Testimony for the US Senate Committee on Homeland Security and Governmental Affairs
"Extreme Weather Events: The Costs of Not Being Prepared"

Wednesday, February 12, 2014

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I appreciate this opportunity to come before this Committee in regard to the benefits of cities being prepared to manage present extreme climate impacts and the increasing threats in the future due to climate change. I have been conducting research and consulting on how to manage the impacts of the changing climate on New England infrastructure for 15 years. Over that time, I have conducted several studies on the long-term economic consequences of cities being impacted by 1) extreme amounts of precipitation occurring during storms and 2) coastal flooding from coastal storm surges during hurricanes (tropical storms) and winter storms (extra-tropical storms, known locally as nor'easters). Here I compare the long-term costs of not being prepared for these present and future threatening events to the benefits of being prepared. Because of the changing climate, climate change impacts on extreme events are part of the analyses. The costs I present may actually underestimate the actual damage costs because these types of costs are not included in the analyses; human deaths and injury; damages to ecosystems and the services they provide (and upon which infrastructure depends such as the flood and water quality mitigation values of coastal wetlands); and indirect costs such as lost employment and business activities, and community displacement and disruption.

Metropolitan Boston and Coastal Flooding: With funding from the US EPA over the period from 1999 to 2004, my colleagues and I investigated integrated adaptation strategies for metro Boston (Kirshen et al, 2008a). The study area shown in Figure 1 was divided into 7 subareas or zones, of which Zones 1 through 4 are directly coastal. When this research was done in the late 1990s, less data were available for these types of studies than exist now (eg, very accurate elevation data was not available), but the results are still representative of the costs. While in reality in every zone there would be a mix of adaptations actions taken in different locations and time periods (Kirshen et al, 2014), we assumed that in each zone only one adaptation action could be taken. Details of the methodology and results are in Kirshen et al (2008b). For each zone we determined a reasonable adaptation action from the choices of:

- No Action: taking no actions and rebuilding after each damaging event.

- Protection: construction of a barrier to lessen the impacts of the climate changes, such as a seawall to protect against more coastal flooding.

- Accommodation: allowing the impacts to occur but attempting to lessen them by taking specific actions. Examples of accommodation actions are flood proofing, flood evacuation, elevating buildings, and purchasing insurance.

- Retreat: moving away from the impact. An example of retreat is leaving a floodplain.

