7-1-2012

COAST in Action: 2012 Projects from New Hampshire and Maine

Casco Bay Estuary Partnership

Piscataqua Region Estuaries Partnership

New England Environmental Finance Center

COAST in Action:

2012 Projects from Maine and New Hampshire

High Tide on Marginal Way in Portland, Maine, October 201l. (M. Craig)

Prepared for US EPA's Climate Ready Estuaries Program,
In collaboration with:
Casco Bay Estuary Partnership and
Piscataqua Region Estuaries Partnership

By the New England Environmental Finance Center, Edmund S. Muskie School of Public Service, University of Southern Maine,
with support of the University of New Hampshire

July 2012

UNIVERSITY OF SOUTHERN MAINE

CLIMATE READY ESTUARIES EPA

New England Environmental Finance Center

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Abstract

In summer 2011 the US EPA's Climate Ready Estuaries program awarded funds to the Casco Bay Estuary Partnership (CBEP) in Portland, Maine, and the Piscataqua Region Estuaries Partnership (PREP) in coastal New Hampshire, to further develop and use COAST (COastal Adaptation to Sea level rise Tool) in their sea level rise adaptation planning processes. The New England Environmental Finance Center worked with municipal staff, elected officials, and other stakeholders to select specific locations, vulnerable assets, and adaptation actions to model using COAST. The EFC then collected the appropriate base data layers, ran the COAST simulations, and provided visual, numeric, and presentation-based products in support of the planning processes underway in both locations. These products helped galvanize support for the adaptation planning efforts. Through facilitated meetings they also led to stakeholders identifying specific action steps and begin to determine how to implement them.

Acknowledgements

This work was funded by the US EPA Climate Ready Estuaries program. It would not have been possible without significant organizational support and leadership from members of the NH Coastal Adaptation Work Group (CAW) and several non-profit organizations in Portland, Maine, including the Portland Society of Architects, the Greater Portland Council of Governments, and others. Numerous graduate students at the Universities of Southern Maine and New Hampshire provided key assistance at several public meetings.

This report may be cited as:

Merrill, S., P. Kirshen, D. Yakovleff, S. Lloyd, C. Keeley, and B. Hill. 2012. COAST in Action: 2012 Projects from New Hampshire and Maine. New England Environmental Finance Center Series Report #12-05. Portland, Maine.

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Introduction

In Portland, Maine and the Hampton/Seabrook Estuary of New Hampshire (the three towns of Seabrook, Hampton, and Hampton Falls), climate change adaptation processes recently completed analyses using COAST (COastal Adaptation to Sea level rise Tool). In summer 2011 the US EPA's Climate Ready Estuaries program awarded funds to the Casco Bay Estuary Partnership (CBEP) and the Piscataqua Region Estuaries Partnership (PREP) to conduct COAST iterations in the locations of each organization. This document provides a full report on these efforts. The work was conducted by the New England Environmental Finance Center (EFC) based at the Edmund S. Muskie School of Public Service, University of Southern Maine, and the University of New Hampshire.

Some SLR planning efforts had been underway in both locations prior to beginning this project. In Portland, public support had increased dramatically for a city-wide planning process to adapt to sea level rise (SLR) after a May 2011 conference on the topic and in meetings of the City Council's "Energy, Environment, and Sustainability Committee." In New Hampshire, the Town of Seabrook contracted the Rockingham Planning Commission in 2009 to provide recommendations for their hazard mitigation plan that incorporate threats from sea level rise and storm surge. Since 2010, the NH Coastal Adaptation Work Group (CAW) has conducted a series of public workshops for coastal communities on adaptation planning and training. In mid 2011, stakeholder groups in both NH and ME wished to examine potential impacts of sea level rise and storm surge (SS) if no adaptation actions were taken. They were also beginning discussions about specific adaptation actions they might undertake in response to these threats, and the costs and benefits of these actions.

Working in partnership with PREP and CBEP, the EFC helped municipal staff, elected officials, and other interested parties select specific locations, vulnerable assets, and adaptation actions to model using COAST. The EFC then collected the appropriate base data layers, ran the COAST calculator, and provided visual, numeric, and presentation-based products in support of the adaptation planning processes underway in both locations. These products helped galvanize

support for the adaptation planning efforts. Through facilitated meetings they also led to stakeholders identifying specific action steps and begin to determine how to implement them. Through this project the EFC also further developed the COAST software. Core elements of the COAST approach have been published in Colgan and Merrill (2008), Merrill et al. (2010), and Kirshen et al. (2012). An update on software engineering results obtained during this project is included as an appendix.

New Hampshire

Context and Methods

The New Hampshire Coastal Adaptation Workgroup (NHCAW) is a collaboration of organizations working to help communities on New Hampshire's seacoast area prepare for the increased extreme weather and other impacts of long term, anthropogenic climate change. NHCAW provides communities with education, facilitation and guidance. At the start of this COAST project in summer 2011, NHCAW had already completed over 18 months of regional climate adaptation planning with over 50 stakeholders from several coastal municipalities. This CRE project was seen as an opportunity to help move this group of stakeholders to the next level of specificity in their adaptation planning efforts. An organizational launch meeting was held in June 2011, and in several public sessions the COAST model was then parameterized. This involved having stakeholders identify vulnerable assets they wished to model (public and private real estate) and agree upon SLR thresholds and SS intensities of concern. Stakeholders also elected to use SLR thresholds from Vermeer and Rahmstorf (2009), specifically: for 2050, low SLR = 7.9" and high SLR = 19.7," and in 2100, low SLR = 27.6" and high SLR = 70.9". COAST software then generated cumulative expected damage tables over multi-decadal periods for no-action scenarios with future dates, tidal extents, and amounts of SLR and SS selected by stakeholders.

Because of limited public meeting time, the modeling team made some parameterization decisions on behalf of the group, including specifying a discount rate of 3.5% for net present value calculations and a 1% increase over inflation in the real value of the asset being modeled.

Regarding amounts of SS to include in the scenarios, the modeling team reviewed the FEMA 100-year floodplain elevation and the elevation determined through local tide gauge analysis in Wake et al. (2011). The FEMA estimate was 2.8 feet lower than the other; therefore a compromise adjustment of decreasing all the Wake et al (2011) storm surge estimates by 1.4 feet was used for the 100-year floodplain extent.

From February to May 2012, NH CAW representatives evaluated economic impacts of SLR and SS, using maps and tables produced by the COAST software, to develop adaptation actions to model to capture stakeholders' interests. Upon seeing clear distinctions in lost real estate value between public and private assets, the outreach group elected to model one set of floodproofing actions for public real estate assetsand another set of actions for private real estate.

For the public assets in Tables 1 and 2 we estimated threshold elevations for when they will be threatened by flooding. This was based upon assessment of when the lowest-elevation building of the asset will receive any flooding. The time for adaptation is when the 100 year flood equals or exceeds the threshold. We determined the possible time of this occurring under both high and low SLR scenarios. We assume it is known what the current trajectory of SLR is and that the modeled adaptation action will be taken just before the above threshold is reached. The adaptation action is to protect against the 100 year flood in 2100, which has an elevation of 15.8 ft NAVD or 12.0 ft NAVD depending upon SLR scenario. Moreover, we also assume the assets will be protected from larger, very low frequency events (e.g., the 500 year flood) by temporary actions such as sandbagging. To model this in COAST, we determined costs of adaptation and compared that to the cumulative expected value costs of damages to the assets under both high and low SLR scenarios. The adaptation action taken was flood walls with gates, using cost estimates provided by Parsons Brinckerhoff (Appendix 2). No discounting was done on the costs of protecting major assets because it was assumed the floodwalls were constructed within the next decade.

For modeling adaptation actions for private assets (primarily hotels, houses, and other buildings), it was assumed these properties will be proactively protected to the 2100 100 Year flood level by a regulation that states if they are damaged by a flood, they must protect to this level when they rebuild. To model this in COAST, we determined the costs of adaptation and compared them to the cumulative expected value of damages to building under the high and low SLR scenarios. In

the high SLR scenario the region would also protected against the low SLR scenario, but extra costs would have been incurred. To model adaptation to the low SLR scenario, we determined costs of adaptation and compared them to the cumulative expected value of damages to buildings under the low SLR scenario. If the high SLR condition occurs when adaptation has been to the low SLR scenario, the residual damage was calculated as the difference between the cumulative expected value costs of the high SLR and low SLR COAST runs. Because the FEMA 100 year flood elevation for this area is 9.0 feet NGVD (equivalent to 8.2 ft NAVD), the first regulation is management to 7.6 feet above base flood elevation (15.8 feet – 8.2 feet). The second regulation is management to 3.8 feet above base flood elevation (12.0 feet – 8.2 feet).

Using Google maps and the 2100 100Y flood maps for high and low SLR scenarios, we estimated for each town the number of buildings that would be flooded to the two depth classes of 1 to 6 feet and 6 ft to 10 feet or more. For each set, we then estimated the cost of floodproofing by elevation using cost figures from FEMA (FEMA 2012). While elevation would take place over the entire planning period, for calculations we assumed elevation took place in 2035 with a discount rate of 3.5 %.

Results

The COAST software merged elevation data with data regarding the selected vulnerable asset (real estate) with a Depth Damage Function that identifies what percent of a structure's value will be lost under different depths of inundation. This function was imported from the Army Corps of Engineers; it was constructed based on large numbers of insurance claims for real estate in different flooding situation. Real estate values that can be expected to be lost under the selected flooding scenarios are shown for single-event and multi-decade periods.

Results generated by COAST for the Hampton-Seabrook Estuary shed light on the scale of potential impacts that could result from sea level rise and storm surge flooding in even the most conservatively, low impact scenario. Figures 1 – 4 demonstrate the potential impacts graphically on a Google Earth landscape. Tables 1 and 2 show potential expected damages from SLR and SS for all public assets modeled in Hampton and Seabrook. Tables 3 and 4 show cumulative

expected damages through 2050 and 2100 for the "No Action" scenarios, pooling public and private assets and the three towns of Seabrook, Hampton, and Hampton Falls. Table 5 lists public assets, threshold elevations and times when adaptation needs to occur under the different SLR scenarios if flooding is to be avoided. As can be seen, No Action in this century will be required for some assets such as the Hampton High School. On the other hand, action may be required now for assets such as the Seabrook wastewater treatment plant. Tables 6 – 11 show costs and benefits of the adaptation actions for private assets modeled in each of the three towns, based on vulnerabilities identified in Figures 1 – 4 and a public process (see Public Participation). Real estate damage is given in dollars and the cost column represents cost of adaptations, which in the No Action scenarios is zero. An early lesson learned, and an important theme throughout development of these models is that a substantial portion of damage in each scenario is a result of SS rather than SLR.

Table 1. Critical Public Assets –Hampton.

Scenario	Action	2050 Expected Value, Cumulative, Discounted Damage Costs ($ Million)	Adaptation Costs, Not Discounted ($ Million)	Net Benefits ($M)	Benefit: Cost
High SLR	No Adaptation	$82.7	0	-$82.7	
	Protect to 2100 Flood	0	$7.1	$75.6	12:1
Low SLR	No Adaptation	$78.8	0	-$78.8	

	Protect to 2100 Flood	0	$4.9	$73.9	16:1

Table 2. Critical Public Assets –Seabrook

Scenario	Action	2050 Expected Value, Cumulative, Discounted Damage Costs ($ Million)	Adaptation Costs, Not Discounted ($ Million)	Net Benefits ($M)	Benefit: Cost
High SLR	No Adaptation	$40.4	0	-$40.4	
	Protect to 2100 Flood	0	$4.2	$36.2	10:1
Low SLR	No Adaptation	$39.4	0	-$39.4	
	Protect to 2100 Flood	0	$1.6	$37.8	25:1

In the below figures, damages and inundation for the four scenarios are measured by parcel (polygon). Colored areas show the extent of inundation inland. The heights of polygons show damages in dollars. The red shaded polygons display inundation and damages from SLR only, while the blue shaded polygons display inundation and damages from SS.

Figures 1 and 2 show stakeholder-identified extremes of SLR and SS for 2050. Figure 1 shows the lowest impacts for 2050, with low SLR and a 10 year SS event, while Figure 2 shows the highest impacts modeled for 2050, with high SLR and a 100 year SS event. It is apparent that SLR alone causes little lost real estate value by 2050. However, SS does become a concern by 2050, particularly with a 100 year SS event. Figures 3 and 4 show stakeholder-identified extremes of SLR and SS for 2100. Figure 3 shows the lowest impacts for 2100, with low SLR

and a 10 year SS event, while Figure 4 shows the highest impact modeled for 2100, with high SLR and a 100 year SS event.

The No Action scenarios captured in figures 1 – 4 reveal an array of lost real estate values. For example, in 2050 with low SLR and a 10 year SS event, the image shows very little lost value (Fig. 1), whereas by the year 2100 with high SLR and a 100 year SS, significant value losses are revealed (Fig. 4). Looking at figures 1-4, it is apparent SS is responsible for most damages. Of all four No Action scenarios, SLR-related lost real estate value increases most dramatically in the highest impact scenario for 2100. While the portion of damages from SLR increases from 15% to 18% between low and high SLR scenarios in 2050, it jumps from 25% to almost 40% of the impact in the 2100 scenarios.

Implementation of adaptation actions in every scenario modeled for Seabrook, Hampton and Hampton Falls has at least a 2:1 benefit:cost ratio. In the least-flooded scenario of low SLR, adaptation actions provide an 8:1, 3:1 and 10:1 benefits to costs ratio for Hampton, Seabrook and Hampton Falls, respectively, providing savings of nearly $260 million between the three towns by 2100 compared to the No Action scenarios. Protection of public assets resulted in benefit:cost ratios as high as 10:1 for Hampton and 25:1 for Seabrook.

Nowhere in the models, where the adaptation actions are implemented, do costs outweigh benefits. Investing in the adaptations would thus be likely to provide a high rate of return with decreasing marginal benefits, mirroring increased damage costs from higher SLR. Even without SLR, the selected adaptation actions would provide benefits in the form of avoided SS damages.

The models developed through this process are useful for weighing opportunities and making decisions concerning land use in coastal flood plains. The models are not designed, however, to predict the future or to estimate engineering or other costs with great degrees of certainty. They are intended to foster engaged dialogue about a wide range of adaptation actions the municipalities might evaluate going forward. Nevertheless, given the benefit:cost ratios identified for the stakeholder-selected adaptation actions, the stakeholder group may wish to consider these adaptation actions in greater detail.

Additional caveats include that it is very unlikely that damages from SLR and SS will actually accrue to existing real estate in the manner depicted. This is partly due to the difficulty of predicting and incorporating ongoing, small scale adaptation actions of individual property owners and developers into the model. COAST assumes that, unless an adaptation action is taken, building owners rebuild each year to the original building conditions if they are damaged in a year. In reality, individuals will continually adjust to SLR and SS, incrementally over time. Further, the vulnerability these models describe is limited by the type and number of vulnerable assets chosen. In the towns modeled, depicted vulnerability only applies to real estate values. Additional COAST iterations could be run to examine vulnerabilities of other assets, such as sewer systems, economic output or community green spaces. The results are valuable, however, in both visualizing the scale and range of vulnerabilities faced by these towns and in beginning to plan a coherent response to SLR and SS events that can be reasonably anticipated.

Figure 1. Lost Real Estate Value for the Year 2050, Low SLR, 10-year Storm in Seabrook, Hampton, and Hampton Falls, NH.

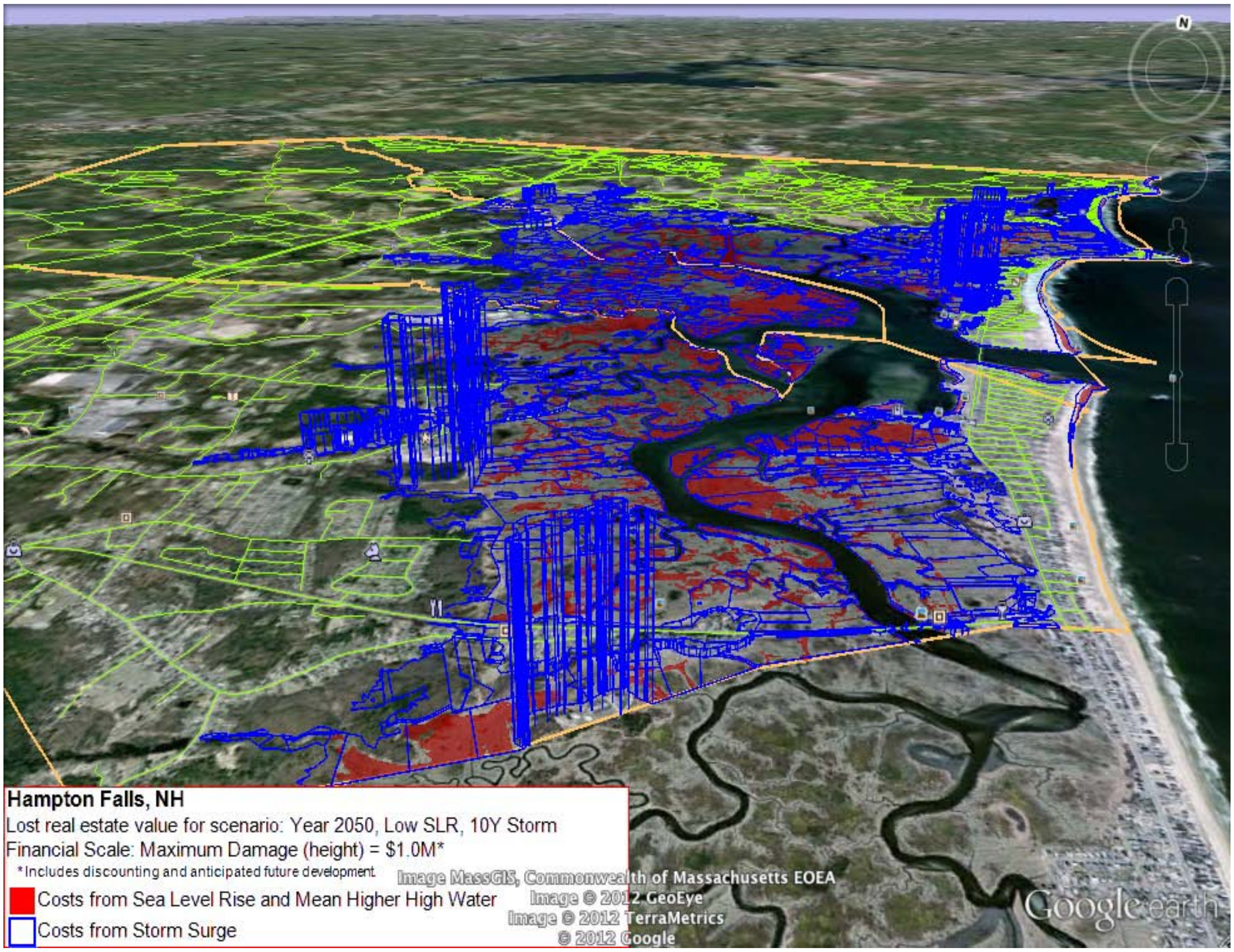

Figure 2. Lost Real Estate Value for the Year 2050, High SLR, 100-year Storm in Seabrook, Hampton, and Hampton Falls, NH.

