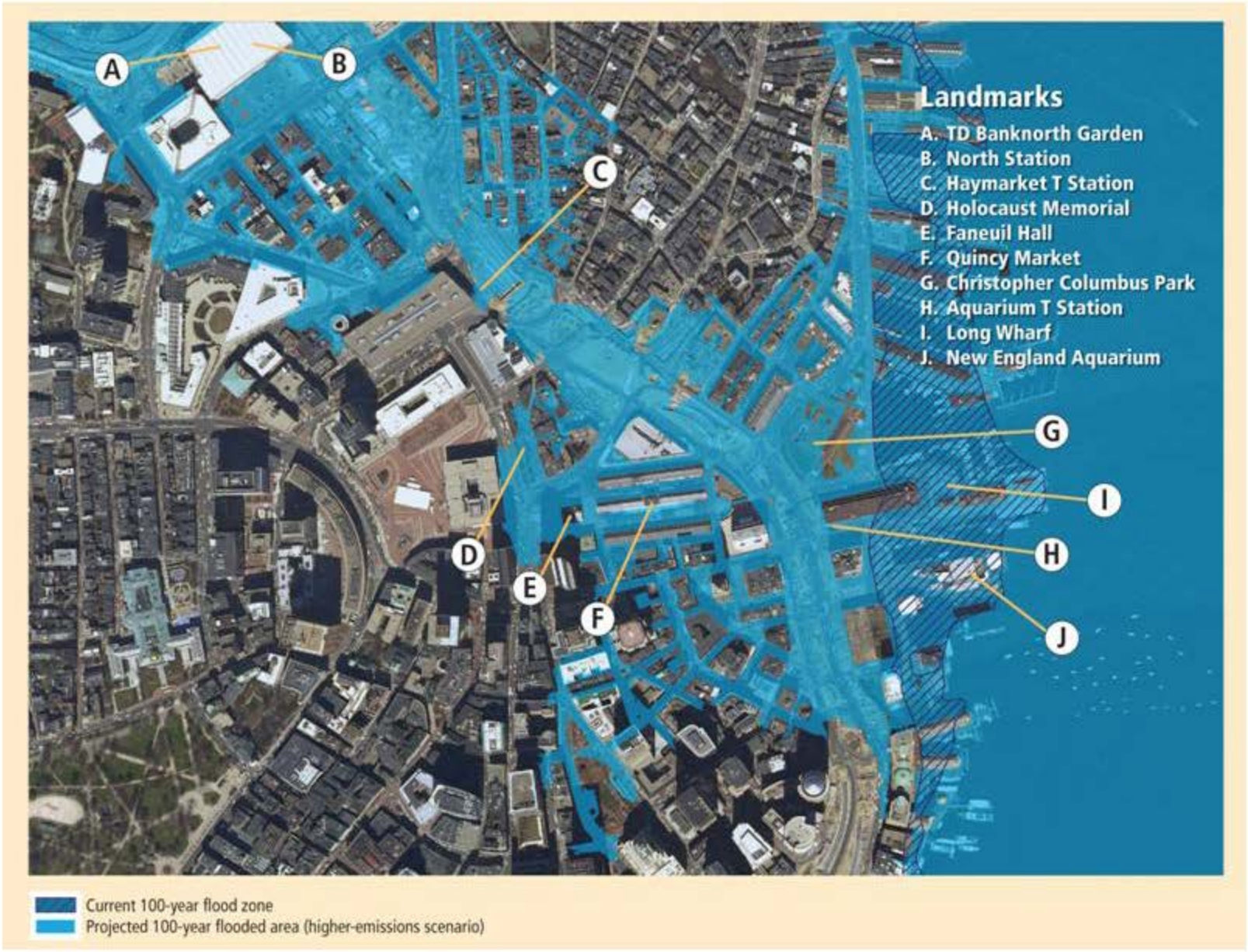
In the High Sea Level Rise Scenario, the Industries at Risk Substantially Expand