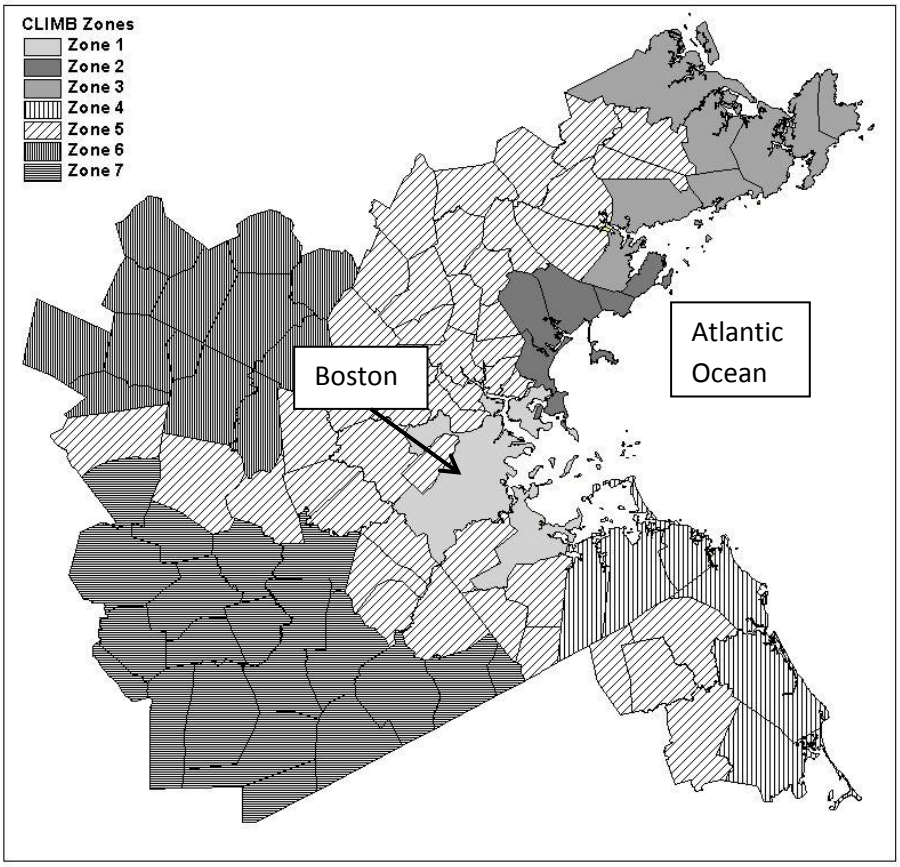

Figure 1. Planning Zones for Metro Boston used in Kirshen et al (2008a)

Using Monte Carlo simulation, we then determined total damages from surge flooding to residential, commercial and industrial buildings over the next 100 years assuming sea level rises (SLR) of both 0.6 m (approximately 2 feet) and 1.0 m (just over 3 feet) with and without adaptation being taken. In the late 1990s, these SLR projections were considered plausible ranges. The US National Climate Assessment now considers both to be at the low end of the plausible range in 2100 (Parrish et al, 2012). Thus these results underestimate the costs of damage due to SLR.

The results are in Table 1 for both SLR scenarios. Column 3 is the total damage and emergency costs over this time period assuming no actions are taken. Column 4 is total adaptation costs when adaptation is undertaken. Column 5 is the cost of the damages that occur even though adaptation has been undertaken, so-called residual damages. Column 6 is the benefit of taking adaptation measured by the costs avoided by undertaking adaptation, which is calculated as the difference of Columns 3 and 5. Column 7 is the ratio of Column 6 to Column 4.

(1) Location	(2) Reasonable Adaptation Action	(3) Expected Value Total Damages from 2000 to 2100 taking No Action ($ billion)	(4) Expected Value Total Costs of Adaptation ($ billion)	(5) Residual Damages ($ Billion)	(6) Expected Value Total Costs Avoided (benefit) ($ billion	(7) Benefit: Cost Ratio
		1.0 M SLR	**By 2100**			
Zone 1, South Urban (essentially Boston and Quincy)	Protection	14.9	0.4	2.0	12.9	32.9
Zone 2, North Urban	Protection	7.8	0.5	1.2	6.6	13.1
Zone 3, North Suburban	Accommodation	6.2	0.5	1.2	5.0	10.0
Zone 4, South Suburban	Accommodation	5.7	0.4	1.2	4.5	12.7
		0.6 M SLR	**By 2100**			
Zone 1, South Urban (essentially Boston and Quincy)	Protection	7.8	0.4	2.2	5.6	14.3
Zone 2, North Urban	Protection	4.5	0.5	1.3	3.2	6.4
Zone 3, North Suburban	Accommodation	3.4	0.3	0.7	2.7	9.6
Zone 4, South Suburban	Accommodation	3.4	0.3	0.7	2.7	10.4

Table1. Benefits and Costs of Adaptation in Metro Boston

As expected, a protection approach is favored in heavily urbanized Zones 1 and 2 to protect valuable, densely built-up areas. Flood proofing, elevating buildings, and other accommodation actions are reasonable for less developed areas. In all cases, the benefit-cost ratios are greater than 1.0. In fact, the benefits of adaptation are particularly positive for very developed areas. The benefit: cost ratios are less under the 0.6 m SLR because the damages are less while adaptation costs do not change as much. The residual damages to Zones 1 and 2 are slightly greater under the 0.6 m SLR scenario than the 1.0 m scenario because the algorithm requires adaptation to take place after the first storm that is greater than the present 100 Year storm occurs. The first 100 Year storm in the 0.6 m SLR scenario occurs later than in the 1.0 m SLR scenario; thus more residual damage can occur in the 0.6 m scenario before adaptation occurs.

In none of the scenarios is taking No Action the more reasonable action in terms of costs.