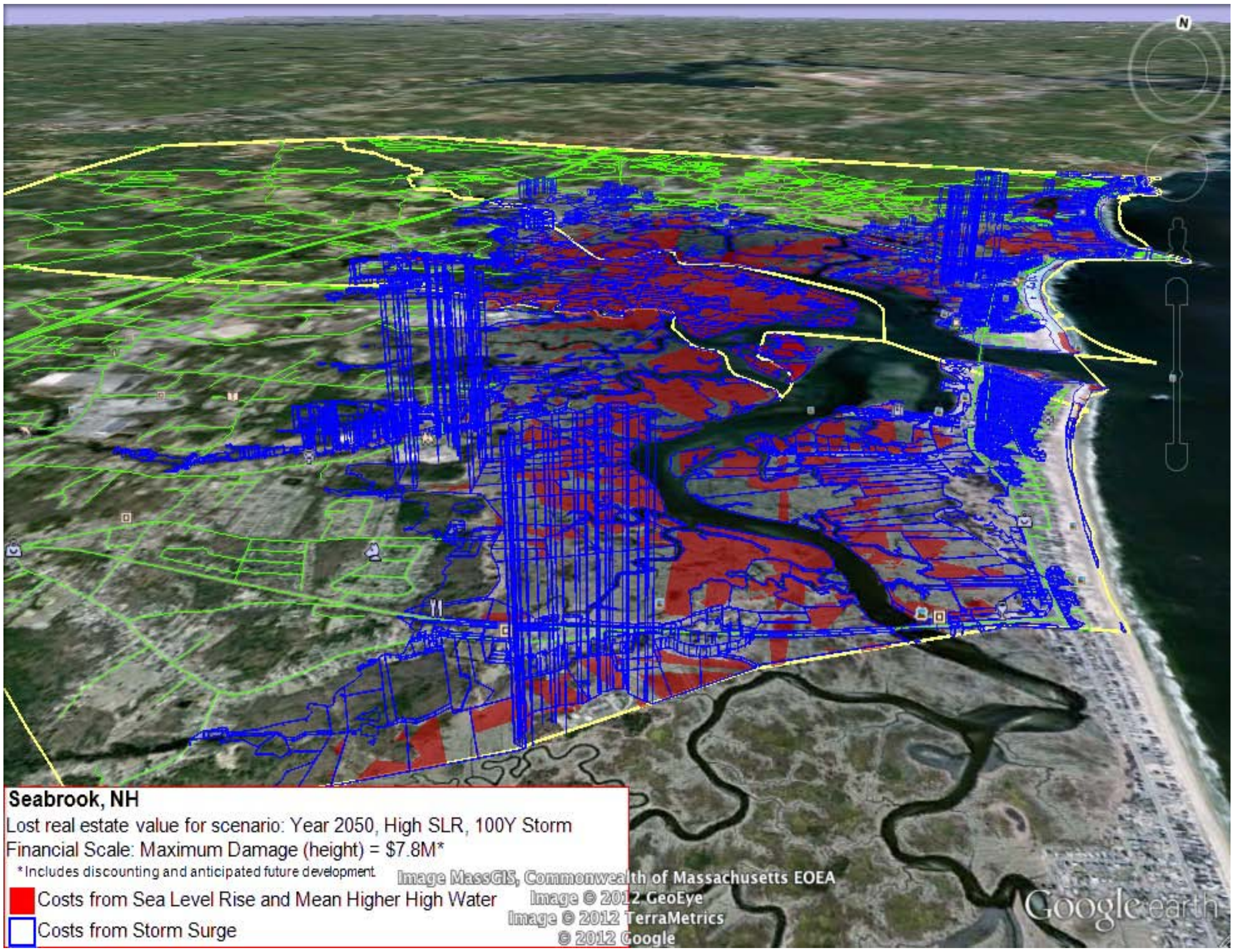

Figure 3. Lost Real Estate Value for the Year 2100, Low SLR, 10-year Storm in Seabrook, Hampton, and Hampton Falls, NH.

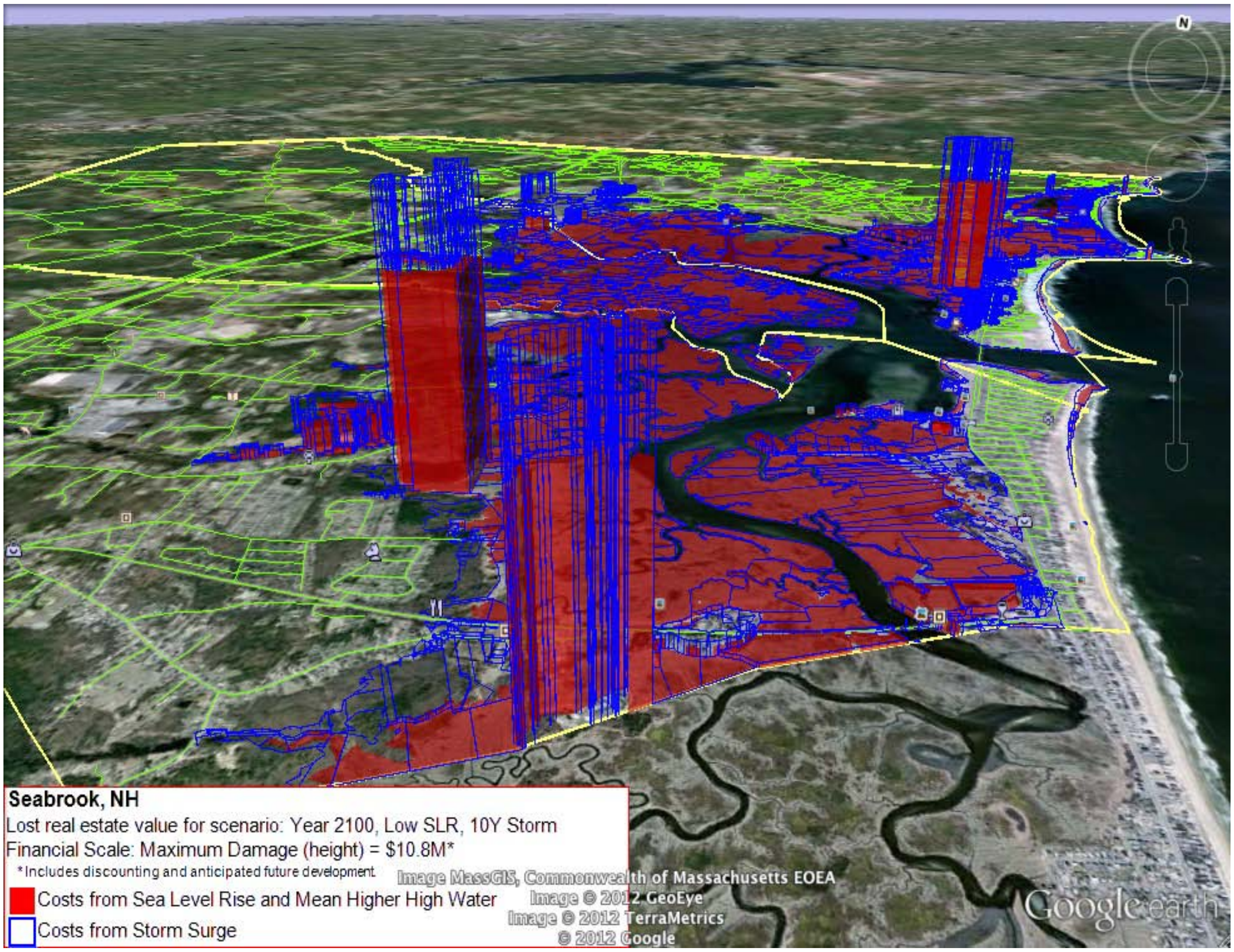

Figure 4. Lost Real Estate Value for the Year 2100, High SLR, 100-year Storm in Seabrook, Hampton, and Hampton Falls, NH.

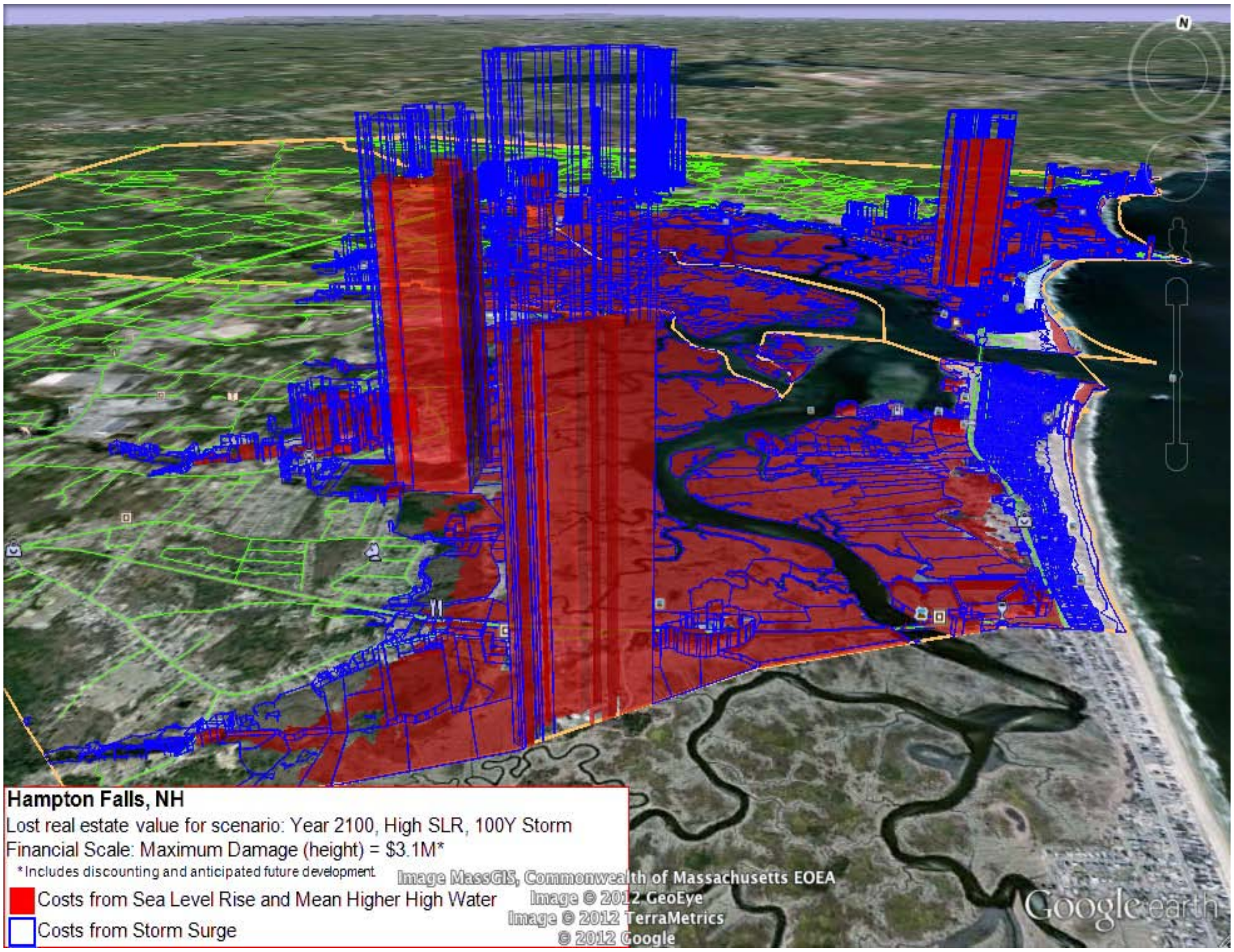

Table 3. Cumulative expected damages, through 2050, from the No Action scenario in Hampton, Seabrook and Hampton Falls, New Hampshire (pooling public and private assets).

2050			Real Estate	Percent Damage from	
SLR Scenario	Adaptation	Cost (M)	Damage	Storm surge	SLR
No SLR	No Action	$0	$463,400,542	100%	0%
Low SLR	No Action	$0	$503,504,672	85%	15%
High SLR	No Action	$0	$550,047,454	82%	18%

Table 4. Cumulative expected damages, through 2100, from No Action scenarios in Hampton, Seabrook and Hampton Falls, New Hampshire (pooling public and private assets).

2100			Real Estate	Percent Damage from	
SLR Scenario	Adaptation	Cost (M)	Damage	Storm surge	SLR
No SLR	No Action	$0	$1,407,215,562	100%	0%
Low SLR	No Action	$0	$1,952,391,293	75%	25%
High SLR	No Action	$0	$2,859,403,212	62%	38%

Table 5. Public Assets and Threshold for Action

Asset	Threshold (ft, NAVD), 100 Year Flood	Time of Occurrence (High SLR)	Time of Occurrence (Low SLR)
Hampton Sewage Pump Station	6.6	now	now
Hampton Police Station	8.2	now	now
Hampton Wastewater Treatment Plant	9.8	now	now
Seabrook Wastewater Treatment Plant	9.8	now	now
Seabrook Middle/Elementary School	14.8	~2080	>2100
NextEra Nuclear Power Plant	19.7	>2100	>2100
Hampton High School	23.0	>2100	>2100

Table 6. Private Assets Accommodation Results, Protect for High Sea Level Rise, Hampton

Scenario	Action	2050 Expected Value, Cumulative, Discounted Damage Costs ($M)	Adaptation Costs Discounted ($M)	Net Benefits (Benefit is damage avoided) ($M)	Benefit: Cost
High SLR	No Adaptation	$318.8	0	-$318.8	
Low SLR	No Adaptation	$287.7	0	-$287.7	
High SLR	Protect to High SLR 2100 100 Y Flood by Regulation	$0	$40.5	$278.3	8:1
Low SLR	Protect to High SLR 2100 100 Y Flood by Regulation	$0	$40.5	247.2	7:1

Table 7. Private Assets Accommodation Results, Protect for <u>Low</u> Sea Level Rise, Hampton

Scenario	Action	2050 Expected Value, Cumulative, Discounted Damage Costs ($M)	Adaptation Costs Discounted ($M)	Net Benefits (Benefit is damage avoided) ($M)	Benefit:Cost
High SLR	Protect to Low SLR 100 Y 2100 Flood by Regulation	$31.1	$36	220.6	4:1
Low SLR	Protect to Low SLR 100 Y 2100 Flood by Regulation	0	$36	$251.7	8:1

Table 8. Private Assets Accommodation Results, Protect for <u>High</u> Sea Level Rise, Seabrook

Scenario	Action	2050 Expected Value, Cumulative, Discounted Damage Costs	Adaptation Costs Discounted ($M)	Net Benefits (Benefit is damage avoided) ($M)	Benefit:Cost
High SLR	No Adaptation	$75.3	0		
Low SLR	No Adaptation	$66.9	0		
High SLR	Protect to High SLR 2100 100 Y Flood by Regulation	0	$30.3	$45	2:1
Low SLR	Protect to High SLR 2100 100 Y Flood by Regulation	0	$30.3	$36.6	2:1

Table 9. Private Assets Accommodation Results, Protect for Low Sea Level Rise, Seabrook

Scenario	Action	2050 Expected Value, Cumulative, Discounted Damage Costs	Adaptation Costs Discounted ($M)	Net Benefits (Benefit is damage avoided) ($M)	Benefit:Cost
High SLR	Protect to Low SLR 100 Y 2100 Flood by Regulation	$8.4	$20.4	$38.1	2:1
Low SLR	Protect to Low SLR 100 Y 2100 Flood by Regulation	0.	$20.4	$46.5	3:1

Table 10. Private Assets Accommodation Results, Protect for High Sea Level Rise, H. Falls

Scenario	**Action**	**2050 Expected Value, Cumulative, Discounted**	**Adaptation Costs Discounted ($M)**	**Net Benefits (Benefit is damage avoided) ($M)**	**Benefit:Cost**
High SLR	No Adaptation	$32.9	0	-$32.9	
Low SLR	No Adaptation	$30.7	0	-$30.7	
High SLR	Protect to High SLR 2100 100 Y Flood by Regulation	$0	$4.0	$28.9	8:1
Low SLR	Protect to High SLR 2100 100 Y Flood by Regulation	$0	$4.0	$26.7	8:1

Table 11. Private Assets Accommodation Results, Protect for Low Sea Level Rise, H. Falls

Scenario	Action	2050 Expected Value, Cumulative Discounted Damage Costs ($M)	Adaptation Costs Discounted ($M)	Net Benefits (Benefit is damage avoided) ($M)	Benefit:Cost
High SLR	Protect to Low SLR 100 Y 2100 Flood by Regulation	2.2	3.1	$25.4	6:1
Low SLR	Protect to Low SLR 100 Y 2100 Flood by Regulation	0	3.1	$27.6	10:1

Community Engagement and Response

The primary purpose of COAST is to facilitate communication of damage estimates from SLR and SS, in various adaptation and no adaptation scenarios, to the at-risk public. From the beginning, the COAST facilitators determined that if the reports were going to focus policy and action in the Hampton-Seabrook Estuary, it would be important to establish a stakeholder-driven process. This decision created an information exchange and decision-making process in NH that was decidedly inclusive in nature. While this inclusivity did slow the process at times by providing more questions than answers, it proved to be of great benefit to the entire project by providing a steering direction in the form of revealed community values. Following are the agendas and a brief description of the three stakeholder working meetings held in NH.

Stakeholder Working Meeting 1

Agenda:

1. Introduce COAST modeling process
2. Discuss sea level rise vulnerabilities
3. Weigh public opinion concerning sea level rise risks
4. Select vulnerable assets for modeling

During the first COAST planning meeting hosted by the New England Environmental Finance Center (NEEFC), in cooperation with PREP, NHCAW, UNH and the Rockingham Planning Commission in October of 2011, stakeholders were introduced to the COAST tool, provided a chance to review coastal flooding threats and select the vulnerable asset to model for the rest of the study. Based on discussions in this first planning meeting, real estate was selected as the vulnerable asset for which to project damages, and the years 2050 and 2100 were selected as time horizons. With guidance from project staff, stakeholders chose four, “No Action” scenarios to be modeled, projecting best and worst case outcomes from sea level rise (SLR) and storm surge (SS) for the respective time horizons.

