Financial Adaptation
to Sea Level Rise and Storm Surge

The COAST Approach
and Issues to Consider in Coastal New Hampshire

Samuel B. Merrill, Ph.D.
June 29, 2011
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 work together and with the public and private sectors to promote a sustainable environment, bolstering efforts to address difficult how-to-pay issues.
Global sea-level rise

Metres

historical records  observations  projections

Source: Cazenave and Llovel, 2009.
Portland Tide gauge = global ocean over last century 1.8 mm/yr (IPCC, 2007).

In Maine, this is the fastest in past 3000 years
Satellite altimetry (1993-2003) = global sea level $3.1 \pm 0.7$ mm/yr (IPCC, 2007)
Bruun’s Rule: each increment of vertical sea level rise \((x)\) produces a landward retreat of the beach profile at a ratio of 1:100 (100 times \(x\)). One foot of sea level rise produces a 100-foot landward retreat of the beach profile.
*Nicholls et al. 2006, Philos. Trans. R. Soc. Lond.*

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**Population flooded (millions/year)**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Degree of protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1/B1: population 8 billion, highest GDP/capita</td>
<td>constant, evolving, enhanced</td>
</tr>
<tr>
<td>A2: population 14 billion, lowest GDP/capita</td>
<td></td>
</tr>
<tr>
<td>B2: population 10 billion, intermediate GDP/capita</td>
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</tr>
</tbody>
</table>

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[Image: A graph showing population flooded over time with varying sea-level rise and different scenarios labeled.]
• More frequent flooding
• More coastal erosion
• Wetland inundation and loss
The Old Port, 3/10 at high tide (D. Yakovleff)
The Old Port, 3/10 at high tide (D. Yakovleff)
Whole Foods 1/9/10 at high tide (R. Obrey.)
Great natural catastrophes worldwide 1950 – 2010
Overall and insured losses with trend

© 2011 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE – As at January 2011
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.

Risk-Based Land Use Planning

Protect development from coastal hazards

- Consider climate change *in plans*
- Provide no-build/no-rebuild zones
- Provide incentives to relinquish property or development rights
Strengthened Ecosystems

Make essential natural infrastructure part of any adaptation strategy

Protect and restore these features through adaptation funding, risk-based land use planning, and post-disaster rebuilding
Occupation of the New Marsh Edge
Wetland Impacts

“The impact of sea level rise on coastal wetlands will depend in large measure on whether developed areas immediately inland of the marsh are protected from rising sea level by levees and bulkheads. In a Charleston case study, protecting developed areas would increase an 80 percent wetland loss to 90 percent for a five-foot rise. In a nationwide analysis, structural protection would increase a 30-80 percent loss to 50-90 percent.”

EPA’s Office of Policy, Planning, and Evaluation
(http://papers.risingsea.net/Sea-level-rise-and-coastal-wetlands.html)
Climate Change >> Sea Level Rise >> Storm Surge

Patriot’s Day Storm 2007: York Beach
2011 CoreLogic®
Storm Surge Report
Residential Storm-Surge
Exposure Estimates
for 10 U.S. Cities
Take home message:

• ... “having a coastal property located outside a FEMA-defined flood zone doesn’t necessarily mean the property owner is free from risk since there are many areas with little correlation between flood zones and storm surge inundation zones”
The Effects of Climate Change on Economic Activity in Maine: Coastal York County Case Study

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.

by Charles S. Colgan
Samuel B. Merrill
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

![Bar graph showing the percent of town economy in at-risk employers for different towns, including BIDDEFORD, KENNEBUNK, KENNEBUNKPORT, KITTERY, OGUNQUIT, OLD ORCHARD BEACH, SACO, WELLS, and TOTAL. The x-axis represents different measures of employment: Establishments, Annual Average Employment, Average Third Quarter Employment, and Total Annual Wages ('000's).]
Within the SLOSH Model Zone, the biggest threat is to Establishments Related to Tourism

Industry of Employment: SLOSH Model Risks

- Accommodation & Food: 63%
- Retail Trade: 18%
- Other: 14%
- Arts, Entertainment & Recreation: 5%

New England Environmental Finance Center
In the High Sea Level Rise Scenario, the Industries at Risk Substantially Expand

**Employment at Risk: High Sea Level Rise Scenario**

- Education & Health: 37%
- Accommodation & Food: 28%
- Arts, Entertainment & Recreation: 2%
- Retail Trade: 14%
- Other: 19%
## Employment at Risk Within SLOSH Model Predictions