Hampton-Seabrook-Hampton Fall NH and Coastal Flooding. These three towns are located on the NH coast as in Figure 2. All the towns have many second homes, but particularly

Hampton and Seabrook on the barrier beach. Under a grant from the US EPA, we examined the benefits and costs of protecting privately owned buildings (i.e., homes and commercial facilities) and key public assets (e.g., sewage treatment plants, schools, fire and police stations) from present and future coastal storms (Merrill et al, 2012). We developed adaptation plans to protect to 2050 under low and high SLR scenarios of approximately one feet to two feet. To protect public assets, we estimated threshold elevations at which they will be impacted by flooding. Adaptation using flood walls is undertaken when the 100 year flood equals or exceeds the threshold elevation. We determined the possible time of this occurring under both high and low SLR scenarios. We assume the current trajectory of SLR is known and that the adaptation action will be taken just before the threshold is exceeded. 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.

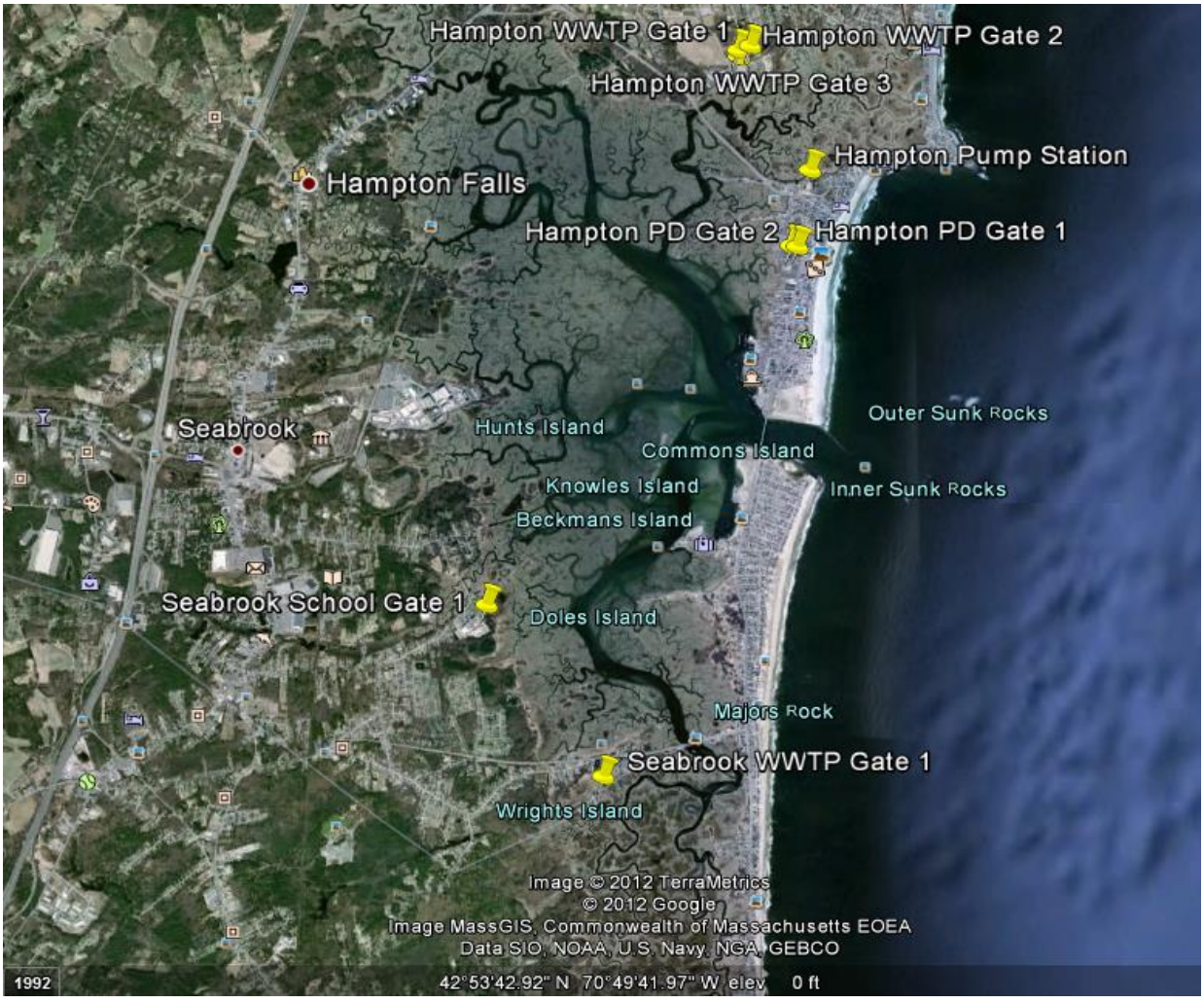

Figure 2. Hampton-Seabrook- Hampton Fall NH

For modeling adaptation actions for private assets, it was assumed these properties will be proactively protected by flood proofing to the 2100 100 Year flood level according to a

regulation that states if a building is damaged by a flood, it must protect to the 2100 100 Year flood level when rebuilt. We assumed two possible adaptation actions here. The first is that they are required to adapt to the 2100 flood level assuming high SLR. The second is that they are required to adapt to the 2100 flood level assuming low SLR. In either case, since this regulation is being implemented as floods occur, regulators do not know what the future may be. Therefore, we modeled all the possible outcomes. Under the high and low SLR scenarios, we determined the costs of adaptation and compared them to the discounted expected value of the damages avoided by adaptation. With the high SLR regulation, the region would also be protected against the low SLR scenario occurring, but extra adaptation costs would have been incurred. With the low SLR regulation, if high SLR actually occurs, then residual damages will result. The results for Hampton are in Table 2.

Scenario	**Adaptation Option**	**Expected Value Total Discounted Damages from 2010 to 2050 taking No Action ($ million)**	**Expected Value Total Discounted Costs of Adaptation ($ million)**	**Residual Discounted Damages ($ million)**	**Expected Value Total Discounted Costs Avoided (benefit) ($ million)**	**Benefit: Cost Ratio**