Stakeholder Working Meeting 2

Agenda:

1. Review October 2011 stakeholder working meeting.
2. Present modeling results for selected vulnerable assets
3. Select adaptation strategies

During the second working meeting, held in February of 2012, Dr. Merrill used a projector to navigate the models in a three dimensional, Google Earth landscape. The parcels were shown from different angles to see where water depths and damages lined up on the landscape. The presentations enabled stakeholders to view landscapes and places familiar to them, from a variety of angles. This format was helpful to understanding how expected damages lined up with those landscapes and places.

Community Discussion of COAST results, February 2012 (PREP)

There were also handouts given to the stakeholders at the second working meeting, displaying each of the four scenarios from different angles. These handouts were reviewed by the stakeholders, allowing them the opportunity to compare the different images side by side, and providing them a medium for understanding and to dialogue about impacts within the range of SLR and SS scenarios.

Using the presentation slides and handout tools in the second working meeting, the facilitators of the project attempted to evaluate the public opinion in the Hampton-Seabrook Estuary on the future risks to coastal areas from SLR and SS.

By the end of the second meeting, the stakeholders reached a point of understanding and empowerment over the issues discussed and were able to effectively communicate their opinions and preferences for various actions or scenarios with the facilitators. Major issues identified as concerns by the stakeholder group include the vulnerability of Route 1 and adjacent assets, preservation of evacuation routes, critical facilities, and preservation of coastal beach assets. With guidance from facilitators, the stakeholder group decided on a combination of three adaptation actions to address these concerns: preservation, protection and accommodation.

The stakeholder-identified purpose of preservation was to maintain natural buffer capacities and habitat in the estuary by ensuring all marsh/road crossings do not restrict tidal flow. The stakeholder-identified purpose of protection was to provide physical barriers to damages to vulnerable real estate. The stakeholder-identified purpose of accommodation was to elevate and/or flood-proof homes and businesses vulnerable to flooding. It is the combination of these latter two strategies that was used for measuring costs and benefits in the models and tables.

Community Discussion of COAST results, February 2012 (PREP)

<u>Stakeholder Working Meeting 3</u>

Agenda:

1. Review of October 2011 and February 2012 stakeholder working meetings.

2. Review results for each town’s cost-benefit analysis of action to protect real estate.
3. Break into groups for Public Real Estate and Private Real Estate - to explore challenges, barriers and opportunities regarding the implications of the model results.
4. As a large group, brainstorm action items to further use or build upon the modeling results, and ways to sustain the dialogue and momentum in adaptation planning in the communities. Actions were categorized separately for community leaders and CAW.

Community Discussion of COAST results, February 2012 (PREP)

Along with the selection of adaptation actions, the stakeholder group was engaged in a process to understand the differences between needs and resources for protecting public and private assets. Looking at the range of impacts and assets, the stakeholders determined that preservation of the estuary’s natural buffering capacities would provide long-term benefits to both private and public real estate, by easing some of the affects of SLR and SS, and therefore defraying costs of adaptation actions needed to protect those assets.

When the discussion turned to vulnerability of public real estate, the stakeholder group decided to implement protection as an adaptation strategy. Using the models and charts, costs and benefits for installation of floodwalls were explored. Through facilitated dialogue the group reached consensus that development of protective walls that could withstand the worst case scenario of high SLR and a 100 year SS in order to reduce vulnerabilities to what the group found to be vital public assets was warranted.

The stakeholder group also explored the vulnerability of private real estate, reaching consensus that accommodation could be a productive adaptation strategy. Once again, this action would be designed to protect the communities from the 100 year SS with high SLR out to 2100. Overall, the accommodation strategies modeled varied greatly with the vulnerability, type and location of the assets. However, the stakeholders found that benefits accrued from investing in accommodation adaptation actions consistently outweighed costs of implementation. Throughout the process the COAST approach proved valuable in stimulating thinking and discussion around tradeoffs necessary to balance divergent community values. Other key points from the discussions are summarized below:

- Adaptation actions are expected to substantially reduce community costs and vulnerability compared to taking no action to adjust to increasing coastal water levels and severe storm events.
- Actions should, if possible, be compatible with greenhouse gas mitigation.
- Historic flooding risk is NOT a good predictor of the level of risk communities will face moving into the future: there is a need to plan proactively for more flooding.
- Damage costs and adaptation designs and costs are very approximate; more detailed analysis will be necessary before particular actions are taken.
- Adaptation strategies should also consider other regional climate stressors such as increases in extreme rainfall, temperatures, and wind.
- A comprehensive adaptation strategy is needed that includes both "here and now" actions and actions to be taken later but planned for now.

Implications for Future Work

Stakeholder Conclusions:

1. There is a great need for wider community engagement.
2. Foundations of good communication need to be built to ensure informed discussion.
3. Fostering regional momentum on climate adaptation will provide greater traction for the communities to take action.

Through the series of working meetings, stakeholders increased their understanding of vulnerabilities, adaptations and tradeoffs, with respect to coastal threats from SLR and SS. Through this increased understanding, the group also developed increased decision making capacities and effective communication skills for collaborating towards future SLR adaptation planning. Some stakeholders expressed their wish to explore ways to increase local outreach in their respective towns. By providing accessible visuals of vulnerabilities that affect multiple jurisdictions, COAST may serve as a catalyst for convening leadership and community members that may not otherwise engage on multi-jurisdictional issues.

Lessons learned from the community discussion sessions additionally include that:

1. Three-dimensional maps are very useful communication tools.
2. It is important to frame adaptation as a relevant issue for today, and keep a positive tone.
3. Individual, self-generated solutions will be the most robust – solutions must come from communities themselves.
4. Groups should focus more on application of results than on the technical process (let the extension/university/agency/consulting assistants focus on technical elements).
5. Future collaborations for adaptation should be regional and multi-jurisdictional

The interactively developed maps were identified as having an overwhelmingly positive effect on understanding of and excitement for developing adaptation strategies. Seeing impacts in the context of their own town allowed stakeholders to conceptualize how they and the places they knew would be directly affected. It was also helpful to empower individuals to create self-generated solutions. Once stakeholders felt they could understand risks and tradeoffs of particular actions they envisioned, they could then brainstorm their own approaches to planning and finance of the candidate adaptation actions. In future modeling efforts with COAST, stakeholders could benefit from continued focus on emergence of stakeholder-driven solutions.

Reflecting on the process, too much time was used to develop and step stakeholders through technical details rather than working to understand results and adaptation themes. This may have been avoidable if the process had started with images and maps, rather than by exploring the

technical process of how to create them. Another important lesson learned, for both facilitators and stakeholders, was the value that could be added by bringing more regional influences into the process. This process did not provide silver bullet solutions to problems of SLR and SS, and in fact there are none. The NH COAST sessions simply served as a catalyst for new discussions – discussions that communities have demonstrated that want to have, but haven't had the forum facilitation, and/or technical information to do so. The COAST tool and stakeholder process has helped the three communities involved to develop robust, adaptive capacity in the face of these threats.

Portland, Maine

Context and Methods

In June of 2011 the City of Portland unanimously adopted a resolution calling for a city-wide SLR planning process, and began taking steps to implement the intentions of the resolution. A few months prior, the Portland Society of Architects had organized a 2-day, > 200-person conference on how SLR might impact Portland, an event that helped galvanize public support for planning initiatives the City would soon initiate. Besides additional new initiatives (Appendix 4) and the COAST study described here, the City was also working with the Greater Portland Council of Governments and the Maine Geologic Survey (both of which groups were also working at the time on similar issues, with South Portland and other municipalities in the region) to evaluate impacts of SLR on roads and other infrastructure, under a range of SLR and SS scenarios through the year 2100. Methods in that study were different from those described here, but results were synergistic with this study and enhanced opportunities for concerned stakeholders to visualize their vulnerabilities and begin important discussions about preparation for rising seas and more frequent and intense storm events.

Portland Waterfront, high tide on October 28, 2011 (CBEP).

City officials met with the EFC in August 2011 to decide which vulnerable assets and adaptation actions to model, which SLR thresholds and SS intensities to consider, and how far into the future they wished to have the model reflect. They selected real estate in the Back Cove area as the vulnerable asset, and for the adaptation actions, a combination of a levee complex to protect against SLR and a hurricane barrier to protect against SS. (For engineering details on the levee, which also included new pumps under I-295 to remove rainfall runoff from the peninsula, a significant contributor to flooding in East Bayside, and for engineering details on the hurricane barrier, see Appendix 5). Stakeholders elected to use SLR thresholds from Vermeer and Rahmstorf (2009), specifically: for 2050, low SLR = 7.9” and high SLR = 19.7,” and in 2100, low SLR = 27.6” and high SLR = 70.9”. Storm surge extents and recurrence intervals were derived from local tide gauge data using methods in Kirshen et al (2010). Cost estimates for these candidate adaptation actions were developed by local engineering firm Sebago Technics (Appendix 5). Because of limited meeting time, the modeling team made some parameterization decisions on behalf of City officials and other local stakeholders, including specifying a discount rate of 3.5% for net present value calculations and a 1% increase over inflation in the real value of the asset being modeled. At the City’s request, the EFC modeling team also evaluated impacts of SLR and SS on one type of public infrastructure: the set of sewer intercepts that line the shore of Back Cove. Details on this subcomponent of the study are in the Results section below.

Results

Results generated by COAST for the vicinity of Portland’s Back Cove emphasize the enormity of potential impacts from storm surge flooding even in low SLR scenarios. Extrusion maps in Figures 1-4 demonstrate this graphically, and Tables 1 and 2 show the cumulative economic impacts for a variety of scenarios and adaptation actions. Ultimately, this model demonstrates that the city is not only at risk in 2050 and 2100; it is also presently vulnerable to larger storms. The estimates generated show large amounts of cumulative damage can be expected even with no SLR, and incrementally increasing levels of damage with the two SLR scenarios explored. Further, it shows in a way that is easily communicated to the public and public officials how adaptation actions can mediate this dismal forecast. Not addressed by these results is the question

of whether structural fortification is the best response to threats of SLR and SS. These issues were discussed in public meetings, notes from the last of which are in Appendix 5 and summarized below in the Lessons Learned section.

For brevity, not all combinations of modeled future scenarios are included here. Those included are intended to show the greatest contrast between the ranges of possibilities modeled by COAST. The first two figures show possible scenarios for 2050. Figure 1 shows the low end of possible damage scenarios: low SLR and a "10 Year" storm event. This is contrasted with the higher end of estimated damages for 2050, shown in figure 2, including a large amount of damage occurring during a "100 Year" storm with higher SLR.

Figures 3 and 4 show a similar contrast for the year 2100. As in 2050, the scenario with the "100 year" storm and high SLR generates more damage than the "10 year" storm with lower levels of SLR. However note that by the year 2100, a 10 year storm generates damage whereas in 2050 such a storm is not forecast to do so even with low rates of SLR. A 10 year storm with conservatively low SLR is shown by 2100 to generate far more damage than the 10 year storm would generate in 2050. Further, damage a 10 year storm does in 2100 with higher levels of SLR is similar to the amount of damage a "100 year" storm will do in 2050 with lower levels of SLR. The figures demonstrate graphically where and how much damage can be expected to accumulate in the study area as it sees a higher frequency of damaging flood events due to SLR.

The tables highlight damages from different inundation scenarios and importantly, show relative benefits taking different adaptation actions the City might undertake, under different SLR scenarios. For example even in the unlikely event there is no SLR, cumulative damage estimates by 2050 total $356M if no adaptation actions are taken. The cumulative damage estimate climbs to $407M for low SLR and $447M for a higher SLR scenario and no adaptation actions (Table 1). The model shows that this damage would come exclusively during storm events from storm surge flooding. The model suggests that by the year 2050, no lost real estate value would result from inundations occurring at the highest of high tide cycles with the amount of SLR modeled. Nevertheless, damage from the storm surge alone is significant enough to warrant consideration

of structural or nonstructural adaptations to this threat. This analysis importantly helps identify when certain types of action might be appropriate.

The adaptation action modeled for the 2050 projection is a hypothetical storm surge barrier located at the mouth of the Back Cove as described in the methods section. Estimated cost of this adaptation action was $103M, considerably less than even the most conservative estimated cumulative damage by 2050. This indicates that further consideration of this significant adaptation action can be economically justified by the COAST model. A somewhat low certainty of the $103M construction cost estimate is outweighed by the approximately $356M, $407M, or $447M in estimated cumulative damage (depending on the rate of SLR) by 2050. Though refinements to these calculations may be appropriate, using more detailed engineering design, these results indicate that the sooner a structural adaptation is implemented, the more likely the city will be to protect real estate in Back Cove. This observation is not meant to recommend structural approaches exclusive of or in place of non-structural approaches to protecting against SLR and SS in Back Cove. Rather the city would be well-advised to continue evaluating, and hopefully implementing, a wide range of structural and non-structural approaches to protect real estate in Back Cove – and elsewhere in the city.

By 2100, cumulative damage estimates increase markedly for all scenarios (Figure 2). Even for the no SLR scenario the forecast cumulative damage estimate is nearly $1.8B if no adaptation actions are taken. With SLR, if no adaptation actions are taken then $2.7B is forecasted for low SLR and $3.7B for a high SLR. Moreover, model results suggest that by 2100, damage will occur even during non-storm high tide events. For the lower SLR scenario, approximately 3% of that damage estimate is merely from inundation during the highest of high tide cycles, but 29% of damage in the higher SLR scenario occurs due to these non-storm inundations. According to this model, nearly all of this damage can be adverted by the construction of a levee complex around the Back Cove (Appendix 5). Table 2 suggests the estimated $40M cost of this levee complex would be easily justified by vastly larger lost real estate values likely by the year 2100.

However an important caveat to this observation is that in fact, the above SLR-related losses in the year 2100 are not likely to occur. On an ongoing basis, as buildings begin to be inundated

more and more frequently, property owners and City government will be adapting to these changes as they occur. For example after any large flooding event, property owners may voluntarily flood proof their building, preventing further losses for the time being. Similarly the City may choose to require that whenever buildings conduct major renovations in Back Cove, they must elevate the structure to 2' above base flood elevation. Nevertheless, the SLR-related damage maps and tables for the year 2100 serve a useful purpose, of generating discussion about what all interests in the City wish to do in response to combined threats of SLR and SS. Upon presenting the maps and tables to about 100 stakeholders in February 2011, the EFC facilitated public discussions about their implications and how the City might wish to move forward in its planning process. Public input transcribed during these meetings is summarized in the Community Engagement and Response section below.

Figure 1. Lost Real Estate Value for the Year 2050, Low SLR, 10-year Storm in Back Cove, Portland, Maine.

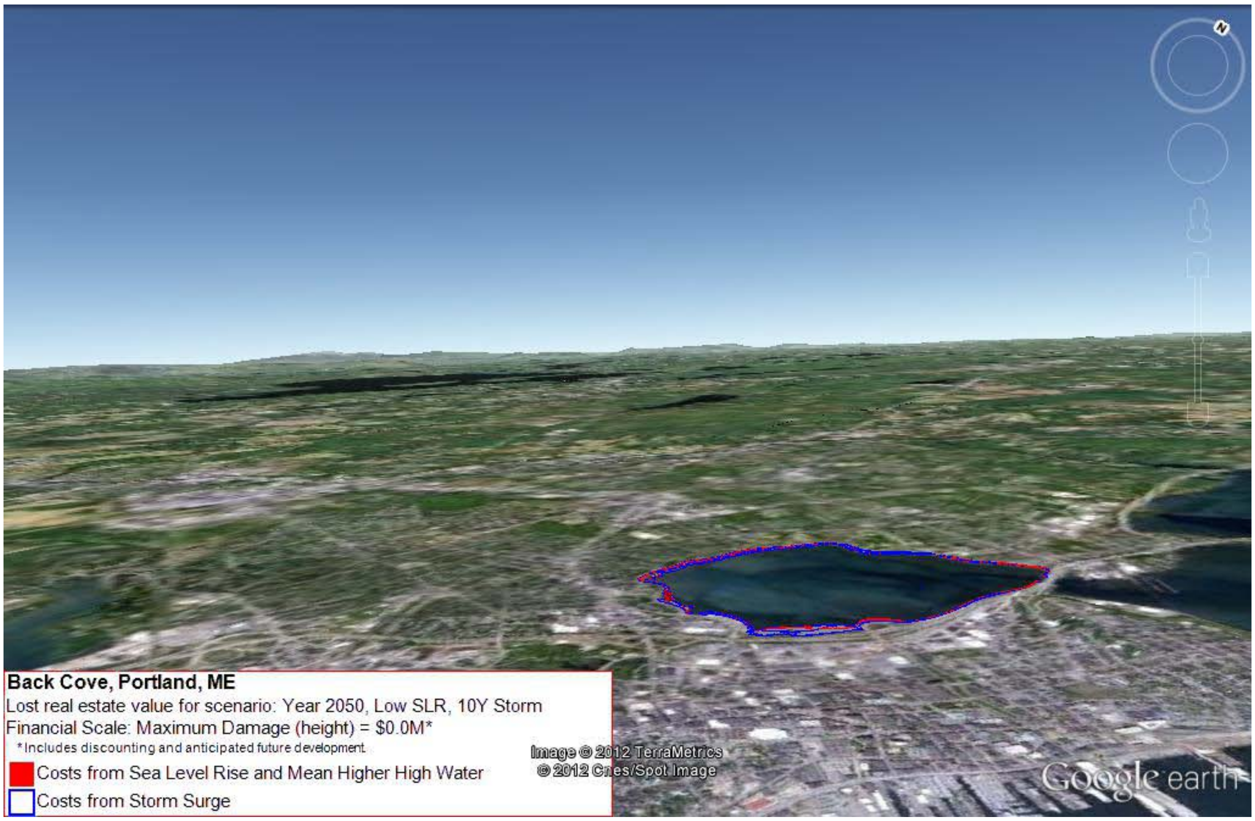

Figure 2. Lost Real Estate Value for the Year 2050, High SLR, 100-year Storm in Back Cove, Portland, Maine.