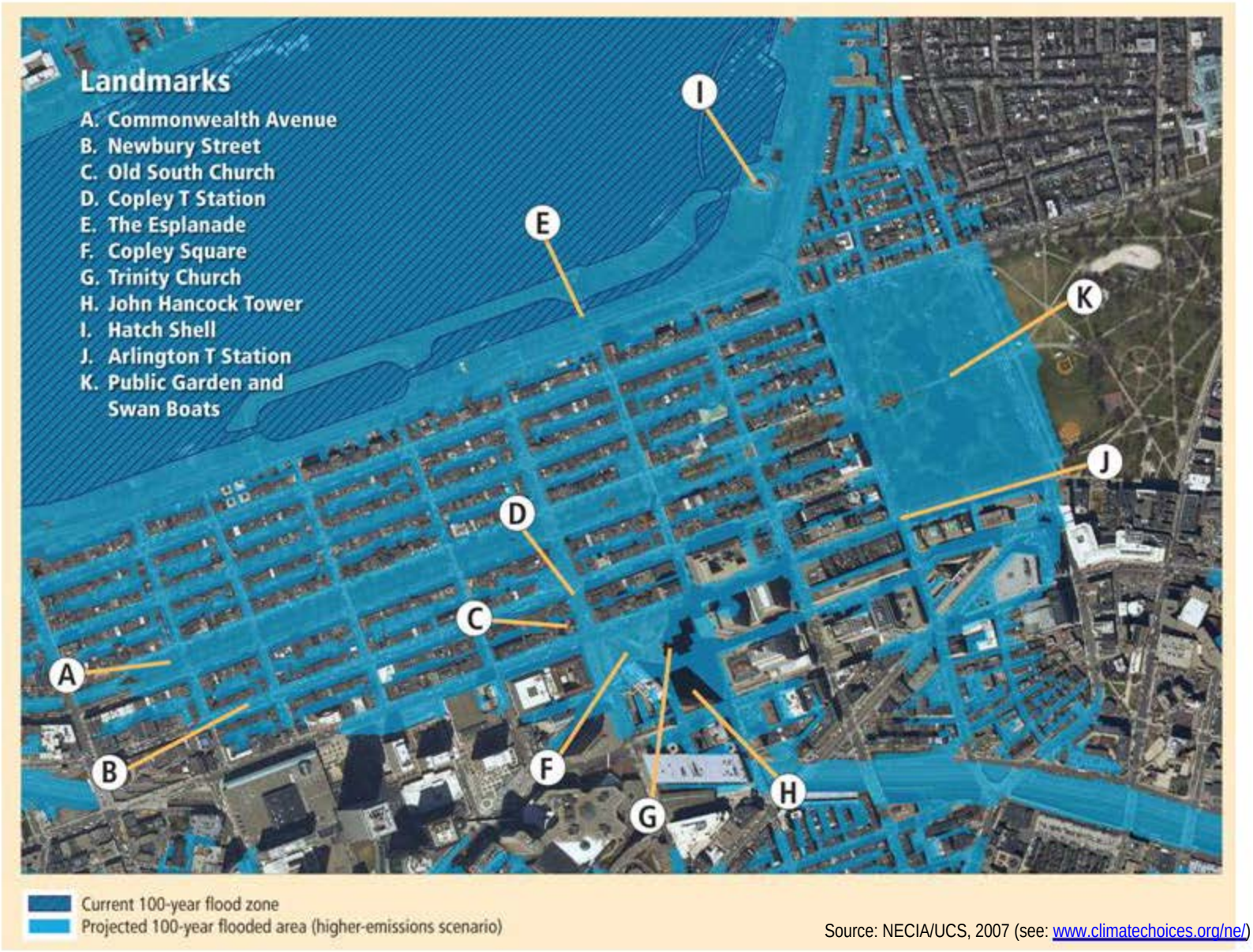
Employment at Risk Within SLOSH Model Predictions

	Establishments	Annual Average Employment	Average Third Quarter Employment	Total Annual Wages ('000's)
BIDDEFORD	24	183	209	$4,511
KENNEBUNK	32	274	341	$5,338
KENNEBUNKPORT	67	524	812	$11,835
KITTERY	7	121	119	$7,026
OGUNQUIT	13	88	167	$1,817
OLD ORCHARD BEACH	103	470	977	$7,345
SACO	7	49	85	$813
WELLS	19	176	260	$3,700
TOTAL	272	1,885	2,971	$42,385

Coastal Flooding in Boston under Present and High Emission Sea Levels



Coastal Flooding in Boston under Present and High Emission Sea Levels



Source: NECIA/UCS, 2007 (see: www.climatechoices.org/ne/)

Ways to Frame Climate Adaptation

- **Be honest. Respect feelings and beliefs. Empower citizen involvement when possible.**
- **Make it local.**
- **Make it concrete, not abstract.**
- **Make it now, not later.**
- **Talk about trade offs between risks and benefits, and the benefits of adapting sooner rather than later.**
- **Frame adaptation within the context of local attitudes towards climate change. (There are other reasons than climate change to take many adaptive actions).**

From "Climate Skeptics Embrace Cleaner Energy."
http://www.nytimes.com/2010/10/19/science/earth/19fossil.html?ref=us