		Critical Public Assets				
High SLR	Protect to 2100	82.7	7.1	0	82.7	11.6
Low SLR	Protect to 2100	78.8	4.9	0	78.8	16.1
		Private Assets				
High SLR	Protect to High SLR 2100 Flood by Regulation	318.8	40.5	0	318.8	7.9
Low SLR	Protect to High SLR 2100 Flood by Regulation	287.7	40.5	0	287.8	7.1
High SLR	Protect to Low SLR 2100 Flood by Regulation	318.8	36.0	31.1	287.7	8.0
Low SLR	Protect to Low SLR 2100 Flood by Regulation	287.7	36.0	0	287.8	8.0

Table 2. Critical Public Assets, Hampton NH.

As can be seen, no matter what combination of SLR scenarios and adaptation actions, the benefit-cost ratios are greater than one. They are particularly large for protecting the expensive public assets from extreme events. Similar results were found for Hampton Falls and Seabrook.

Somerville MA and Stormwater. With a 2010 population of 75,754 over an area of approximately 11 square kilometers, Somerville MA is the most densely populated municipality in New England (see Figure 3). The city is highly urbanized, almost completely built-out, and

has limited open space. Our case study site was the Winter Hill neighborhood and the commercial Assembly Square area, which are serviced by a combined sewer system that carries both stormwater and sanitary waste. Presently, the system has the capacity to handle all the wastewater flow but can only handle additional storm flows resulting from small storms. When larger storms occur, some of the extra combined sewage is treated at the regional Deer Island Wastewater Treatment Plant, some of the combined waste is discharged partially-treated into the nearby tidal Mystic River, and there is flooding in streets with untreated sewage. In this project funded by US NOAA, we investigated the performance of several alternative strategies to manage the stormwater under present and future climates (Kirshen, et al, 2014). We developed plausible scenarios of increases in extreme precipitation by storm frequencies between the 2010 and 2070 and also for sea level rise in the Mystic River, which impacts the drainage capacity of the drainage network. We determined the expected present value discounted costs to the community of extra treatment costs at Deer Island, treating and discharging sewage into the Mystic River, and street flooding if no actions were taken now or in the future to respond to the impacts of increased storm precipitation and less drainage capacity due to higher sea levels. We found that separation of the presently combined system into separate storm and sanitary sewers was the most reasonable approach among the alternatives. The costs and benefits of this approach are in Table 3.