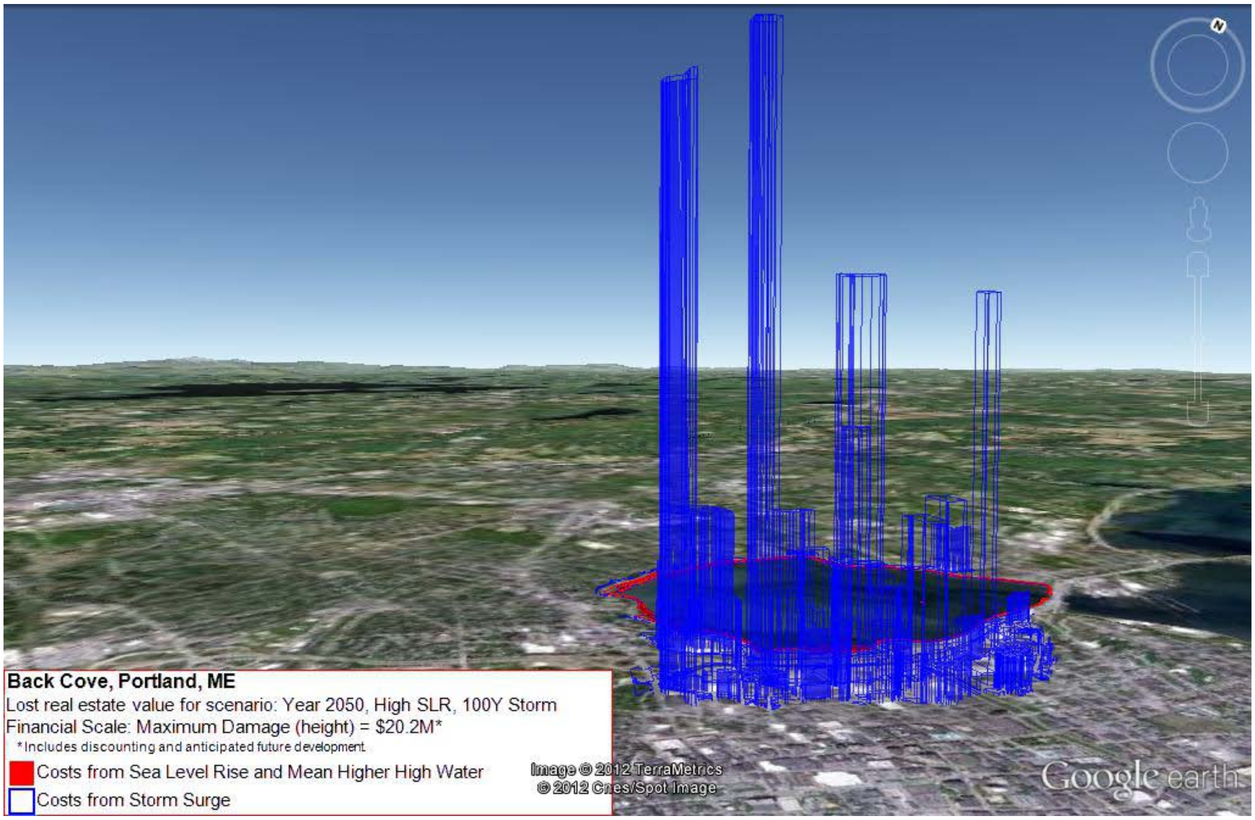

Figure 3. Lost Real Estate Value for the Year 2100, Low SLR, 10-year Storm in Back Cove, Portland, Maine.

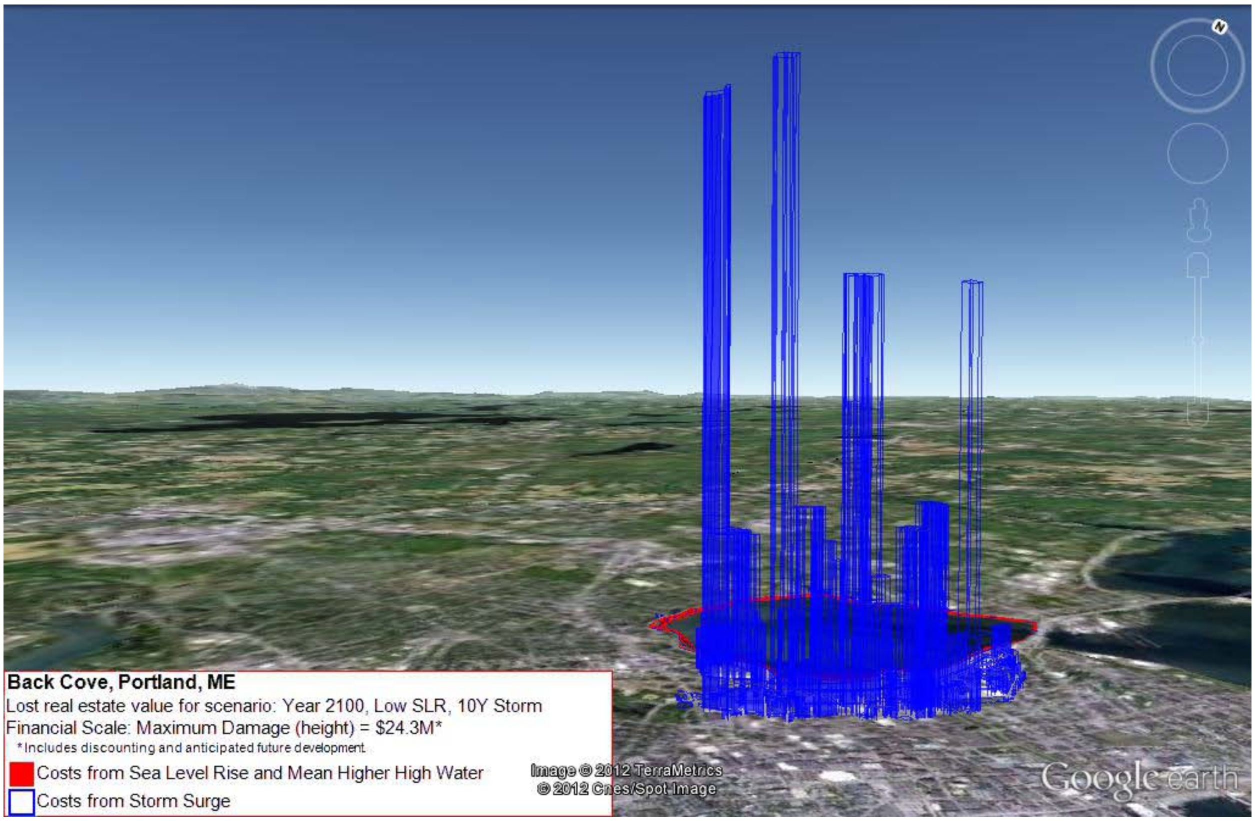

Figure 4. Lost Real Estate Value for the Year 2100, High SLR, 100-year Storm in Back Cove, Portland, Maine.

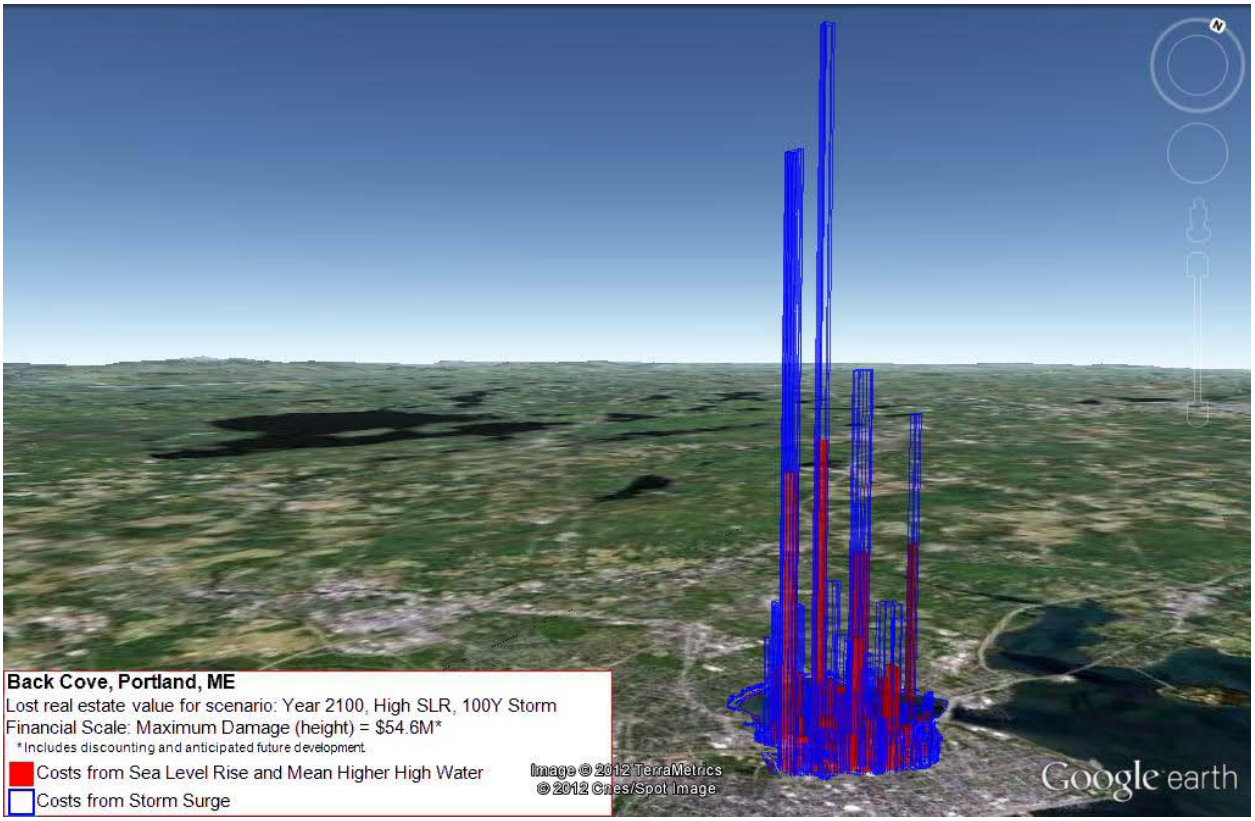

Table 1. Adaptation Costs and Cumulative Expected Damages through 2050, Portland, Maine

2050 SLR Scenario	Adaptation	Cost (M)*	Real Estate Damage (M)	Percent of damage from Storm surge	Percent of damage from SLR
No SLR	No Action	$0	$356	100%	0%
	Surge Barrier / Levee	$103 / $0	$0		
Low SLR (7.9")	No Action	$0	$407	100%	0%
	Surge Barrier / Levee	$103 / $0	$0		
High SLR (19.7")	No Action	$0	$447	100%	0%
	Surge Barrier / Levee	$103 / $0	$0		

*These adaptation costs assume the surge barrier would be built in 2015 and the levee complex would be built in 2051.

Table 2. Adaptation Costs and Cumulative Expected Damages through 2100, Portland, Maine.

SLR Scenario	Adaptation	Cost (M)*	Real Estate Damage (M)	Percent of damage from Storm surge	Percent of damage from SLR
No SLR	No Action	$0	$1,791	100%	0%
	Surge Barrier / Levee	$0 / $40	$0		
Low SLR (27.6")	No Action	$0	$2,674	97%	3%
	Surge Barrier / Levee	$0 / $40	$0		
High SLR (70.9")	No Action	$0	$3,680	71%	29%
	Surge Barrier / Levee	$0 / $40	$0		

*These adaptation costs assume the surge barrier would be built in 2015 and the levee complex would be built in 2051.

Adaptation for Interceptor and Pump Station, Back Cove, ME

Besides evaluating lost real estate value as the vulnerable asset, City officials in Portland also wished to consider impacts of SLR and SS on public infrastructure. To help begin these discussions, the interceptor sewer around Back Cove was selected as the representative vulnerable asset (Figure 5). In the COAST process, the normal approach is to create a customized Depth Damage Function for each vulnerable asset (see the Methods section in the NH chapter for discussion on how this function is structured). In this case, because relatively little damage to structural value of the intercepts was anticipated under the various flooding scenarios, up to the point of catastrophic failure of each intercept, a Depth Damage Function was not used, and evaluation of adaptation possibilities over time was conducted outside of the COAST software shell. Observations and conclusions on these issues are below.

Figure 5. Sewer Intercept Locations around Back Cove, Portland, Maine.

Realistic adaptation options for the sewer interceptor system and pump station surrounding Back Cove, Portland ME are limited and also driven by the renewal cycle for the interceptor and the pump station. It is also difficult to assign a cost for taking "No Action" in response to SLR and SS because the consequences are so severe that some actions will certainly be taken over time by the Portland Water District (PWD), and because consequences of inaction cannot be priced without considerable effort, due both to their complexity and uncertainty. However, at a cursory level it is possible to specify that consequences from more tidal flooding associated with SLR, more SS, and "No Action" include:

a) Higher groundwater table and increased hydraulic pressure;
b) Increased inflow and infiltration rates resulting in additional pumping to the wastewater treatment plant and more treatment at the plant;
c) Bank erosion; new, higher tidal zones may require bank stabilization around some infrastructure elements;
d) Baxter Boulevard pump station: there may be a need for more pumping, and access points around and into the pump station would need to improve;
e) Combined sewer overflow (CSO) regulators may not properly function, causing backups on streets and homes (public health issues);
f) Saltwater intrusion at the wastewater treatment plant just outside of Tukey's Bridge under I-295 is another possible consequence of CSO overload (and has the potential to alter the bacterial composition required for proper function);

Over the next 25 to 50 years (~ 2035 to 2060), these impacts would force PWD to elevate or seal some manholes and line pipes or replace leaky pipes. (And notably, the costs of inaction would be incurred even if the hurricane barrier under I-295 is built, as described above; that barrier would not keep the intercepts dry during the high-frequency, low-impact reality of substantially higher tides than we have at present). Or, in advance of these impacts, these actions can be planned for and taken as a matter of course, when PWD replaces and repairs the intercept system in the course of its useful life (and assuming the shoreline remains stable enough for this).

According to estimates derived in collaboration with PWD, these actions would cost $6-$12 million in addition to current normal maintenance and replacement costs. These actions would also protect the interceptor system from major damage during coastal flooding events over this period. Because height of the 100 year flood in 2050 under a high SLR scenario is possibly 13 feet (3.96m) NAVD88 and the floor elevation of the Back Cove pumping station is 15 feet (4.57m), there would also be no major damage to the pumping station over this period.

In approximately 2050 a major decision may need to be made on how to further adapt the interceptor system and pump station (including possible options such as moving their locations a little inland) against tidal flooding based upon SLR projections. Costs would range from $20 – $35M to move the intercepts, and roughly $10M to elevate or move the pump station. . This does not include the cost of moving the Back Cove pumping station because of increased flooding if adaptation measures were not taken; it is only the cost of responding to higher tidal flooding.

Both a hurricane barrier and levee would not lessen the hydraulic forces on the interceptor; they would only, if properly sized, prevent storm surge damage to the pump station and be only necessary after 2050 or so for that purpose. So the above changes would still be needed in the interceptor system, regardless of whether the levee and surge barrier are constructed.

Community Engagement and Response

The primary purpose of the COAST approach is to facilitate communication of SLR and SS damage estimates, in various scenarios, with or without adaptation actions, in a way that helps the at-risk public meaningfully engage with substantive discussion about choices at hand. Using results from the COAST simulations, the EFC hosted an event in February 2012 to provide stakeholders an opportunity to have this type of discussion. The event, attended by about 100 people, was located close to the area modeled for flood damage impacts in the study, and was co-sponsored by the Portland Society of Architects and the City of Portland. Public sector stakeholders included several city councilors, members of the Planning and Public Works Departments, and Portland mayor Michael Brennan. Private stakeholders included many residents of the City's Bayside and East Bayside neighborhoods, located on a floodplain in the

southern portion of the study area. An effort was made to invite businesses in the study area through personal invitations and leafleting at >25 business outlets. While not all invitees participated, the outreach effort did enhance private sector involvement in the discussion.

Mayor Brennan began the event with a welcome that stressed the importance of long term planning for SLR. Following the Mayor's address, Dr. Merrill from the EFC set the stage by laying out goals for the meeting. Peter Slovinsky from the Maine Geologic Survey then presented a summary of historic changes in Maine sea levels. Dr. Merrill concluded the presentation section of the event by describing the COAST process and analysis generated for the study area. Prior to a set of facilitated breakout sessions, unstructured and silent time was allotted in the presentation hall (10 minutes), for stakeholders to view >12 poster-sized maps generated with COAST, depicting flood damage impacts to the study area for the variety of scenarios previously discussed.

Attendees were divided into 4 breakout groups to allow detailed discussion of possible responses to the scenarios presented. The purpose of these sessions was to help City staff and interested parties evaluate the overall sense of community members' interest in taking one type of adaptation action or another. Each group was given three questions to answer: 1) "What approaches should be undertaken?" (four options were presented: fortification, accommodation, relocation, and do nothing); 2) "Who should be responsible for taking these actions?"; and 3) "How should the responses be implemented?" Each group had 90 minutes for facilitated discussion. Notes from the discussions are in Appendix 6 and summarized below.

Question 1: What approaches should be undertaken?

The purpose of this question was to establish which directions stakeholders wanted City planners to take in response to anticipated flood damages in their communities and in many cases their own personal real estate holdings. Overall, there was a consensus for a multi-faceted, iterative approach involving a suite of discussions over a several-year planning process. There were, however, fundamentally two different perspectives about how far and fast the response should proceed. Essentially there was not one temperature but a range of "temperatures in the room"

regarding what type of adaptation actions might be appropriate. One end of the spectrum advocated a slower and less publically involved approach, the other a more aggressive and very engaged response.

A common response to Question 1 was that, of the 4 options (fortification, accommodation, relocation, and do nothing), all but "do-nothing" were appropriate but at different time scales. There was general agreement among groups that different approaches made sense for different assets. Further, more than one group suggested different approaches should be taken with public property and infrastructure versus private property. More comments were made in support of a public role in protecting public property but there were widely divergent opinions on how much public involvement there should be in helping safeguard private property.

Relocation approaches were intensely debated by those of all spectrums of opinion, and represented significant points of contention in all groups. One group concluded that accommodation was the best option in the near term, but relocation was the best option in the long run. This group suggested that there was a considerable amount of vacant land in Maine and even within Portland, and as such it made sense to move development to those areas not vulnerable to future flooding due to SLR. A point was raised that the Bayside neighborhood lies in one of the most vulnerable areas, but has been targeted for extensive new development by the city. This group of stakeholders argued that since only about 25% of the build out toward this development goal has been completed, now would be a good time to arrest such development in Bayside. This group argued that the development could instead be shifted to less vulnerable areas (but stopped short of discussing how that process might be conducted).

Stakeholders advocating a more aggressive response, however, opposed relocation. They stated that relocation or arresting of new development now planned for Bayside was inconsistent with many other policy goals. Among the reasons cited were social, cultural, and economic equity. Stakeholders voicing this sentiment were primarily residents or business owners in the East Bayside or Bayside neighborhoods. This area is located in the flood zone, is one of the most demographically diverse in the state, and is predominately lower income. These stakeholders voiced the opinion that, if a wealthier neighborhood were vulnerable, there would be more

discussion about investment in fortification and less about relocation. They emphasized that their neighborhood's future development and cohesion depends on its protection and maintaining its geographical extent and infrastructure.