<u>There are only four options:</u>

1) Do nothing (usually = remain in denial)
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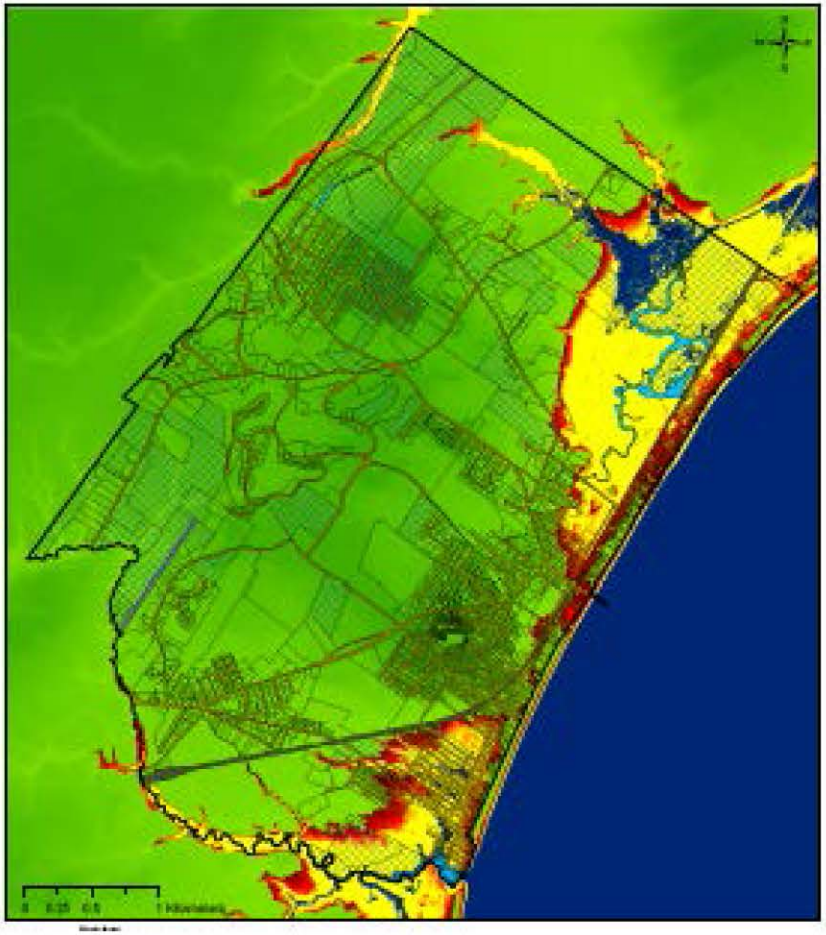
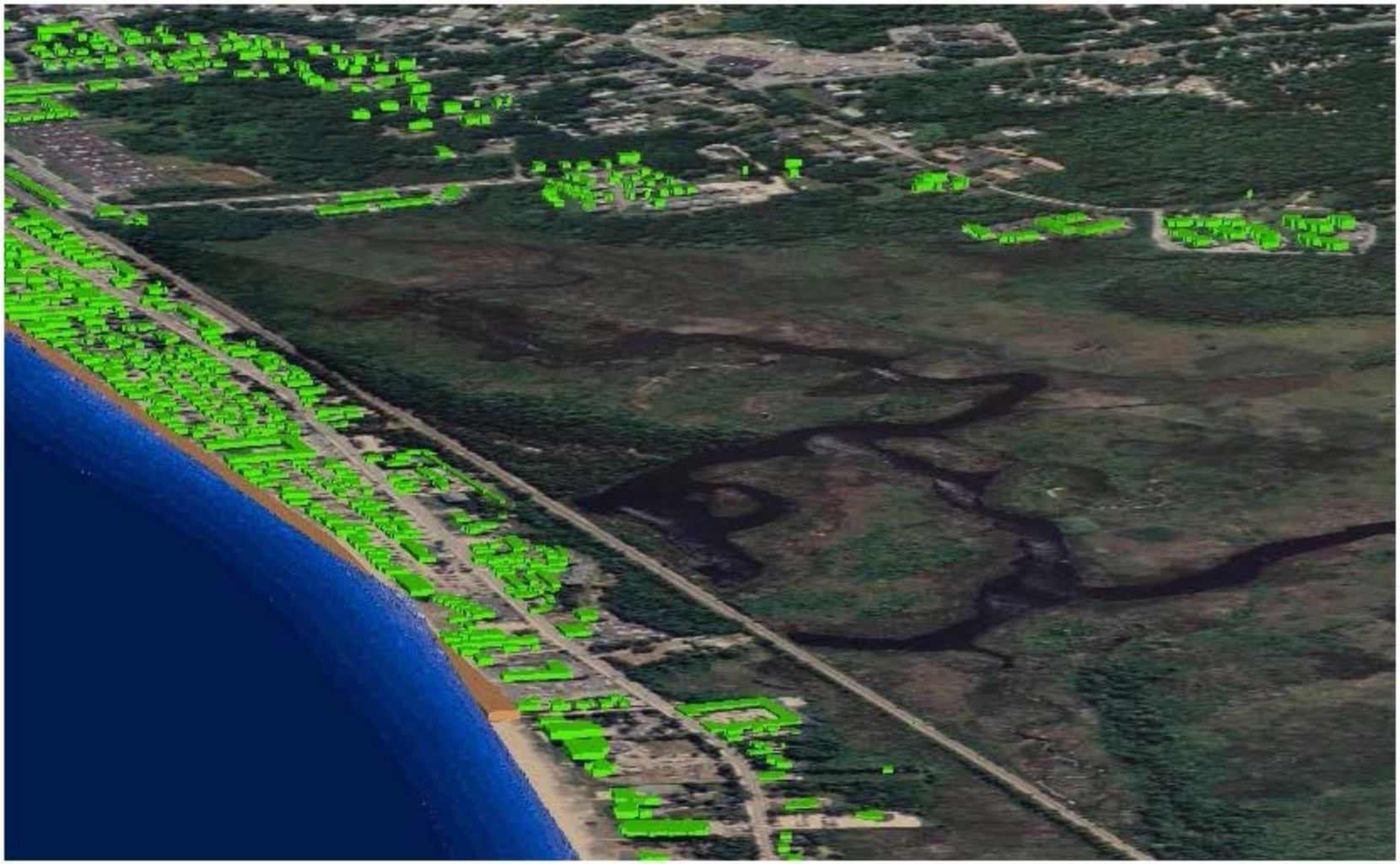
COAST is a tool to help evaluate costs and benefits of these options.