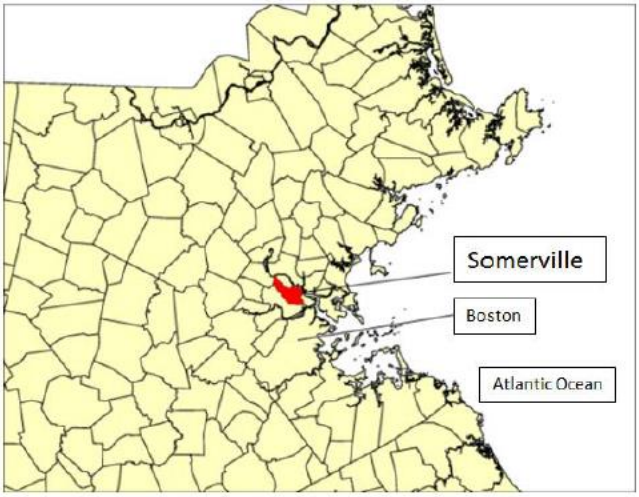

Figure 3: Location of Somerville MA

Climate Change and SLR Scenario	Total Expected Present Value Total Discounted Costs from 2010 to 2070 taking No Action ($million)	Total Expected Present Value Discounted Cost of Sewer Separation ($ million)	Total Expected Present Value Discounted Residual Damages ($ million)	Total Expected Present Value Total Discounted Costs Avoided (Benefit) ($ million)	6) Benefit: Cost Ratio
Low	746.2	191.2	-6.0	752.2	3.9
Moderate	756.2	191.2	-5.8	762.0	4.0
High	769.1	191.2	-5.6	774.7	4.1

Table 3. Benefits and Costs of Sewer Separation in Winter Hill, Somerville MA, 2010-2070

The benefit-cost ratio is positive here over a plausible range of climate change scenarios; again indicating the value of undertaking adaptation to extreme events rather than just bearing the consequences.

Reaping the Benefits of Adaptation to Extreme Events and Climate Change. I have summarized some of my recent research on the benefits of adaptation to climate change compared to the costs of damages. Even with not all the damage costs included, in all the examples under a range of climate change and SLR scenarios investing in adaptation paid off in terms of damages avoided. Undertaking no adaptation was never the most reasonable action in terms of costs. With the benefit-cost ratios so high, these adaptation actions are probably beneficial even without climate change (i.e., no regrets actions). In order for a community, an industrial facility, or a military base to avoid the serious consequences of climate change and obtain these benefits, an adaptation planning process must be carried out now. This does not mean that the construction of all adaptation actions must be done now. Rather, as has been modeled in these examples, if an asset is not presently threatened by extreme events, the adaptation action can be under taken in the future when the threat is more evident. The key is to plan for the future now so adaptation actions can be reserved for the future, implemented when needed, and decisions are not taken now that make hinder the implementation of an action in the future. It may also be possible to implement infrastructure adaptation actions when the infrastructure is scheduled for regular rebuilding. Adaptation plans can also be implemented as zoning and master plans are updated. Such actions can help lower the costs of adaptation. A good summary of adaptation planning is in Kirshen et al (2014) and in Rosner et al (2014).

Thank you for this opportunity and I am glad to take any questions or comments.

References

Kirshen, P., Ruth. M., and Anderson, W., Interdependencies of Urban Climate Change Impacts and Adaptation Strategies: A Case Study of Metropolitan Boston USA, Climatic Change, 86:105-122, January, 2008a.

Kirshen, P.H., Knee, K., Ruth, M., Adaptation to Sea Level Rise in Metro Boston, Climatic Change, 90(4), pages 453-473, October 2008b.

Kirshen, P., Caputo, L., Vogel, R., Rosner, A., and Mathisen, P., Urban Drainage Adaptation Planning, accepted with revisions, Journal of Water Resources Planning and Management, 2014.

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

Parris, A., et al, Global Sea Level Rise Scenarios for the US National Climate Assessment, NOAA Technical Report OAR CPO-1, December 6, 2012.

Rosner, A., Vogel, R,. and Kirshen, P., A Risk-Based Approach to Flood Management Decisions in a Nonstationary World, accepted with revisions, Water Resources Research, 2014.