On the subject of fortification, there was substantial disagreement between groups. The camp of stakeholders advocating a more aggressive response was in favor of hard barriers, and recommended the surge barrier at the site of Tukey's bridge be constructed as soon as possible. On the other hand, the group interested in a slower response thought such hard fortification uneconomical, and instead advocated for soft approaches like floodproofing, especially of the most valuable assets, in a piecemeal approach. Ultimately, opinions on fortification were based on cultural and social good rather than economically derived benefits.

One area of substantial agreement between all groups was the need for some kind of increased public regulation. Both the more aggressive and the less aggressive groups agreed on advocating for changes to make new development in the most vulnerable areas more difficult, so that life cycle replacement of the most vulnerable infrastructure and real estate would follow. Vulnerable structures would, over time, be replaced with either more resilient forms or relocated to higher terrain. This category of planning response may therefore be the easiest way to develop compromise approaches that most effectively satisfy both the more aggressive and less aggressive groups.

Question 2: Who should be responsible for taking these actions?

There was less disagreement between stakeholders about who bears responsibility for implementation of adaptation actions. There was vast agreement that the City of Portland should ultimately be responsible for coordination of the adaptation response. This is not to say they felt the city should be solely responsible. Rather, they felt that there are certain goals other groups should focus on, with the city being the overall coordinator. The one exception was public infrastructure: there was substantial agreement that the city should be directly responsible for adaptation actions to protect public infrastructure.

The role of FEMA was discussed by several stakeholders. One group voiced the opinion that, should a large flood event strike the city, there would then be a shift of responsibilities, and FEMA would have to play a significant response role. Until then, however, the primary responsibility of FEMA (and the federal government in general) should be to provide data assessing the vulnerability of specific areas in the form of flood maps currently maintained.

Several groups discussed the role of non-profit organizations, which could provide support to the public interests at stake and conduct research to assist public decision makers in choosing appropriate adaptation strategies. The Casco Bay Estuary Partnership was specifically mentioned as a key resource, as was the Portland Society of Architects, Greater Portland Landmarks, Portland Trails, and the Greater Portland Council of Governments, among others. In different ways, each could represent community interests when the government and private sector would fail to do so, safeguarding both neighborhood social cohesion and economic viability.

There was a consensus between groups that the private sector will often need to be directly responsible for adaptation on particular properties. However, there was discussion about the role the private sector should play in the overarching goal of protecting the community at large from flood disasters. The general consensus was that there is a burden of responsibility on insurance companies, real estate developers, and banks that provide mortgage services to coordinate with the City as it develops new regulations consistent with safeguarding or restricting development in the most vulnerable areas, and that City government and the non-profit sector could serve an important role in convening events where this coordination may occur.

Question 3: How should the responses be implemented?

Stakeholders had several ideas about how responses should be implemented. Multiple breakout groups agreed there needs to be a substantial public education effort about potential problems. Some groups suggested greater interaction and communication among stakeholders. There was a general consensus that, as a first step, the City or a non-profit with interest should host a public planning meeting or series of meetings on the subject, to help organize a strategic approach to the city-wide SLR planning process authorized in the City Council resolution of June 2011

(Appendix 4). One participant suggested a similar process to that hosted in 2000 on redevelopment in Bayside.

Stakeholders also discussed how to finance the adaptation responses and who should pay. There was a disagreement in this area that mirrored the difference opinion observed in response to Question 1, on what the pace of implementation of adaptation actions should be. Several stakeholders voiced the opinion that those receiving benefits should pay, because property taxes collected from the City would be far less than the expenditure of protecting those properties. One participant stated that because of this, relocation was the best option and that spending money on adaptation didn't make sense. On the other hand, some participants suggested that the value of maintaining the coherence of neighborhoods, especially in Bayside and East Bayside, was not an easy thing to put a price on. In the end the difference of opinion appeared to be between those who had a vested stake in the future and growth of those neighborhoods, and those who were not concerned about vulnerable assets in those areas.

Apart from several participants advocating abandonment of all vulnerable areas, among the remaining participants there was moderate agreement on how to pay for adaptations. One idea was that developers could be charged a special one-time fee for building in vulnerable areas. Another idea was creation of a special taxing district for vulnerable properties, for example through some kind of tax-increment financing that could be explored. There was also a discussion about how to pay for infrastructure upgrades or relocations. Participants in one session argued that the local, state, and federal governments are responsible for paying to safeguard infrastructure in the vulnerable areas. However they suggested owners of utilities in such areas should be required to partially defray the cost of these protections.

Reconvening and Next Steps

Following the breakout sessions, the four groups assembled to discuss their ideas and next steps in the planning process. While different stakeholders presented different aspects of handling the implementation of response to SLR flooding, there was notable consistency between responses. In particular, there was similarity between responses to Questions 2 and 3 in that since the City

was singled out as being the most responsible entity, it should be responsible for coordinating and implementing the response, in collaboration with local non-profit organizations. There was also consistency among responses to Question 1: stakeholders felt that the response should be implemented by the city in a way that is multi-faceted and iterative. It should involve some combination of regulatory changes such as to zoning codes as well as some level of fortification. It also may need to involve zoning changes which, through life cycle attrition, demolition, and/or replacement, will lead over time to relocation of the most vulnerable real estate and public infrastructure in the Back Cove area.

The concluding session was helpful in allowing stakeholders to integrate their ideas, and to bring concerns directly to decision makers present in the room. City councilor Kevin Donoghue, who represents portions of the study area, discussed his particular concern that public actions addressing SLR and SS would address interests of all concerned stakeholders. It was clear from this final portion of the public meeting that discussion of this topic was more successful as a result of holding the breakout sessions, following the technical description of the modeling process and results. It appears likely that, without the fine-grained analysis provided by the COAST approach, there would not have been a shared understanding of specific threats facing the diverse stakeholders and decision makers that participated, and the discussions might have been less robust.

Two primary points stood out from input received from participants in these discussions. First, existing storm surge vulnerabilities provide a powerful argument for the “no regrets” scenario of taking some adaptation actions in the near term. Second, the public’s interest in the pace and vigor of implementation of adaptation actions depends at least partly on whether a particular stakeholder has financial, cultural, or emotional ties to a vulnerable area. The technique of breaking large public meetings into small group discussions allowed for substantive interaction between individuals and exchange of viewpoints between 1) those most vulnerable to flood damage and 2) those not directly vulnerable who would nevertheless need to be financially involved in some adaptation actions being considered.

Implications for Future Work

In Portland and countless other coastal cities, an enormous amount of real estate has been constructed in areas known to be vulnerable to damage from storm surge flooding at existing sea levels. It is difficult to model actions individual property owners will take to protect these assets. To prevent undue model complexity and to evaluate the possibility of publically funded, area-wide adaptation actions, COAST does not model smaller scale adaptation actions. However, especially in the "No Action" scenarios, such adaptation actions should not be discounted. Small scale SLR adaptation actions are myriad. They include wet and dry floodproofing, structural elevation, and relocation. Homeowners associations and other private organizations may also engage in neighborhood or block level actions such as sandbagging, especially during storm events. Insurance companies may play an increasingly important role in requiring private property owners to adapt to anticipated SLR increases and more damaging storm events. While important, these collections of small actions are beyond the scope of how COAST was used in this location.

However, regarding the candidate adaptation actions evaluated, a few conclusions can be drawn. Because most real estate loss in the modeled scenarios is from SS and not SLR, building the levee complex in Portland may not be a good investment (of $43M) until at least 2050, at least from the perspective of real estate. However because surge-related losses could be large, the $103M hurricane barrier (+/- a considerable amount of estimation error; see costing report in Appendix 5) may be a good investment well before 2050 (see Tables 1 and 2). Nevertheless, given a broad range of uncertainties, limitations in the data, political sensitivities, and other constraints, a substantial amount of further process and discussion would be required before concrete recommendations for particular courses of engineering or other action are appropriate. And importantly, any such decisions would need to be developed through involved public process, as was initiated at the February 2012 meeting in Portland.

Results of the COAST analysis in Portland have contributed to the beginning of a long process of adaptation to SLR and SS. The importance of taking substantive action in the short term cannot be adequately underscored, but nor can the reality that there will be significant divisions between

those who stand to benefit most directly from adaptation action and those who perceive little in the way of personal benefit. Stakeholders with viewpoints somewhere between these two positions will no doubt also play an important role in discussions to begin soon. If this early experience is any indication, a crucial aspect of taking any large scale adaptation action in Portland will be educating those with little direct economic stake about the value of such adaptation action, which would unfold on behalf of the larger community interests at stake.

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Appendix 1. Software report and excerpt from the COAST User's Manual, current version.

The COAST Tool Window

The main COAST Tool window is shown in Figure 2.

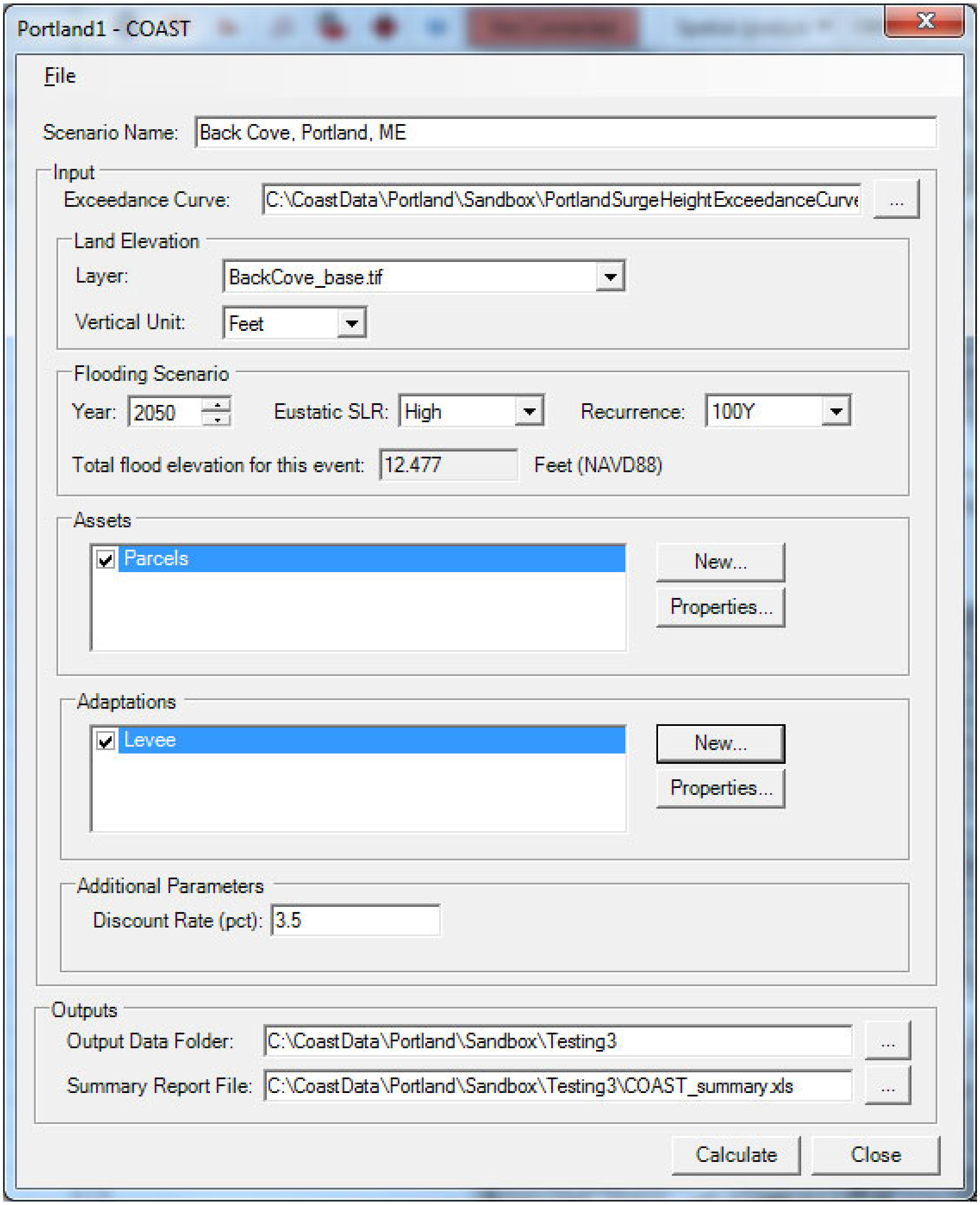

Figure 2: The Main COAST Window

File Menu

The **File** menu contains functionality for opening and saving COAST scenario definitions and licensing the COAST tool. The menu options are:

New	Clear the current scenario definition.
Open...	Open a file containing a scenario definition
Save	Save the current scenario definition to a file. If the scenario has not been saved, you will be prompted for a file name.
Save As...	Save the current scenario definition to a different file. You will be prompted for a file name.
Licensing...	Set up a license for the COAST tool. See Licensing the COAST Toolbar on page 5 for more information.
Exit	Closes the COAST Tool main window.

Scenario Name

Type the name of the scenario here. This name will be used in folder and file names for the output maps.

Exceedance Curve

Use this field to specify the name of the file that defines the Exceedance Curve to be used in the model. This file can be an Excel spreadsheet or a comma-separated value (CSV) file. (See Exceedance Curve on page 11 for a description of the required file layout.) You can type the full path to the file in the field, or use the Browse button ("**...**") to select a file using the standard Windows file dialog.

Land Elevation

The Land Elevation section specifies the Esri ArcMap layer that represents the initial Land Elevation Layer and the unit used to specify the elevation value.

The **Layer** is a raster Digital Elevation Model (DEM) file produced from LIDAR data, where each pixel contains an elevation value. The format should be either ARC Digitized Raster Graphics (*.img) or GeoTIFF (*.tif). The drop-down list contains all of the raster layers in the current map. Select the layer that you want to use.

Use the **Vertical Unit** to specify the unit for the elevation values in the Land Elevation Layer. All elevation values must be based on NAVD88. The choices for Vertical Unit are feet and meters.

Flooding Scenario

Use the values in this section to define the flooding scenario used to generate the inundation maps. The Flooding Scenario section will be disabled until an Exceedance Curve has been specified.

Year is the future year that will be used to estimate the total increase in water level for the scenario. The starting year is the current year. This year will also represent the ending year when calculating cumulative expected damages.

Use **Eustatic SLR** to indicate the degree of global sea-level rise (SLR) to be applied when calculating the flood elevation for the scenario. There are three choices:

1. **None** means that the calculation should use no Eustatic SLR in the calculation. In this case, the model will use only local SLR.

2. **Low** indicates that the model should use global SLR at the low end of the estimates based on Vermeer & Rahmstorf (2009).
3. **High** tells the model to use global SLR at the high end of the estimates based on Vermeer & Rahmstorf (2009).

Recurrence indicates the level of storm surge based on the probability that a storm producing that storm surge will occur. Typically, the recurrence interval is indicated as a 10-year storm, 100-year, storm, etc. The COAST tool reads the recurrence probabilities used to create this list from the Exceedance Curve file.

Total flood elevation for this event indicates the rise in water level that will be applied in the model, based on the settings for Year, Eustatic SLR, and Recurrence.

Assets

This section lists the assets that have been defined for the scenario. An asset is a map feature whose value is used to calculate expected damages for the defined scenario. Each asset in the list has a check-box to the left of its name. Click the check-box to include and asset in or exclude an asset from the model. Although the list can contain more than one asset, only one asset can be used in any particular run of the model.

Click the **New...** button to add a new asset to the list. Click the **Properties...** button to view or update the information about an asset. See Define Asset Window on page 9 for information about adding or modifying assets.

Adaptations

This section lists the adaptations that have been defined for the scenario. An adaptation is a change that is expected to result in a reduction of damages in the scenario being modeled. Some examples are

- building a levee or sea wall
- flood-proofing buildings
- changing zoning rules to restrict development in flood-prone areas

Each adaptation in the list has a check-box to the left of its name. Click the check-box to include an adaptation in or exclude it from the model.

Click the **New...** button to add a new adaptation to the list. Click the **Properties...** button to view or update the information about an adaptation. See Define Adaptation Window on page 11 for information about adding and modifying adaptations.

Additional Parameters

Discount Rate is the overall inflation rate that will be used to discount future values while calculating damages and expected values.

Outputs

Output Data Folder defines the base location where model intermediate files and final results will be stored. Intermediate data from a run of the model will be saved in a subfolder named by concatenating the Scenario Name, Asset Name, Year, Eustatic SLR level, and Recurrence interval name. The output maps will be stored a folder called Results, located below the folder where the intermediate data was written.

Summary Report File contains the full path and file name for the summary report containing cumulative expected damages for the scenario.

Define Asset Window

The Define Asset window is used to specify the definition for an asset to be used when running the COAST model. The window layout can be seen in Figure 3.

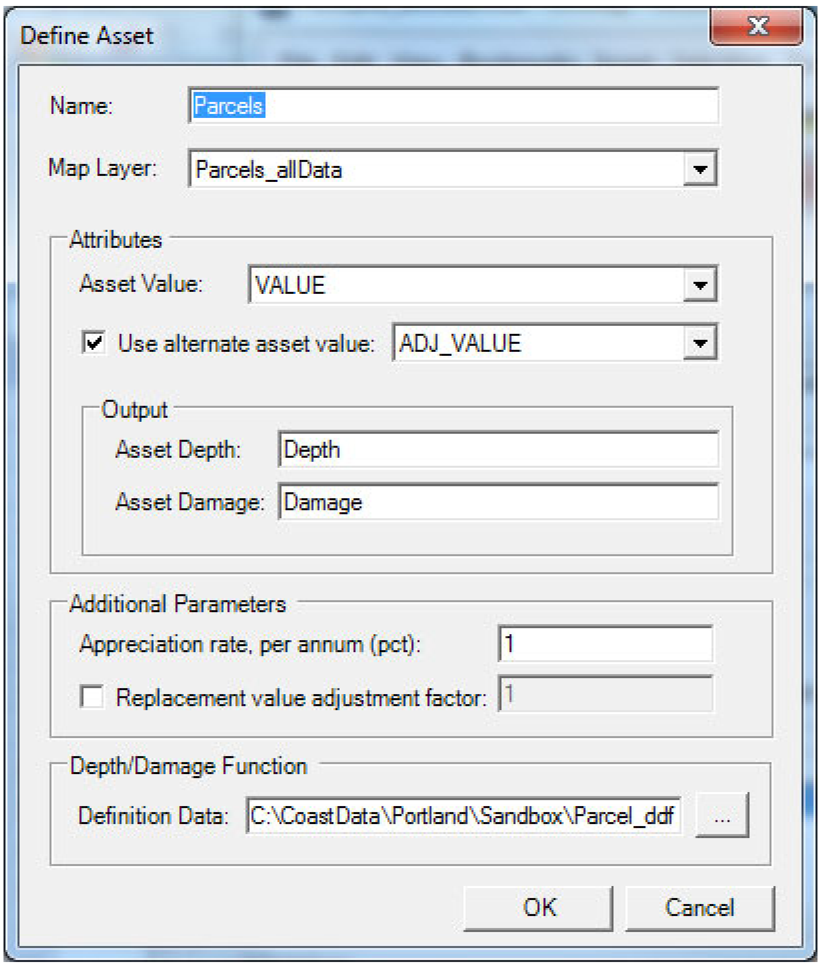

Figure 3: The COAST Define Asset Window

Name

Type the name of the asset in this field. This will be the value displayed in the Assets list on the main window.