<table>
<thead>
<tr>
<th>Location</th>
<th>Establishments</th>
<th>Annual Average Employment</th>
<th>Average Third Quarter Employment</th>
<th>Total Annual Wages ('000's)</th>
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</thead>
<tbody>
<tr>
<td>BIDDEFORD</td>
<td>24</td>
<td>183</td>
<td>209</td>
<td>$4,511</td>
</tr>
<tr>
<td>KENNEBUNK</td>
<td>32</td>
<td>274</td>
<td>341</td>
<td>$5,338</td>
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<tr>
<td>KENNEBUNKPORT</td>
<td>67</td>
<td>524</td>
<td>812</td>
<td>$11,835</td>
</tr>
<tr>
<td>KITTERY</td>
<td>7</td>
<td>121</td>
<td>119</td>
<td>$7,026</td>
</tr>
<tr>
<td>Ogunquit</td>
<td>13</td>
<td>88</td>
<td>167</td>
<td>$1,817</td>
</tr>
<tr>
<td>Old Orchard Beach</td>
<td>103</td>
<td>470</td>
<td>977</td>
<td>$7,345</td>
</tr>
<tr>
<td>Saco</td>
<td>7</td>
<td>49</td>
<td>85</td>
<td>$813</td>
</tr>
<tr>
<td>Wells</td>
<td>19</td>
<td>176</td>
<td>260</td>
<td>$3,700</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>272</strong></td>
<td><strong>1,885</strong></td>
<td><strong>2,971</strong></td>
<td><strong>$42,385</strong></td>
</tr>
</tbody>
</table>
Coastal Flooding in Boston under Present and High Emission Sea Levels
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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.”
**DAMAGE FUNCTIONS FOR SINGLE FAMILY RESIDENTIAL STRUCTURES WITH BASEMENTS**

*Structure Depth-Damage*

<table>
<thead>
<tr>
<th>Depth</th>
<th>Mean of Damage</th>
<th>Standard Deviation of Damage</th>
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<tbody>
<tr>
<td>-8</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>-7</td>
<td>0.7%</td>
<td>1.34</td>
</tr>
<tr>
<td>-6</td>
<td>0.8%</td>
<td>1.06</td>
</tr>
<tr>
<td>-5</td>
<td>2.4%</td>
<td>0.94</td>
</tr>
<tr>
<td>-4</td>
<td>5.2%</td>
<td>0.91</td>
</tr>
<tr>
<td>-3</td>
<td>9.0%</td>
<td>0.88</td>
</tr>
<tr>
<td>-2</td>
<td>13.8%</td>
<td>0.85</td>
</tr>
<tr>
<td>-1</td>
<td>19.4%</td>
<td>0.83</td>
</tr>
<tr>
<td>0</td>
<td>25.5%</td>
<td>0.85</td>
</tr>
<tr>
<td>1</td>
<td>32.0%</td>
<td>0.96</td>
</tr>
<tr>
<td>2</td>
<td>38.7%</td>
<td>1.14</td>
</tr>
<tr>
<td>3</td>
<td>45.5%</td>
<td>1.37</td>
</tr>
<tr>
<td>4</td>
<td>52.2%</td>
<td>1.63</td>
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<td>5</td>
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<td>1.89</td>
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<tr>
<td>6</td>
<td>64.5%</td>
<td>2.14</td>
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<td>7</td>
<td>69.8%</td>
<td>2.35</td>
</tr>
<tr>
<td>8</td>
<td>74.2%</td>
<td>2.52</td>
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<tr>
<td>9</td>
<td>77.7%</td>
<td>2.66</td>
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<td>10</td>
<td>80.1%</td>
<td>2.77</td>
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<tr>
<td>11</td>
<td>81.1%</td>
<td>2.88</td>
</tr>
<tr>
<td>12</td>
<td>81.1%</td>
<td>2.88</td>
</tr>
<tr>
<td>13</td>
<td>81.1%</td>
<td>2.88</td>
</tr>
<tr>
<td>14</td>
<td>81.1%</td>
<td>2.88</td>
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<td>15</td>
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<td>2.88</td>
</tr>
<tr>
<td>16</td>
<td>81.1%</td>
<td>2.88</td>
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</table>
## Expected costs and damages, 2010 - 2050

<table>
<thead>
<tr>
<th>SLR Scenario</th>
<th>Adaptation</th>
<th>Residual Damages ($ million)</th>
<th>Adaptation Cost ($ million)</th>
<th>Total Damages and Costs ($ million)</th>
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</thead>
<tbody>
<tr>
<td>No SLR</td>
<td>No Action</td>
<td>680</td>
<td>0</td>
<td>680</td>
</tr>
<tr>
<td></td>
<td>50 yr flood</td>
<td>3.4</td>
<td>52.4</td>
<td>55.8</td>
</tr>
<tr>
<td></td>
<td>100 yr flood</td>
<td>0</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Low</td>
<td>No Action</td>
<td>899.3</td>
<td>0</td>
<td>899.3</td>
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<tr>
<td></td>
<td>50 yr flood</td>
<td>28.3</td>
<td>52.4</td>
<td>80.7</td>
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<tr>
<td></td>
<td>100 yr flood</td>
<td>0</td>
<td>60</td>
<td>60</td>
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<tr>
<td>High</td>
<td>No Action</td>
<td>1016.6</td>
<td>0</td>
<td>1016.6</td>
</tr>
<tr>
<td></td>
<td>50 yr flood</td>
<td>67.8</td>
<td>52.4</td>
<td>120.2</td>
</tr>
<tr>
<td></td>
<td>100 yr flood</td>
<td>37.6</td>
<td>60</td>
<td>97.6</td>
</tr>
</tbody>
</table>
Maine Sea Level, 1912-2100
Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
- Jetties