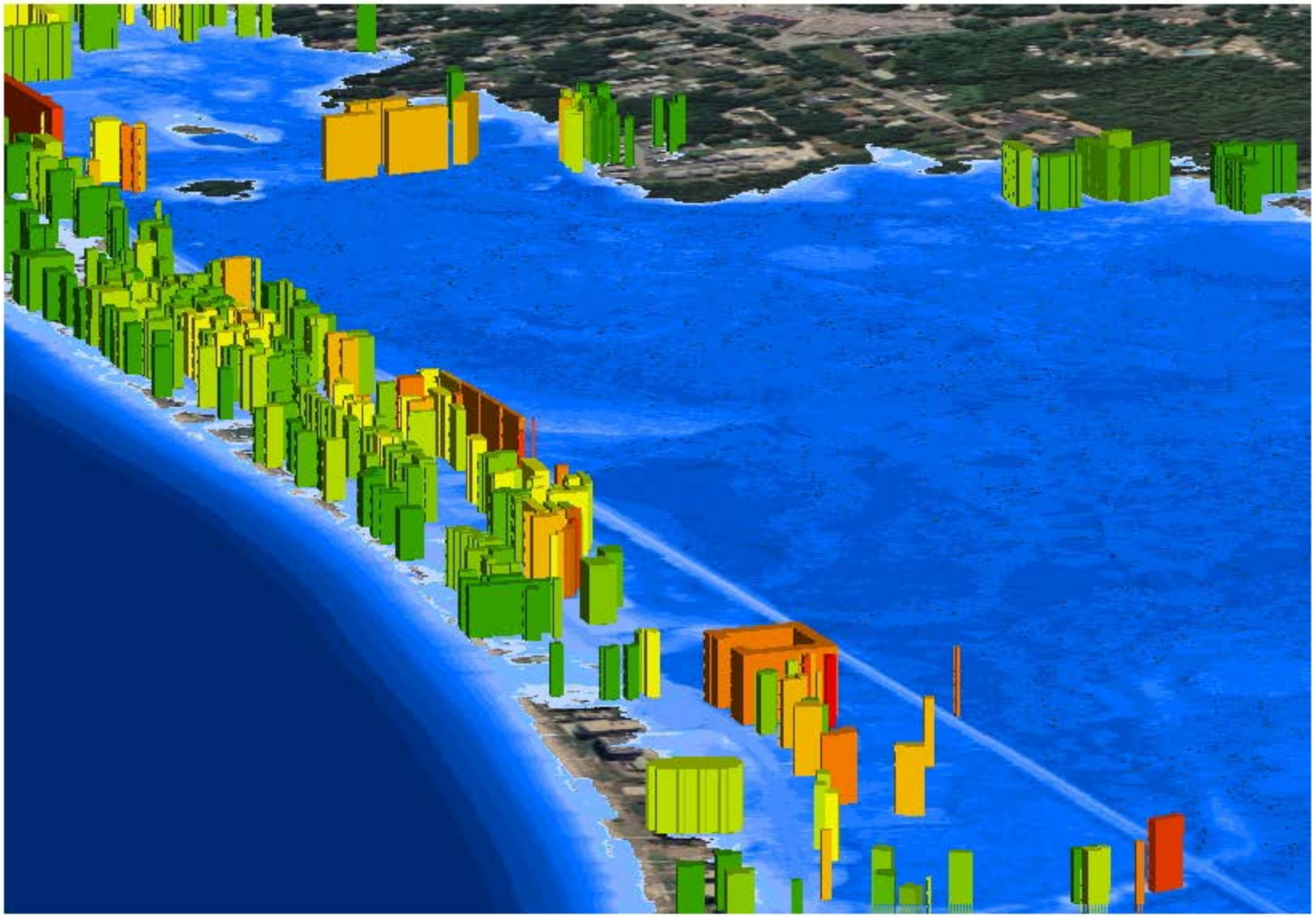




DAMAGE FUNCTIONS FOR SINGLE FAMILY RESIDENTIAL STRUCTURES WITH BASEMENTS

Structure Depth-Damage

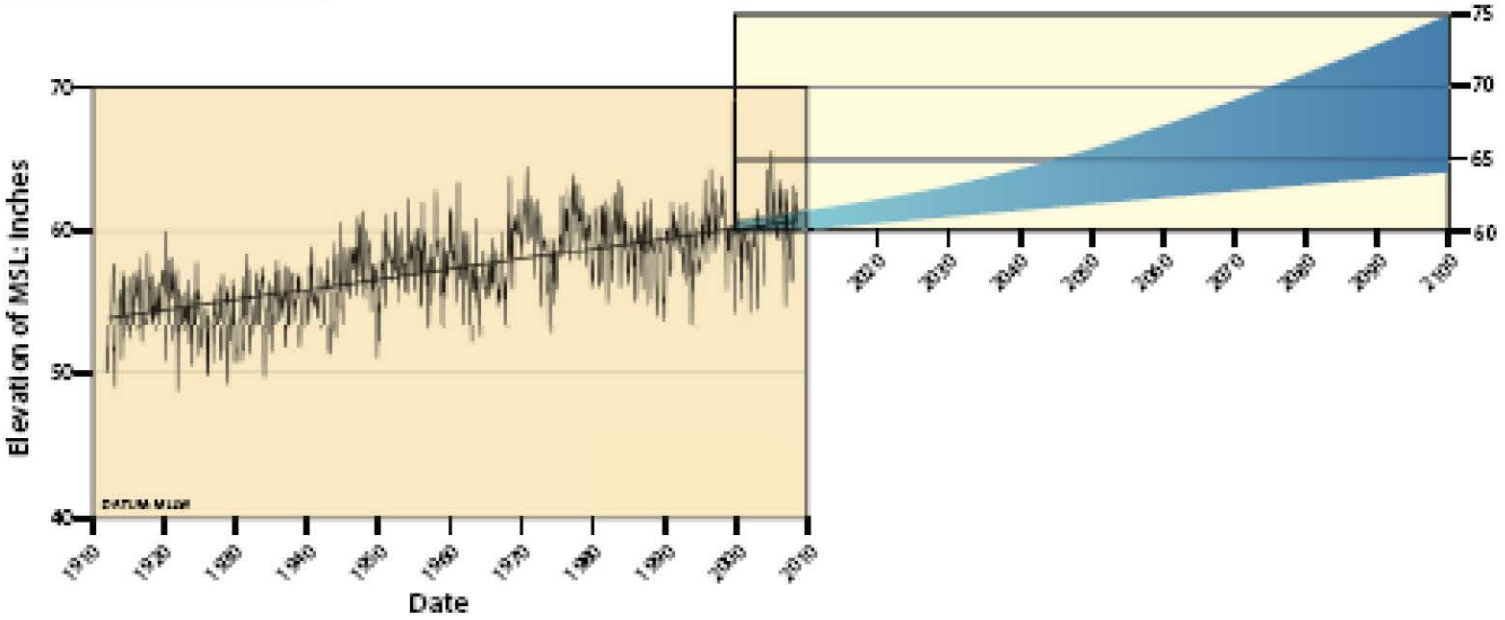
Table 1 Structure One Story, With Basement		
Depth	Mean of Damage	Standard Deviation of Damage
-8	0%	0
-7	0.7%	1.34
-6	0.8%	1.06
-5	2.4%	0.94
-4	5.2%	0.91
-3	9.0%	0.88
-2	13.8%	0.85
-1	19.4%	0.83
0	25.5%	0.85
1	32.0%	0.96
2	38.7%	1.14
3	45.5%	1.37
4	52.2%	1.63
5	58.6%	1.89
6	64.5%	2.14
7	69.8%	2.35
8	74.2%	2.52
9	77.7%	2.66
10	80.1%	2.77
11	81.1%	2.88
12	81.1%	2.88
13	81.1%	2.88
14	81.1%	2.88
15	81.1%	2.88
16	81.1%	2.88