Map Layer

All vector layers currently loaded into Esri ArcMap will be included in this list. Choose the map layer that represents this asset.

Attributes

This section allows the user to specify the asset layer attributes to be used for various purposes.

Choose the **Asset Value** attribute from the drop-down list. This is the attribute that indicates the monetary value used to calculate damages. The list includes all of the numeric attributes from the asset's map layer.

The COAST model allows for the use of a second asset value to replace the main asset value attribute for a subset of the assets during model calculations. For example, in a scenario that models damage to land parcels, a user may want to include future development in the damage calculations. Since only some of the parcels will have values for future development, only non-zero values of the alternate attribute will replace the original value. To enable this functionality, place a check next to **Use alternate asset value** and choose the attribute from the list.

Asset Depth contains the name of an attribute containing the depth for an asset. This attribute will be added to the output dataset, and its value will be calculated by the model. You can choose the name for this attribute.

Asset Damage contains the name of an attribute that will contain the estimated damage for an asset based on its depth. The attribute value will be calculated by the model. You can choose the name for this attribute.

Additional Parameters

Use the **Appreciation Rate** to indicate that an asset will appreciate faster than inflation. This rate will be applied to the asset value before the discount rate is applied. Enter the value as a percentage, e.g., if you think the asset will appreciate 1% faster than inflation, enter a value of "1".

Sometimes, the asset value does not reflect the cost of replacing it when it gets damaged. For example, the tax assessors valuation of a building may not reflect its replacement cost. In order to apply an adjustment for this condition, check the box next to **Replacement value adjustment factor** and type the factor into the adjacent field. When the tool calculates damages for an asset, the asset value will be multiplied by this value to produce the replacement cost. For example, if you think that replacement costs average about 40% higher than the assessed value, enter "1.4".

Depth/Damage Function

The **Definition Data** field specifies the full path to the file name that contains the depth/damage function for this asset. For information about the contents and format for this file, see Depth/Damage Function on page 12.

Define Adaptation Window

The Define Adaptation window is used to specify the definition for an adaptation strategy to be applied to the COAST model. The window layout can be seen in Figure 4.

Use the **Name** field to specify the name of the adaptation.

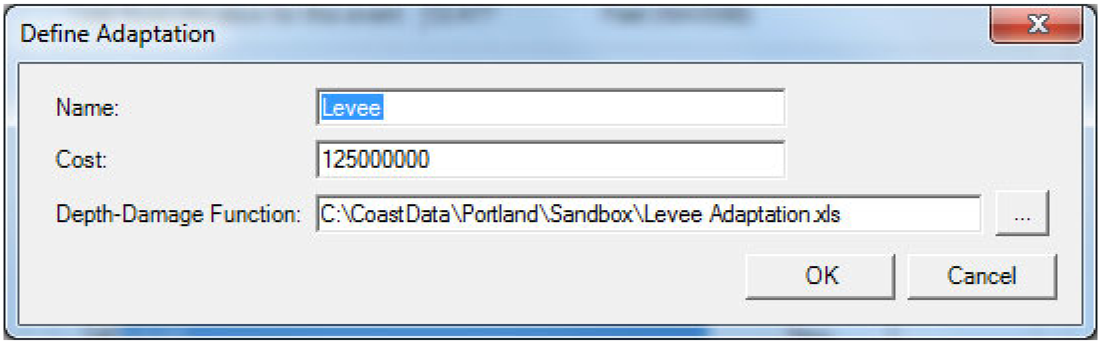

Figure 4: COAST Define Adaptation Window

Use the **Cost** field to specify the cost, in current dollars, of implementing the adaptation. This information will be used in the summary report.

The **Depth/Damage Function** field specifies the full path to the file name that contains the depth/damage function for this adaptation. To account for effect of this adaptation, this depth/damage function will replace the asset's depth damage function when calculating damages. For information about the contents and format for this file, see Depth/Damage Function on page 12.

COAST Scenario Data Requirements

In order to set up a COAST scenario, you will need the following:

1. A base land elevation layer.
2. A base asset data layer. This is a vector file containing features representing the assets to be included in the model, and can be a shapefile or a table in an Esri geodatabase. This layer must have an attribute containing the asset value to be used in the damage calculations.
3. An Excel spreadsheet containing the exceedance curve data (see Exceedance Curve on page 11.)
4. An Excel spreadsheet containing the asset's DDF (see Depth/Damage Function on page 12.)
5. If you are planning to model one or more adaptations, you will need an additional Excel spreadsheet for each adaptation, containing the DDF for the adaptation.

Exceedance Curve Data

In COAST, an Exceedance curve describes the probability that various levels of flood elevation will be exceeded. The COAST tool reads the data from an Excel spreadsheet or CSV file that contains the following columns (in the order listed):

Probability	A number representing the chance that this flood elevation will occur. This is a raw probability value, e.g., a 1% chance is .01, a 5%

	chance is .05, etc.
Surge Height (ft)	The increase in flood elevation due to storm surge associated with the probability, measured in feet (NAVD88).
Surge Height (m)	The increase in flood elevation due to storm surge associated with the probability, measured in meters (NAVD88)
Description	A description of the probability reflecting the recurrence interval, in years.
MHHW (ft)	The local Mean Higher High Water (MHHW) level, in feet (NAVD88)
MHHW (m)	The local MHHW level, in meters (NAVD88)
Local SLR (ft)	The local Sea-Level Rise (SLR) per year, in feet (NAVD88)
Local SLR (m)	The local SLR per year, in meters (NAVD88)

Currently, the COAST tool stores the probability, and values measured in feet, so the only columns that are required to contain values are:

- Probability
- Surge Height (ft)
- MHHW (ft)
- Local SLR (ft)

The following table is a sample of Exceedance Curve data:

Probability	Surge Height (ft)	Surge Height (m)	Description	MHHW (ft)	MHHW (m)	Local SLR (ft)	Local SLR (m)
0.002	9.153543307	2.79	500 Y	4.652230971	1.418	0.000721785	0.00022
0.01	6.496062992	1.98	100 Y				
0.02	5.61023622	1.71	50 Y				
0.05	4.593175853	1.4	20 Y				
0.1	3.904199475	1.19	10 Y				

Depth/Damage Function Data

A Depth/Damage Function maps the flood depth to the percentage of an asset's value that is lost, i.e., the damage done to an asset. . The COAST tool reads the data from an Excel spreadsheet or CSV file that contains the following columns (in the order listed):

Depth (ft)	The depth level, in feet.
Damage	The damage factor. This asset value will be multiplied by the damage factor to calculate the asset damage. For example, if damage is 36.9%, enter .369.

The following table is a sample of a Depth/Damage function.

Depth	Damage

(ft)	
0	0.179
1	0.223
2	0.27
3	0.319
4	0.369
5	0.419
6	0.469
7	0.518
8	0.564
9	0.608
10	0.648
11	0.684
12	0.714
13	0.737
14	0.754
15	0.764

Asset	Item	Description	Takeoff Quantity	Total Cost/Unit	Total Amount
2A		**Hampton Wastewater Treatment Plant (6' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	3,737.00 lf	21.71 /lf	81,122
		Minor Site Demolition			**81,122**
		Precast Wall Panels			
	0750	Precast wall panel	31,765.00 sf	61.24 /sf	1,945,429
		Precast Wall Panels			**1,945,429**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	411.00 cy	6.53 /cy	2,684
		Excavating, Trench			**2,684**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	52,318.00 sf	36.68 /sf	1,918,763
	2300	Sheet piling, Steel, for embedment	7,474.00 sf	21.75 /sf	162,530
		Sheet Piling Systems			**2,081,293**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	3.00 ea	108,501.02 /ea	325,503
		Canal Gates			**325,503**
		2A Hampton Wastewater Treatment Plant (6' Wall)	**3,782.00 LF**	**1,172.93 /LF**	**4,436,031**
2B		**Hampton Wastewater Treatment Plant (2.5' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	3,737.00 lf	21.71 /lf	81,122
		Minor Site Demolition			**81,122**
		Precast Wall Panels			
	0750	Precast wall panel	18,685.00 sf	61.24 /sf	1,144,352
		Precast Wall Panels			**1,144,352**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	411.00 cy	6.53 /cy	2,684
		Excavating, Trench			**2,684**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	37,370.00 sf	36.68 /sf	1,370,545
	2300	Sheet piling, Steel, for embedment	7,474.00 sf	21.75 /sf	162,530
		Sheet Piling Systems			**1,533,075**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	3.00 ea	108,501.03 /ea	325,503

Asset	Item	Description	Takeoff Quantity	Total Cost/Unit	Total Amount
		Canal Gates			**325,503**
		2B Hampton Wastewater Treatment Plant (2.5' Wall)	**3,782.00 LF**	**816.17 /LF**	**3,086,736**
3A		**Hampton Police Station (8' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	1,273.00 lf	21.71 /lf	27,634
		Minor Site Demolition			**27,634**
		Precast Wall Panels			
	0750	Precast wall panel	13,367.00 sf	61.24 /sf	818,654
		Precast Wall Panels			**818,654**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	140.00 cy	6.53 /cy	914
		Excavating, Trench			**914**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	22,914.00 sf	36.68 /sf	840,371
	2300	Sheet piling, Steel, for embedment	2,546.00 sf	21.75 /sf	55,365
		Sheet Piling Systems			**895,737**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	2.00 ea	108,501.04 /ea	217,002
		Canal Gates			**217,002**
		3A Hampton Police Station (8' Wall)	**1,303.00 LF**	**1,504.18 /LF**	**1,959,941**
3B		**Hampton Police Station (4' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	1,273.00 lf	21.71 /lf	27,634
		Minor Site Demolition			**27,634**
		Precast Wall Panels			
	0750	Precast wall panel	8,275.00 sf	61.24 /sf	506,798
		Precast Wall Panels			**506,798**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	140.00 cy	6.53 /cy	914
		Excavating, Trench			**914**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	12,730.00 sf	36.68 /sf	466,873
	2300	Sheet piling, Steel, for embedment	2,546.00 sf	21.75 /sf	55,365
		Sheet Piling Systems			**522,238**
		Canal Gates			

Asset	Item	Description	Takeoff Quantity	Total Cost/Unit	Total Amount
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	2.00 ea	108,501.02 /ea	217,002
		Canal Gates			**217,002**
		3B Hampton Police Station (4' Wall)	**1,303.00 LF**	**978.19 /LF**	**1,274,586**
4A		**Seabrook Middle/Elementary School (2.5' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	2,465.00 lf	21.71 /lf	53,510
		Minor Site Demolition			**53,510**
		Precast Wall Panels			
	0750	Precast wall panel	12,325.00 sf	61.24 /sf	754,838
		Precast Wall Panels			**754,838**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	271.00 cy	6.53 /cy	1,770
		Excavating, Trench			**1,770**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	24,650.00 sf	36.68 /sf	904,039
	2300	Sheet piling, Steel, for embedment	4,930.00 sf	21.75 /sf	107,208
		Sheet Piling Systems			**1,011,247**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	1.00 ea	108,501.03 /ea	108,501
		Canal Gates			**108,501**
		4A Seabrook Middle/Elementary School (2.5' Wall)	**2,480.00 LF**	**778.17 /LF**	**1,929,865**
5A		**Seabrook Wastewater Treatment Plant (6' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	2,015.00 lf	21.71 /lf	43,741
		Minor Site Demolition			**43,741**
		Precast Wall Panels			
	0750	Precast wall panel	17,128.00 sf	61.24 /sf	1,048,995
		Precast Wall Panels			**1,048,995**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	222.00 cy	6.53 /cy	1,450
		Excavating, Trench			**1,450**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	28,210.00 sf	36.68 /sf	1,034,602
	2300	Sheet piling, Steel, for embedment	4,030.00 sf	21.75 /sf	87,636

Asset	Item	Description	Takeoff Quantity	Total Cost/Unit	Total Amount
		Sheet Piling Systems			**1,122,238**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	1.00 ea	108,501.04 /ea	108,501
		Canal Gates			**108,501**
		5A Seabrook Wastewater Treatment Plant (6' Wall)	**2,030.00 LF**	**1,145.28 /LF**	**2,324,925**
5B		**Seabrook Wastewater Treatment Plant (2.5' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	2,015.00 lf	21.71 /lf	43,741
		Minor Site Demolition			**43,741**
		Precast Wall Panels			
	0750	Precast wall panel	10,075.00 sf	61.24 /sf	617,038
		Precast Wall Panels			**617,038**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	222.00 cy	6.53 /cy	1,450
		Excavating, Trench			**1,450**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	20,150.00 sf	36.68 /sf	739,001
	2300	Sheet piling, Steel, for embedment	4,030.00 sf	21.75 /sf	87,636
		Sheet Piling Systems			**826,638**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	1.00 ea	108,501.02 /ea	108,501
		Canal Gates			**108,501**
		5B Seabrook Wastewater Treatment Plant (2.5' Wall)	**2,030.00 LF**	**786.88 /LF**	**1,597,367**
7A		**Hampton Sewage Pump Station (10' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	326.00 lf	21.71 /lf	7,077
		Minor Site Demolition			**7,077**
		Precast Wall Panels			
	0750	Precast wall panel	4,075.00 sf	61.24 /sf	249,571
		Precast Wall Panels			**249,571**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	36.00 cy	6.53 /cy	235
		Excavating, Trench			**235**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	7,824.00 sf	36.68 /sf	286,945

Asset	Item	Description	Takeoff Quantity	Total Cost/Unit	Total Amount
		Sheet Piling Systems			
	2300	Sheet piling, Steel, for embedment	4,075.00 sf	21.75 /sf	88,615
		Sheet Piling Systems			**375,560**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	1.00 ea	108,501.04 /ea	108,501
		Canal Gates			**108,501**
		7A Hampton Sewage Pump Station (10' Wall)	**341.00 LF**	**2,172.86 /LF**	**740,944**
7B		**Hampton Sewage Pump Station (6' Wall)**			
		Minor Site Demolition			
	2930	Minor site demolition	326.00 lf	21.71 /lf	7,077
		Minor Site Demolition			**7,077**
		Precast Wall Panels			
	0750	Precast wall panel	2,771.00 sf	61.24 /sf	169,708
		Precast Wall Panels			**169,708**
		Excavating, Trench			
	0090	Excavating, trench or continuous footing	36.00 cy	6.53 /cy	235
		Excavating, Trench			**235**
		Sheet Piling Systems			
	1500	Sheet piling, steel, driven, left in place	4,564.00 sf	36.68 /sf	167,385
	2300	Sheet piling, Steel, for embedment	4,075.00 sf	21.75 /sf	88,615
		Sheet Piling Systems			**256,000**
		Canal Gates			
	0200	Automatic flood gate, vehicular, 15' wide	1.00 ea	108,501.03 /ea	108,501
		Canal Gates			**108,501**
		7B Hampton Sewage Pump Station (6' Wall)	**341.00 LF**	**1,588.04 /LF**	**541,521**

Analysis Assumptions

- All floodwall length estimates were made in Google Earth and are subject to measurement errors. To account for this and maintain conservative estimates, a 5% allowance was added to the length of each wall as measured from Google Earth.
- Sites are assumed to be level and to require floodwalls all around each facility to achieve the specified level of protection.
- A cantilever wall consisting of a concrete section with a sheetpile foundation is assumed.
  - This is a simple section which requires the minimum space, excavation, and concrete needs.
- There are no obstacles to driving sheetpiles at any of the sites to the depths considered.
  - This includes no fill debris, existing/abandoned utilities or foundations, or dense layers such as bedrock.
  - Local soils are assumed to be relatively loose sandy soils (beach or coastal deposits).
- All sites are easily accessible with no significant work restrictions.
- Earthwork is limited to possible excavation for placing the concrete wall sections. No site grading, cut, or fill is needed.
- No significant secondary impacts or costs are included. Such costs could include:
  - Earthwork/grading
  - Permits
  - Relocation of overhead or underground utilities
  - Wetland impacts
- The loading is assumed to be a brief duration flood.
  - The static water level rises to the heights indicated in the table provided and then recedes.
  - Dynamic loads, such as vehicle or vessel impacts, wave impacts, and seismic loads are not considered in the flood wall concept.
  - The flood event is relatively short such that long term seepage protection is not needed.
  - The wall heights are adequate for these events. Overtopping protection and scour/erosion prevention measures are not included in costs.
- Minimum depth of the sheetpile foundation is 10 feet based on industry practice
- Concept design follows AASHTO 20120 LRFD design specifications
- Material prices are 2012 prices and may change over time.
- Prices for ancillary measures, such as pumps, are not included.

Appendix 3. Sample process agenda from a NH COAST meeting.