- Wet or dry floodproofing
- Zoning and other regulatory changes
Groton Long Point
2050, Low SLR, 10 Year Flood

Total Damage
$40,655,366
Groton Long Point
2050, Low SLR, 10 Year Flood

Total Damage
$40,655,366
Cumulative Damage: $8,768,776

FLOOD LEVEL (ft)    FLOOD DAMAGE IN DOLLARS

- 6    $0 - $51,976
- 5    $51,976 - $98,670
- 4    $98,670 - $207,761
- 3    $207,761 - $606,502
- 2    $606,502 - $841,579

MYSTIC, NO ACTION
2070, 10 YEAR EVENT, LOW SLR
<table>
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<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level rise, normal tides</td>
<td>A 3.2 – 4.0</td>
<td>No action up to minimal flood proofing and infrastructure elevation along river.</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td></td>
<td>B 5.5 – 6.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-year storm event in 2010</td>
<td>C 5.4</td>
<td>Hurricane Barrier at Mystic River entrance.</td>
<td>$18 Million</td>
<td>$75,000</td>
</tr>
<tr>
<td></td>
<td>D 7.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-year storm in 2070, Hi SLR</td>
<td>E 7.0</td>
<td>Hurricane Barrier at Mystic River entrance.</td>
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<td>$100,000</td>
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<tr>
<td></td>
<td>F 8.9</td>
<td>ADDITIONAL FORTIFICATION and elevating the railroad, as well as increased diking to east.</td>
<td></td>
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From “Climate Skeptics Embrace Cleaner Energy.”
Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
- Jetties
- Wet or dry floodproofing
- Zoning and other regulatory changes
Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)
Output: a range of “economic floodplains”

• Lost real estate values (e.g., Groton, CT)
• Lost economic output (e.g., 8-town coastal ME study)
• Infrastructure costs (e.g., 100’ bridges in Maine)
A Financial Impact Assessment of LD 1725: Stream Crossings

How much to upsize? Should we?

Prepared by: The New England Environmental Finance Center
For the Maine Department of Transportation Office of Environmental Planning
Output: a range of “economic floodplains”

• Lost real estate values (e.g., Groton, CT)
• Lost economic output (e.g., 8-town coastal ME study)
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• Displaced persons (getting started in Boston)
Output: a range of “economic floodplains”

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- Lost cultural resources values (e.g., NPS gravesites)
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- Displaced persons (getting started in Boston)
- Lost natural resources values (collaborators wanted)
- Lost cultural resources values (e.g., NPS gravesites)

>> Software development is underway. Core shell is customizable for CBA on a range of vulnerable asset types.
Sea Isle City, NJ

Geotextile Tubes
Possible Activities in Coastal New Hampshire

- Stakeholders identify vulnerable assets to model.
- Stakeholders identify adaptation actions to consider.
- EFC runs calculations, produces maps and tables, and communicates results to group.
- Stakeholders use products in planning process as appropriate.
Contact info:

Sam Merrill:
smerrill@usm.maine.edu
207-228-8596

New England Environmental Finance Center:
http://efc.muskie.usm.maine.edu

Thank you!
Input: a range of adaptation options

- Revetments
Pea Patch Island, DE (Delaware River)
Input: a range of adaptation options

- Revetments
- Geotextile tubes
Sea Isle City, NJ

Geotextile Tubes
“Facing the bluntness of reality is the highest form of sanity and enlightened vision.”

- Chogyam Trungpa Rinpoche
Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
- Jetties
Preliminary Impact Analysis of built and natural environment using existing analyses, generalized downscaled data, and distribution of impacts to identify and educate potential stakeholders.

Stakeholder Assessment to establish Guiding Principles, identify issues, values, metrics of importance, key stakeholders groups and their representatives, develop stakeholder participation plan.

Joint Fact Finding process with stakeholders incorporating multi-criteria scenario and risk assessments and decision analysis; includes no action alternative (vulnerability analysis).

Historic and Present Data and Possible Future Values of climate, socio-economic, and environmental conditions and other change drivers.

Continuous Monitoring of natural and socio-economic local and global environments.

Robust Strategies and Actions that function acceptably well under all uncertainties.

Outcomes of Actions

Take Action Now because, e.g., “no regrets”, new projects, adjustable, or Adaptive Management.

Prepare and Monitor Actions with preservation of options, predetermined trigger points, and monitoring.

Institutional Analysis to review and adjust procedures, policies, laws and regulations relevant to adaptation.

Adaptation Planning Process
Kirshen, Merrill, and Kartez

Always part of process
As needed part of process
Learn the alchemy
True human beings know.
The moment you accept
what troubles you’ve been given,
The door will open.

- Jalallabad Rumi, 13th Century Persia