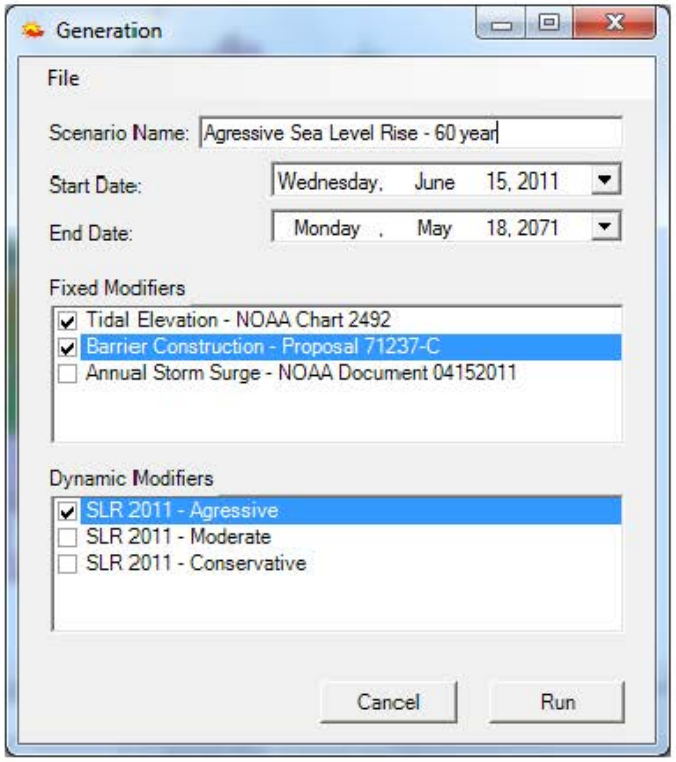
Expected costs and damages, 2010 - 2050

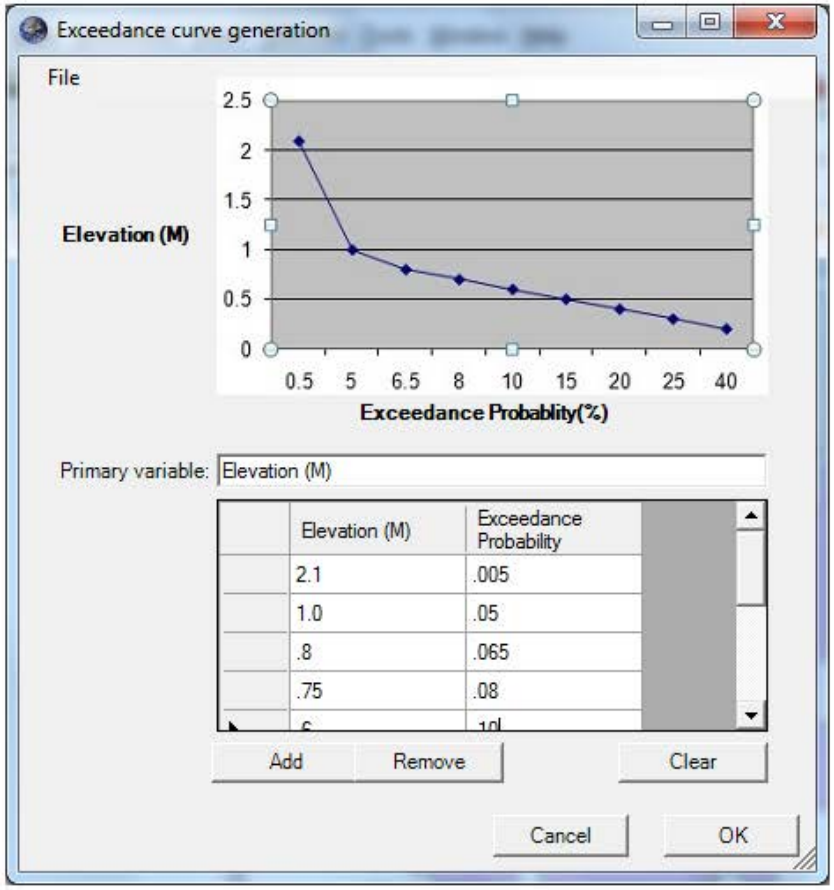
SLR Scenario	Adaptation	Residual Damages ($ million)	Adaptation Cost ($ million)	Total Damages and Costs ($ million)
No SLR	No Action	680	0	680
	50 yr flood	3.4	52.4	55.8
	100 yr flood	0	60	60
Low	No Action	899.3	0	899.3
	50 yr flood	28.3	52.4	80.7
	100 yr flood	0	60	60
High	No Action	1016.6	0	1016.6
	50 yr flood	67.8	52.4	120.2
	100 yr flood	37.6	60	97.6