CRE/COAST Project: Stakeholder Meeting #2 Process Agenda for NHCAW
Thursday, February 23, 2012, 6:00-8:30 pm, Hampton Falls Town Hall, NH

Meeting Objectives:

- Participants understand their community's vulnerability to coastal flooding
- Participants identify and prioritize vulnerable areas of concern
- Participants provide input on flood damage reduction options for modeling work

Time	*Objectives & Process*	*Materials*
6:00-6:15	**Welcome and Introductions (Derek)** Process: ▪ Short welcome and project overview (<u>3 minutes</u>) ▪ Meeting participants introduce themselves (name, town, why they decided to come to this meeting)	Sign in sheet, each participant given tonight's agenda and project overview handout from first meeting
6:15-6:45	**Presentation of coastal flooding and property damage maps for various storm events and sea level rise scenarios (Sam)** *Session Objective: Participants understand flood and property damage data presented in series of maps.* Process: ▪ Sam sequentially introduces scenarios by showing Cam's coastal hazard cartoon drawing and corresponding inundation maps. Sam walks group through increasingly more damaging scenarios and explains property damage cost estimates. ▪ Participants welcomed to ask questions throughout presentation ▪ Sam directs audience attention to the wall maps and explains what they show and the order of scenarios	Slideshow of maps and scenario summaries; projector; screen; laptop; laser pointer; CAW member takes notes to capture questions and discussion
6:45-6:55	**Stakeholder review of wall maps and identification of vulnerabilities at whole estuary scale** *Session Objective: Participants have a chance to examine the flooding/economic impacts on all three towns for various model scenarios* Process: Participants asked to review maps in silence except for clarifying questions to CAW members	Pencils/pens; pads of paper; printed maps on walls
6:55-7:30	**Facilitated break-out groups organized by each of the three towns** *Session Objective: Participants identify specific vulnerabilities in their town* Break-out lead facilitators: Hampton (Derek), Hampton Falls (Steve), Seabrook (Julie) – one additional CAW member per table needed to fill in vulnerability matrix table on flipchart. Process: ▪ Break-out groups formed by town ▪ Participants walk through each scenario with facilitator and note assets of concern on flipchart table ▪ Flipchart tables have pre-determined columns (roads, neighborhoods, critical facilities, environmental resources, etc.) and a few open columns for new ideas ▪ Facilitators are familiar with impacts on town assets and help highlight them for participants ▪ Facilitators can use laptop to zoom into specific areas of concern and address questions ▪ Facilitators make sure discussion stays on track (don't dwell on minutia) ▪ Facilitators will lead group to prioritize concerns into top 3 using individual sticker votes. Each participant will have 2 votes (red sticker for top concern, blue sticker for second highest priority) ▪ Facilitators will identify 1 person from each group to provide the report out to whole group	4 large-format maps (1 for each scenario) on each breakout table zoomed to town boundary scale. 1 Laptop per table loaded with Google Earth and model output layers. 1 flipchart per table, markers, easel.
7:30-7:45	**Facilitated all group review of community concerns and discussion of priorities (Julie)** *Session Objective: Participants share top town concerns with each other to inform hazard reduction strategies*	Flip chart; markers; easel; CAW member takes notes to capture questions

<table>
<tr><td></td><td>Process:
Julie will facilitate report outs from each group to share their top concerns, ask clarifying questions so that we all understand each concern, and record concern on flip chart
Julie will review the top concerns, note similarity or differences, and facilitate discussion to gain consensus on priority concerns (say 2-3) to inform next step in project – selection and modeling of adaptation strategies/actions</td><td>and discussion</td></tr>
<tr><td>7:45-
8:05</td><td>Overview presentation of potential management options (protection, accommodation, retreat, and preservation) to address coastal impacts and vulnerability (Sam)
Session Objective: Participants understand management options/philosophies available to address vulnerability concerns
Process: Sam will provide a short presentation on management options/philosophies, including examples of management actions, and economic/environmental/social tradeoffs of strategies</td><td>Powerpoint; Handout on management options and tradeoffs; CAW member takes notes to capture questions and discussion</td></tr>
<tr><td>8:05-
8:20</td><td>Individual stakeholder feedback on flood hazard reduction strategy questions. (Julie)
Session Objective: Participants individually answer a series of questions in order to guide the identification of coastal flooding hazard reduction actions to be modeled for the remainder of the study.
Process: Julie will provide directions to participants on how to fill out question sheet. Town name should be filled in at top of sheets, participant names are optional. This exercise enables participants to reflect on the top priority community concerns and provide feedback on what they believe to be the most appropriate management options to reduce hazards. Questions also gather insight on perception of risks/costs between private and public assets.</td><td>Questionnaire handouts; pencils</td></tr>
<tr><td>8:20-
8:30</td><td>Review of next steps (Derek)
Process:
Derek will summarize
progress made to date in overall project (what has been accomplished and what is left to be completed)
how tonight’s work will inform next steps for modeling actions
next meeting timeframe
Participants will be invited to share any “ah-ha” moments from the night.</td><td>Slide showing timeline/milestones for this project</td></tr>
<tr><td>8:30
pm</td><td>Adjourn</td><td></td></tr>
</table>

CITY OF PORTLAND

IN THE CITY COUNCIL

RESOLUTION SUPPORTING THE DEVELOPMENT OF A SEA-LEVEL RISE ADAPTATION PLAN.

WHEREAS, recorded data in Casco Bay indicates that sea-level rise is occurring in Portland Harbor; and

WHEREAS, international scientific theories indicate that sea-level rise is accelerating and may result in sea-level rise of an additional three to six feet over the next one hundred years; and

WHEREAS, many of Portland's economic, cultural, and ecological resources, and public infrastructure is located at low elevations at or near the shoreline; and

WHEREAS, estimated sea-level rise may cause permanent flooding of certain low elevation areas of the City; and

WHEREAS, potential permanent flooding represents an economic, cultural, ecological, and public infrastructure loss for the City; and

WHEREAS, there is community interest to understand the implications of and prepare for sea-level rise and the City Council believes it is important to understand the implications of sea-level rise; and

WHEREAS, communities around Maine, New England and throughout the world are currently grappling with sea-level rise adaptation and provide feasible models for Portland's citizens to consider; and

WHEREAS, there are financial and technical resources available to conduct a sea-level rise study;

NOW THEREFORE BE IT RESOLVED, that the Portland City Council supports the development of a sea-level rise adaptation plan; and

BE IT FURTHER RESOLVED, that a draft timetable and draft scope of work shall be developed and presented to the Energy and Environmental Sustainability Committee no later than September 1, 2011; and

BE IT FURTHER RESOLVED, that the City should seek to coordinate planning efforts with the City of South Portland, the Greater Portland Council of Governments, Southern Maine Regional Planning Commission, the New England Environmental Finance Center, and other coastal communities in Casco Bay as practical and feasible and learn from sea-level rise planning efforts already undertaken in Maine.

PORTLAND MAINE

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MEMORANDUM

To: Energy and Environmental Sustainability Committee

From: Ian Houseal, Sustainability Coordinator

Date: September 1, 2011

Re: Sea-level Rise Adaptation Plan Draft Scope of Work and Draft Timeline

On July 18, 2011 the City Council passed a resolution supporting the development of a sea-level rise adaptation plan. The resolution specified the delivery of a draft scope of work and draft timeline to the Energy and Environmental Sustainability Committee (EESC) on September 1, 2011. This memo serves as the referenced draft timeline and draft scope of work.

Draft Scope of Work

Two tasks have been scheduled to study sea-level rise adaption in Portland. The intent of the two tasks is to study sea-level rise vulnerability and begin assessing sea-level rise adaption actions. The results of these tasks will either determine that more information is needed before development of a sea-level rise adaption plan or will yield enough information to develop a plan based on the tasks. Both tasks include opportunities for public participation and feedback and will include a report. Both reports will be presented to the EESC. At the conclusion of these two tasks, an update will be provided to EESC on recommended next steps to complete an adaption plan. The two tasks include:

- Task 1: Complete a pilot study/small area study focusing on the Back Cove vicinity to be conducted by Sam Merrill of the New England Environmental Finance Center (NEEFC) looking at the financial impacts of sea-level rise on real property under a no action scenario and under certain adaptation scenarios resulting in a mapped and tabulated cost-benefit analysis of adaptive actions. This study is being conducted at no cost to the City through a grant from the Environmental Protection Agency (EPA) to NEEFC; and

- Task 2: Complete a mapping assessment of all the areas of Portland vulnerable to sea-level rise to be conducted by Peter Slovinsky of the Maine Geological Survey under certain sea-level rise scenarios. This task is being conducted at no cost to the City through a grant managed by the Greater Portland Council of Governments (GPCOG) in partnership with South Portland.

Draft Timeline

Task 1: Back Cove Study	Sea-level rise analysis on real property	October 2011
	Public meeting presenting simulation results, evaluation, and feedback	November 2011
	Report	March 2012
Task 2: Vulnerability Assessment	Mapping Assessment	October 2011
	Presentation to EESC on method, results, and evaluation	December 2011 (tentative)
Update to EESC	Discuss next steps on sea-level rise adaption plan	February 2012

PORTLAND MAINE

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Public Services Department
Michael J. Bobinsky

To: Ian Houseal, Energy and Sustainability Coordinator

From: Michael J. Bobinsky, Director of Public Services

Date: August 24, 2011

Subject: Preparing for Sea Level Rise in Design of Public Works Projects

The Energy and Sustainability Committee has asked what the current thinking is by the Department of Public Services in considering sea level rise in the design and development of capital improvement projects. The Department is developing its understanding of sea level rise and its impacts to current and future public infrastructure in the City, through training resources; communications with other partnering agencies such as MaineDOT, MTA, and DEP; and participation in a current pilot study evaluating future impacts to Back Cove and current engineering projects.

An example of a current project where sea level rise implications will be factored in includes the future storm water /CSO storage conduit planned for Baxter Boulevard impacting the Back Cove area. The Department has entered into an engineering design contract with Sebago Technics to develop the engineering and construction drawings for a new two (2) million gallon storm water and CSO storage tank to be built in the northern tier of Baxter Boulevard. The new storage conduit is associated with the current Tier II CSO abatement projects that will be designed over the next 12 months and constructed by the end of 2012.

We have asked our engineering and design consultants to factor impacts from developing information on sea level rise and its impacts to the structural integrity of the storage conduit material. Due to the nature of the tides impacting Back Cove, we understand that the new storage conduit will be under water or exposed to high water underneath Baxter Blvd and while this will be controlled somewhat with tide gates, the exterior material chosen for the storage conduit must be designed to accommodate the impacts. Our design team is presently working on that but will be providing us with a solution that best meets present and future impacts of ocean water levels in this area.

55 Portland Street Portland, Maine 04101-2921 Ph (207) 874-8801 Fax (207) 874-8816

sebagotechnics.com

One Chabot Street
P.O. Box 1339
Westbrook, Maine
04098-1339
Ph. 207-856-0277
Fax 856-2206

January 4, 2012
11293

Dr. Samuel Merrill, PhD
USM Muskie School of Public Service
P.O. Box 9300, 34 Bedford Street
Portland, ME 04104

**<u>Sea Level Rise Opinion of Costs –
Back Bay Levee & Storm Surge Barrier at Tukey's Bridge</u>**

Dear Mr. Merrill:

Thank you for the opportunity to assist the USM Muskie School of Public Service in your assessment of sea level rise in the Back Bay area of Portland. As part of your efforts to assess the impacts of sea level in Portland, Sebago Technics, Inc. was retained to prepare an opinion of potential costs to construct a Levee System around Back Bay and a Storm Surge Barrier at Tukey's Bridge. The following summary of findings provides the results of our cost assessments for consideration in your work.

A. Project Background and Introduction:

The Muskie School of Public Services is conducting a social-economic impact study of sea level rise to the Portland waterfront. The study includes an assessment of potential costs to mitigate the impacts of sea level rise in Back Bay. Sebago Technics has been retained to assist with developing a potential cost and improvement scenario within the Back Bay area of Portland. The "opinion of costs" is intended to represent a potential order of magnitude for planning purposes based upon limited conceptual planning.

If the project were to be undertaken, a more formal process with multiple stages would be required beginning with an Environmental Impact Statement (EIS) and schematic project design well beyond the scope of our work. There are many variables that will impact a project of this type to include but not limited to regulatory requirements, environmental impacts, public interaction and political will, program objectives, physical investigations, advances in technology, types of construction chosen and future value of money affecting project costs. The individual or collective nature of each variable can have significant effects on the ultimate approach chosen and project costs.

B. Assessment and Evaluation Parameters:

1. ***Sea Level Rise Expectations:*** The following provides a tabulated summary of low and high predications based upon information provided to Sebago Technics from the USM Muskie School of Public Service:

Sea Level & Storm Surge Rise Summary

	Sea Level Rise – Low Estimate (Feet & Elevation)	Sea Level Rise – High Estimate (Feet & Elevation)	Storm Surge – 50 Year Recurrence Interval (Low - High Est.)	Storm Surge – 100 Year Recurrence Interval (Low – High Est.)
Year 2050	.98' (6.38)	2.46' (7.20)	(12.02 – 12.84)	(12.90-13.72)
Year 2100	1.8' (7.85)	5.91' (11.30)	(13.53 – 16.97)	(14.41-17.86)

( ) indicate water surface elevation in feet –NGVD 29

2. ***Levee Parameters:*** Two scenarios where considered for establishing a top of levee as follows:

   A. Mean Higher High Water (MHHW) plus sea level rise for the year 2050. We assumed the most conservative sea level rise elevation of 7.20.'

   B. Mean Higher High Water (MHHW) plus sea level rise for the year 2100. We assumed the most conservative sea level rise elevation of 11.30.'

   * Mean Higher High Water (MHHW): A tidal datum. The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

   The levee system considered under this assessment includes expanding on the current Back Bay shoreline to create an elevated earth embankment to address sea level rise. The earth embankment would extend from the current esplanade along Baxter Boulevard and adjacent areas inward to Back Bay (See attached section). It is important to note this option would have a substantive impact on the Back Bay estuary to accommodate the extension of a new fill slope associated with the levee.

   While environmental impacts are expected, this approach strives to recognize the potentially greater impacts required modify or change grade elevations at Baxter Boulevard, construct new public infrastructure and the impacts to the adjacent developed properties. It should be noted this assessment does not address impacts of sea level rise on the City sewer and storm sewer systems which will be hydraulically affected from sea level rise. An assessment of this magnitude is beyond the scope of our work but will need to be a City consideration potentially requiring installation of tide gates or pumping stations.

3. ***Storm Surge Barrier:*** Since the inner cove area Levee system is intended to only accommodate the MHHW, a secondary means of wave and surge protection is required for the 50 and 100 year storm recurrence intervals. The technology continues to develop for storm surge barriers to include vertical lifting gates, inflatable dams, radial gates, floating sector gates, hinged flap gates, etc. For the purposes of this assessment, a limited review of constructed barriers was completed and a comparative cost assessed for the value of a barrier at Tukey's Bridge.

Cost Assessment Findings:

1. ***Year 2050 condition:*** The Back Bay area of Portland has elevations (NGVD 29) ranging from a low of 6 - 8 feet to 12 feet along the majority of the Baxter Boulevard. The I-295 corridor increases in elevation from 12 to 40 feet. Within the bay, the predicted MHHW surface elevation (6.38 – 7.2) feet for year 2050 is generally lower than the existing roadway and trail system around Back Bay. The exception is the playfield located along the easterly side of Back Bay which has an elevational range of 6 to 8 feet. As a result, this area is at risk from inundation due to sea level rise.

   As shown in the attached Exhibit (Labeled Year 2050 Condition), a levee berm is recommended around this section of Back Bay. The levee is estimated at approximately 1,600 linear feet and will need to blend into the higher elevations at each of the levee. We anticipate the top of levee elevation to be elevation 14.0 including an allowance for freeboard above the maximum expected sea level elevation. This elevation would also allow the berm to match the predicted year 2100 sea level rise elevation requiring no future modification or reconstruction.

   Since the levee system is only intended to accommodate MHHW with sea level rise, a supplemental system will be needed to accommodate storm surge and flooding events. Tukey's Bridge is the point of control for Back Bay and provides and opportunity to consider a storm surge barrier at this location. The storm surge barrier needs to allow for navigation in and out of the bay and to establish a barrier meeting the expected surge height for a 100 year or greater event. We have assumed the barrier will be constructed to accommodate storm surge in the year 2100 to avoid future costs of construction or structure replacement.

2. ***Year 2100 Condition:*** Within the Bay, the predicted MHHW surface elevation for year 2100 will range between a low of 7.85 feet and 11.3 feet. At the higher prediction, a levee system will be needed around the entire cove as shown on the attached exhibit, labled "Year 2100 Condition." The levee is estimated at approximately 3,300 total linear feet and will need to blend into the higher elevations at each end Tukey's Bridge. We anticipate the top of levee elevation to be elevation 14.0 including an allowance for freeboard above the maximum expected elevation.

In-circling the Back Bay with a levee will present a number of design considerations to include relocating the trail system, landscaping and visual character, lighting transitions to street level, environmental impacts and regulatory permitting. Although not reviewed as part of this assessment, the undertaking of an EIS will most likely require considerations of a constructed wall system which typically reduces environmental impacts due to a small footprint. A wall system (while creating less environmental impacts) would most likely be as or more expensive and present some adverse aesthetics.

It is assumed the storm surge barrier will be constructed as part of the 2050 program and therefore costs are assumed to have been incurred during the 2050 condition.

Opinion of Potential Project Costs

	YEAR 2050 EXPENDITURE	YEAR 2100 ADDITIONAL EXPENDITURE
EIS & Preliminary Planning	$1,500,000	$750,000
Design & Construction Management	$25,500,750	$2,218,750
Levee System	$3,507,500.00	$21,437,500
Storm Surge Barrier	$250,000,000	$0
Total	$280,508,250	$24,406,250

*Estimated costs are in 2011 dollars.

Closure:

This conceptual level evaluation is based upon a limited assessment and is intended to provide a generalized evaluation of one potential alternative to address level rise within the Back Bay area of Portland. No field investigations or design work was completed in conjunction with this assessment. As part of a comprehensive EIS and planning study, a more substantive evaluation would be completed to identify design alternatives; conduct field assessments evaluate overall impacts, include public participation and develop tailored cost estimates to each alternative.

On behalf of Sebago Technics, we have appreciated the opportunity to participate in this social-economic planning study for sea level rise impacts in Portland. Best wishes as you complete your work.

Sincerely,

SEBAGO TECHNICS, INC.

STATE OF MAINE
OWENS
A.
McCULLOUGH
No. 7122
LICENSED
PROFESSIONAL ENGINEER

Owens A. McCullough, P.E., LEED-AP
Vice President, Engineering/Project Development

OAM:oam/kn

Appendix 5. Rough cost estimates and preliminary engineering report for a surge barrier and levee complex in Portland, Maine (Sebago Technics).

Sebago Technics
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One Chabot Street
P.O. Box 1339
Westbrook, Maine
04098-1339
Ph. 207-856-0277
Fax 856-2206

January 4, 2012
11293

Dr. Samuel Merrill, PhD
USM Muskie School of Public Service
P.O. Box 9300, 34 Bedford Street
Portland, ME 04104

Sea Level Rise Opinion of Costs –
Back Bay Levee & Storm Surge Barrier at Tukey's Bridge

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On behalf of Sebago Technics, we have appreciated the opportunity to participate in this social-economic planning study for sea level rise impacts in Portland. Best wishes as you complete your work.

Sincerely,

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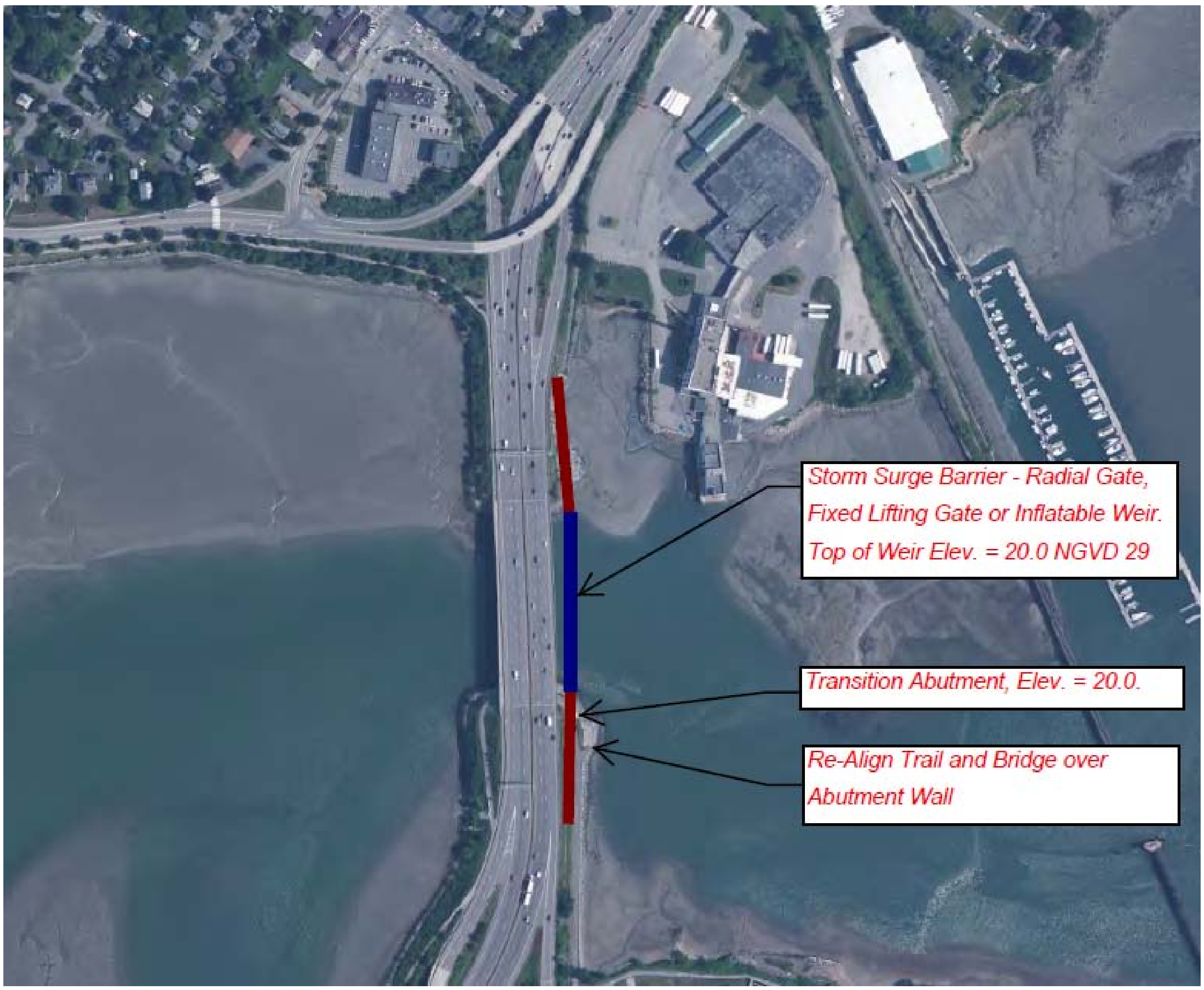
PROFESSIONAL ENGINEER

Owens A. McCullough, P.E., LEED-AP
Vice President, Engineering/Project Development

OAM:oam/kn

Schematic representation of a levee complex tentatively designed and costed by Sebago Technics, Inc., as a protection against damage from SLR.

Schematic representation of a hurricane barrier tentatively designed and costed by Sebago Technics, Inc., as a protection against damage from storm surge.



Appendix 6. Summary notes from a COAST public meeting in Maine.

Sea Level Rise Public Discussion in Portland, Maine held February 24, 2012
Summary from break out groups
Prepared by Sadie Lloyd

Group 1, Room 205, question 1
Initially there was a lot of uncertainty among the participants in group 1. There was preliminary discussion about what the four approaches to addressing sea level and storm surge inundation were that some of the other groups did not require. There was also a fairly high level of resistance to answering the questions at first because of the challenge the group had with understanding the concepts. It was clear that this was the first time many of the group members had been introduced to the information that had been presented prior to the break-out sessions. It may have been helpful for them to have been part of a preliminary conversation where they could have asked more broad questions about the data and implications of sea level rise and storm surge. Eventually, the group was able to move on to the first question.

The discussion for question 1 included a wide range of opinions. All of the approaches were suggested as potential responses to sea level rise/storm surge in the Bayside neighborhood, with the exception of “do nothing”. The approaches most commonly brought up were accommodate (soft approaches), followed by fortify, and then abandon/relocate. Some people felt certain approaches should not be up for consideration, like abandonment. There was some agreement that going forward there should be no new development in Bayside. Twice it was brought up that regulations would have to be used to direct development, and that current regulations would need to be adapted. Someone pointed out the need to address infrastructure, and multiple people talked about the need for adaptability over time.

Collectively the group landed on a mixture of approaches. They felt that timing was an important factor, and which approach taken would be dependent on a timeline; not all approaches would be appropriate at any given time. For example, accommodation might make more sense in the immediate to near-term, but as 2100 gets closer, when storm inundation is more severe, relocating could be the reasonable response.

Group 1, Room 205, question 2
The discussion about who was responsible for implementing a response was similar to question 1. The ideas that came out included a diverse group of stakeholders. Some felt that FEMA had responsibility because of their current role in flood hazard planning, but that if left up to them there would be no approach. Other people suggested city government was responsible as well as insurance companies and banks because of their role in enabling development to happen, the private sector operating and developing in the Bayside neighborhood, and even the community and general public. The group then talked through what the current role of each of these groups was.

This question led the group to discuss some bigger issues they were thinking about. In particular, they talked about education and that local government should use events that have already happened (like the Patriots Day Storm) to highlight the need for action. This might include something like a media campaign. It was suggested that the City/community could not afford to stay and fortify, so which approach was taken might affect responsibility. One of the group

members made the point that who they *wanted* to be responsible was not necessarily the most effective solution. Some felt that the variability of the data had an impact on what to do and who was responsible; the most extreme situation would potentially call for a different set of actions and players than the least extreme.

Ultimately, the group decided that responding to sea level rise/storm surge would take a public/private/community partnership in part because a group approach would save money, and because those who had a stake should have responsibility. The City had a responsibility for infrastructure and private owners were responsible for their own properties. While it was unclear what the community was responsible for specifically, the group felt they should have some role because it is their neighborhood.

Group 1, Room 205, question 3

The discussion moved to how a response should be implemented and someone suggested having a TIF district in Bayside that would apply to vulnerable properties. Some implementation required a government response, which might include regulations on buildings. It was the opinion of some that the government wouldn't pay and so the community needed to push for policy to be formulated and for the funds to implement the chosen response. Discussion then moved to management of utilities and infrastructure and the responsibility of relevant parties to manage those. The group questioned whether the saved properties would generate enough income to justify protecting them (the issue of affordability), which led to tax equity and beneficiary questions.

Some felt, because of the role insurance companies are already playing in building accommodations, that they would be the leader in implementing approaches. Some felt it was difficult to determine how implementation should occur before an approach was selected and who was responsible had been established. Despite the range of topics that came up the group did conclude that the City should lead and manage any implementation but with local collaboration of public and private stakeholders (including tax payers and utilities).

Group 2, Room 203, question 1

This group felt that private property should not be looked at separately from other assets like infrastructure, and that the City should look at all of the vulnerable assets together because they are connected. As an example, it was pointed out that the new stormwater storage tanks that will be installed under Baxter Boulevard could be inundated by sea level rise and/or storm surge, which could potentially impact homeowners.

Someone voiced support for a "Portland of the future" and the need to approach this as a long-term planning project that considers 25, 50, and 100 years out, acknowledging that what will be important at those times may differ. Down the line the City and community may look back and wish they had made decisions now.

There was a lot of discussion in this break out room about relocation. They felt that now was the time to identify properties most at risk and the possibility of incentivizing relocation for those property owners. In this buy out/financial incentive to retreat model the best financial deals

would be given to those who left earlier. This was seen as a short-term model. Additionally, it was suggested that zoning be adjusted to prohibit new construction in the flood zone.

One person saw Maine (and even Portland) as a place that still had a lot of space to build on in non-vulnerable areas, further justifying retreating and relocating. In regards to property/assets with the highest value (historic, aesthetic, recreational) the group thought fortification was appropriate to consider. Accommodation was considered for recreational purposes only around Back Cove, where a landscape like wetlands could absorb sea water, and Baxter Boulevard re-engineered to allow recreation but not motorists. There was skepticism about hard fortification and a preference to avoid it. They discussed elevated construction and the possibility, as well as the consequences, of building on stilts. They came back to the point about infrastructure though, and that despite different building standards there were still things like sewer and roads that would need to be considered.

In summary, for the question of which of the four approaches should be considered, group 2 generally agreed that a mix of approaches was needed depending on the time frame. Which asset was being looked at would determine which approach would be taken. They felt relocation was key in the short term with soft fortification (especially of most valuable and vulnerable assets) also playing a role. They felt strongly that the City needed to take a long-term planning approach.

Group 2, Room 203, question 2
While discussing who was responsible for implementing a response, group 2 specifically called out private citizens, municipal government, and the local community. The municipal government would be interested in protecting its tax base, and the State will have a strong interest in protecting the City. They pointed out that certain responses (like building a hurricane barrier under Tukey's Bridge) will involve substantial regulatory review at the local, state, and federal level (including players like DEP, Army Corps, and FEMA). While they felt it was unlikely the City could get money from the State or Feds, they believed that cost-sharing should be part of adaptation planning and response. It was pointed out that bankers and insurers would have an influence whether they were asked to or not.

Group 2 felt that ultimately the public was responsible for public health and welfare, and that the City (with public input) was responsible for developing and implementing an adaptation plan. They thought that banks and insurance companies would "drive the ship", and because help from the State and Feds was unlikely, it would take local action.

Group 2, Room 203, question 3
In order for the City to implement a response the group concluded that the City needed to first do an overall adaptation plan because of the numerous variables at play. They again pointed out the need for mixed approaches as well as incremental approaches that would allow the City to adapt over time, because things would keep changing. Similarly to question two, this group felt that banks and insurers would lead the way and beat government planning to a response. They questioned whether the state could help somehow. Part of the implementation would be regulatory (like having building restrictions in flood zones) as well as incentives for things like elevating structures and relocation. Someone commented that there was not currently money in

the City planning budget for adaptation planning or implementing responses, and so the first step was to develop line items. They also talked about the problem of people not seeing sea level rise as an issue.

In summary the group wanted to see mixed approaches incrementally implemented. Public process should determine specific implementation steps. Implementation would likely include financial and other incentives, regulation, and education, with possible cost-sharing strategies with State and Federal funds.

Group 3, Room 211, question 1
Right away group 3 established their belief that sea level rise trends would continue past 2100, and acknowledged the possibility of learning in a year or two that future sea level would be higher than expected. They questioned whether there was a single correct response or if it would take an array of strategies. They felt there were a number of needs that once addressed would better inform which approach to take. They felt hazard maps that clearly showed where and what the risks were would be important going forward. These maps would hopefully be developed with the Feds and FEMA. Once an agreement was reached on the risks then the maps could be developed and the planning process started.

There were differing opinions on which approach to take. They indicated the possibility that zoning and land use changes were needed. Someone questioned if bayside should just be filled again, and some wondered if any action should be taken at all but instead let people do what they want and abandon when the time comes. Those representing the design community were much more passive to hard engineering approaches. The group felt fortification was appropriate in the short-term, with the possibility of including accommodation, although appropriate timing was questioned. Specific responses were suggested, like raising the trail around Back Cove and prohibiting certain land uses and creating adaptation tools through ordinances and regulation. The importance of flexibility and adaptability came up numerous times. While softer approaches were considered to be ok in the short term, continued adaptation would be key in the long-term. Likewise, ongoing education while land is developed and redeveloped would inform a continual learning process.

Some of the concerns this group discussed were whether it was possible to defend filled land (due to the geological uncertainty of filled land) and what types of engineering challenges this might pose, as well as unintended consequences that could result from blocking water in one place. They wondered if the private sector would have expectations of the public sector in terms of protection.

In summary, the group agreed that the correct approach would be multi-faceted and iterative to accommodate a range of sea level rise/ storm surge events over time, involving education, policy, and infrastructure.

Group 3, Room 211, question 2
The group grappled with some big questions during this part of the discussion. A lot revolved around the question of who was responsible in general, and whether the City was responsible for protecting private development in Bayside, and who can make the decision that land cannot be

further developed (who champions public good over public interest). More overarching questions were: who are we as a community? How do we choose what to protect in that context?

Delving further into the question of who is responsible there was agreement that those receiving the benefits of any approach taken, like those developing in low lying areas, should contribute towards protection costs, such as having a premium to build in a hazard zone. There was a fair amount of discussion about the insurance industry and whether current requirements are aggressive enough. They saw that insurance companies are already requiring development to adapt, but wondered what their long-term interest was and if they are involved in addressing the risks with 20, 40, 60 year models.

Group 3 felt the City should take the lead but that there would be some public/private relationship involved. They felt that because regulation had not caught up with science, the government was responsible for the education needed and that it could be a mechanism to keep a dialogue going as decisions are made now. They believed that current regulations were based on information that was no longer accurate, and people with knowledge needed to go into neighborhoods.

This group summarized that the local community would be the driver at the grass roots level to begin the process and the government would follow and be a part of a mixed partnership. They felt that education and knowledge sharing was important among private development firms, the design community, higher education and research institutions, and all levels of government. Lastly, they added that the development community has a responsibility for the development of resilient public infrastructure because it protects or enhances their resilient public investment.

Group 3, Room 211, question 3

In addressing how a response should be implemented the group voiced concern that because the development community is not looking long-term there is a disconnect with development and what the sea level/storm surge data is telling us. They felt that hazards such as unstable soils may need a regulatory approach and that any response should be implemented carefully by various entities depending on which approach is taken. Any response would take a synthesis of financial, regulatory, and managed approaches.

The group then talked about risk. They believed that gradations of hazard would need to be identified, and then information created and disseminated about risk levels so that they could be better understood. Additionally they felt a hazard map should be created for educational purposes, assuming that better information would lead to better decisions. In summary, group 3 saw the first step to implementing a response as developing and disseminating hazard maps.

Group 4, question 1

This group was less concerned about education and information regarding sea level rise and were more politically oriented. They talked through and saw room for various approaches, but felt that fortifying assets and accommodating more water were the most practical, where as doing nothing and relocating were more problematic. It was suggested that there is the desire and purpose in developing urban spaces like Bayside. Some in group 4 felt that 75% of the problem Bayside is now (and would be) facing was poor planning, and when considering doing nothing as an

approach wondered whether neighborhoods could survive without taking action. Seeing abandonment of Bayside as a poor option, accommodation was preferred through actions like elevating roadways (and other infrastructure) and buildings. The engineers' perspective was seen as preference for fortification, like a surge gate. They acknowledged this appeal but felt accommodation would be a better long-term approach. They felt it was important to consider infrastructure across entire communities rather than by individual properties.

The tipping point was a concept of discussion that would necessitate the needs for strategies that would change over time. This group came to the conclusion that a dynamic approach would focus on fortification and accommodation because they were the most amenable. They believed relocation to be inconsistent with other policy goals and doing nothing was not "smart". Fortification and accommodation would need to happen at various times and be location specific.

Group 4, question 2

Determining who was responsible for implementing a response brought up a number of ideas. Some felt the City had a role, with the help of financial and insurance institutions, to force developers to bear adaptation costs. Others felt that zoning needed to be consistent and address infrastructure needs, where costs would be balanced between the developer and the City. This led to the suggestion of a private/public partnership and the notion that joint responsibility was critical. They questioned whose responsibility it was to initiate a cooperative relationship and/or dialogue. Regardless, cooperation would be required of the City, developers, and insurance companies. More broadly, they thought cooperation should include parties that can provide expertise and perspective, including architects, engineers, the real estate industry, and neighbors.

They saw the potential for planning and regulations to be informed through engagement with the development community to assess economic/market feasibility to absorb costs on a per project (or building) basis, versus fortifying public infrastructure on an area basis. It was acknowledged however, that meshing project by project accommodation strategies with existing conditions was a complex problem. The group questioned how evaluative judgments would be made, by whom, with whose input and engagement, thinking ultimately that it would be a complex decision process to reflect dynamic response strategies.

On a less specific scale someone brought up the fact that people are resistant to change/relocating and prefer to be on the coast and in urban areas. More specifically, there was concern for who would help those already in vulnerable areas. Some felt it was time to revisit planning costs for Bayside and Back Cove through a community engagement process like the Bayside charrette held in 2000. One participant thought that Bayside already had a TIF district and perhaps it could be targeted to adaptation costs for infrastructure or building costs.

Lastly, many felt Bayside should be seen as a super-regional resource with its importance to the state as a whole considered. They saw the possibility to put responsibility in the hands of a voluntary cooperative group that would include all levels of government. Some, but not all, felt that the City had a role in structuring a regional financial framework to capture a broad range of beneficiaries.

Group 4, question 3

Group 4 felt that any implemented response needed to consider the appropriate scale (regional, watershed, or estuarine systems, for example). Suggestions for implementation included:

- a tool kit with the combination of a TIF program and zoning to set physical building parameters, restrictions, and design implications
- an overlay district with a form based code approach to provide clarity to developers with costs offset by a TIF
- zoning to phase out buildings (and begin relocation) over time
- form based codes to allow buildings to accommodate sea level rise over time
- statewide financing mechanism (like a transfer or gas tax) for multiple communities to draw from
- not using form based code, but other, less rigid regulatory programs

One participant talked about the high percentage of Maine’s economy generated by the Greater Portland region, and if this area experiences substantial economic loss (including development potential), there will be economic impacts to the State as a whole. That being said, it was mentioned that a statewide effort would not sell if it was perceived as only benefiting Portland.

While the group could not reach consensus on how accommodation and fortification would be implemented, they felt it would take some combination of regulations, with financing from Federal, State, local, and private parties. They saw a dynamic investment strategy that would evolve based on the value of economic assets (over time) with justification for investment based on derived community wide value.