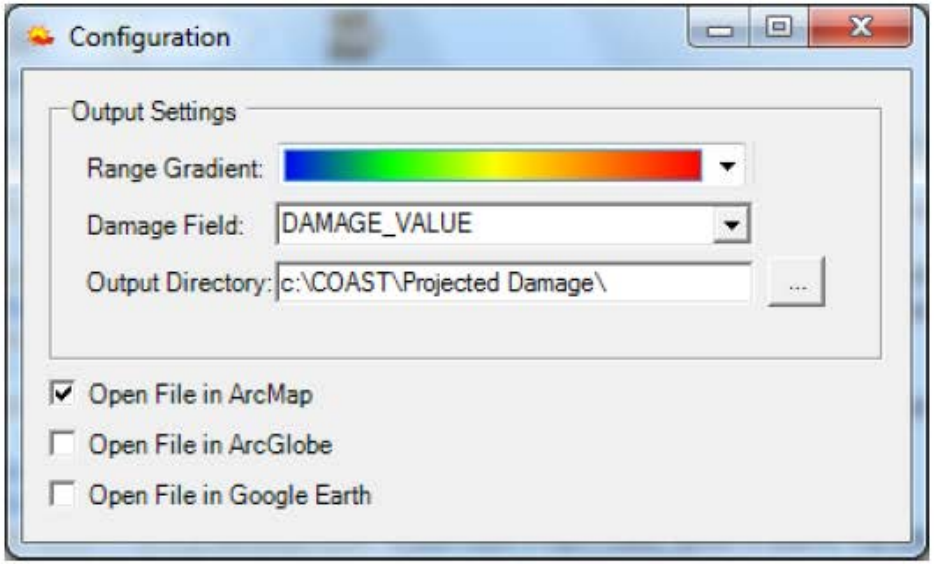
Maine Sea Level, 1912-2100



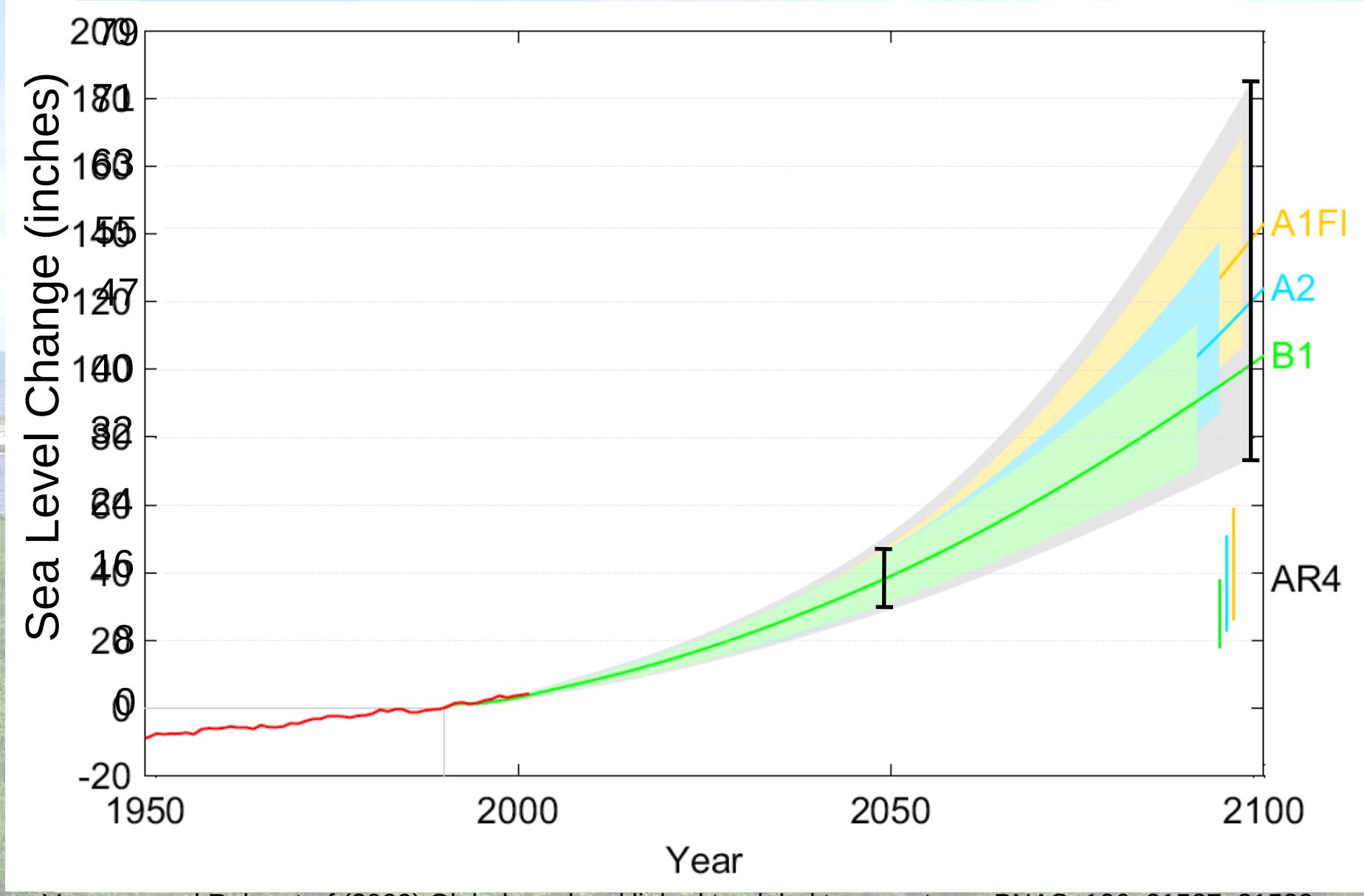

COAST


Generation
File
Scenario Name: Agressive Sea Level Rise - 60 year
Start Date: Wednesday, June 15, 2011
End Date: Monday , May 18, 2071
Fixed Modifiers
Tidal Elevation - NOAA Chart 2492
Barrier Construction - Proposal 71237-C
Annual Storm Surge - NOAA Document 04152011
Dynamic Modifiers
SLR 2011 - Agressive
SLR 2011 - Moderate
SLR 2011 - Conservative
Cancel
Run


Exceedance curve generation
File
Elevation (M)
2.5
2
1.5
1
0.5
0
0.5 5 6.5 8 10 15 20 25 40
Exceedance Probablity(%)
Primary variable: Elevation (M)
Elevation (M)
Exceedance Probability
2.1 .005
1.0 .05
.8 .065
.75 .08
Add
Remove
Clear
Cancel
OK


Configuration
Output Settings
Range Gradient:
Damage Field: DAMAGE_VALUE
Output Directory: c:\COAST\Projected Damage\
...
Open File in ArcMap
Open File in ArcGlobe
Open File in Google Earth

Projection of Sea Level Rise from 1990 to 2100



Vermeer and Rahmstorf (2009) Global sea level linked to global temperature. PNAS 106, 21527–21532.

The COAST Process

1. Specify location and vulnerable asset
2. Select time horizons, SLR and SS thresholds
3. Select adaptation action, estimate costs
4. Input Depth Damage Function
5. Input reference data (parcel, elevation, etc)
6. Run the model
7. Use maps and tables in public process

Possible Assets to Model

- Lost real estate values
- Lost economic output
- Displaced persons
- Lost natural resources values
- Lost cultural resources values
- Infrastructure (culverts, bridges, roads, utility lines)

Adaptation Actions: Hard or Soft

- Revetments

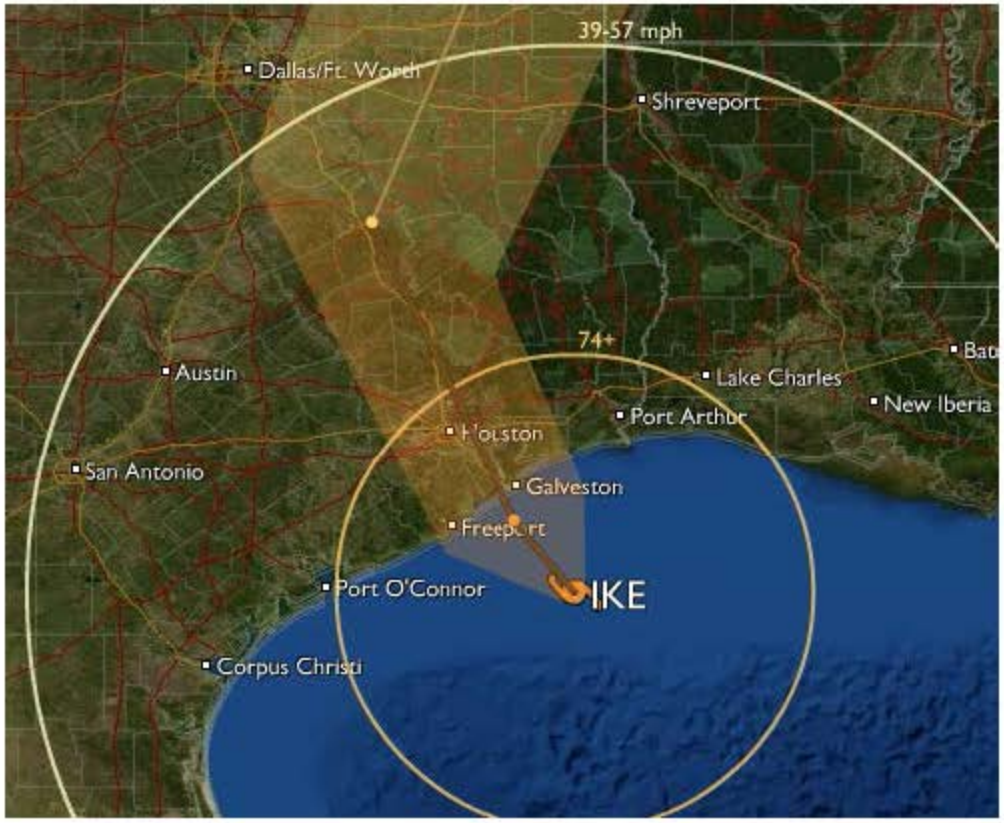
Pea Patch Island, DE (Delaware River)

Adaptation Actions: Hard or Soft

- Revetments
- Geotextile tubes

Adaptation Actions: Hard or Soft

- Revetments
- Geotextile tubes
- Sea walls


39-57 mph
Dallas/Ft. Worth
Shreveport
74+
Austin
Lake Charles
New Iberia
Port Arthur
Houston
San Antonio
Galveston
Freeport
Port O'Connor
IKE
Corpus Christi

Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
- Jetties

Adaptation Actions: Hard or Soft

- Revetments
- Geotextile tubes
- Sea walls
- Jetties
- Other creative approaches

Floodwalls with removable aluminum or steel gates. Cologne, Germany (Rhine).

Buildings have a “hardened” 1st story along a wide pedestrian walkway.

Urban design strategy: Hamburg, city on the water

Adaptation Actions: Hard or Soft

- Revetments
- Geotextile tubes
- Sea walls
- Jetties
- Other creative approaches

- Wet or dry floodproofing
- Incentives, zoning, and other regulatory changes

Old Orchard Beach – East Grand Avenue Area

The COAST Process

1. Specify location and vulnerable asset
2. Select time horizons, SLR and SS thresholds
3. Select adaptation action, estimate costs
4. Input Depth Damage Function
5. Input reference data (parcel, elevation, etc)
6. Run the model
7. Use maps and tables in public process
   >>> with multiple analytic formats