Executive Summary

Climate change is the greatest environmental challenge of this generation, with potentially profound effects on the economy, public health, water resources, infrastructure, coastal resources, energy demand, natural features, and recreation. The Commonwealth of Massachusetts is committed to doing its part to mitigate and adapt to this challenge, recognizing the necessity of engaging in adaptation planning today by taking a close look at strategies that could help the state become more resilient and ready to adapt to climate change as it occurs.

The Global Warming Solutions Act, passed by the Massachusetts Legislature and signed by Governor Deval Patrick in 2008, directed the Secretary of Energy and Environmental Affairs (EEA) to convene an advisory committee to develop a report, analyzing strategies for adapting to the predicted changes in climate. This report by the Massachusetts Climate Change Adaptation Advisory Committee is organized into two parts. Part I includes an overview of the observed and predicted changes to Massachusetts' climate and their anticipated impacts, key findings, a set of guiding principles to follow, and key adaptation strategies that cut across multiple sectors. Part II is organized into five broad areas, describing for each area the vulnerabilities to climate change and outlining adaptation strategies that could help increase resilience and preparedness.

Key Predictions and Impacts

Massachusetts' climate is already changing and will continue to do so over the course of this century—ambient temperature has increased by approximately 1°C (1.8°F) since 1970 and sea surface temperature by 1.3°C (2.3°F) between 1970 and 2002. These warming trends have been associated with other observed changes, including a rise in sea level of 22 centimeters (cms) between 1921 and 2006, more frequent days with temperatures above 32°C (90°F), reduced snowpack, and earlier snow melt and spring peak flows (Frumhoff et al., 2006, 2007; Hayhoe et al., 2006). By the end of the century, under the high emissions scenario of the Intergovernmental Panel on Climate Change (IPCC), Massachusetts is set to experience a 3° to 5°C (5° to 10°F) increase in average ambient temperature, with several more days of extreme heat during the summer months. Days with temperatures greater than 32°C (90°F) are predicted to increase from 5 to 20 days annually that Massachusetts experiences today to between 30 to 60 days annually; while up to 28 days annually are predicted to reach above 38°C (100°F), compared to up to two days annually today (Frumhoff et al., 2006, 2007). Sea surface temperatures are also predicted to increase by 4°C (8°F) (Dutil and Brander, 2003; Frumhoff et al., 2007; Nixon et al., 2004), while winter precipitation—mostly in the form of rain—is expected to increase by 12 to 30 percent. The number of snow events is predicted to decrease from five each

month to one to three each month (Hayhoe et al., 2006).

Massachusetts' vast coastline makes it particularly vulnerable to climate change. Assuming that sea level continues to increase at its current rate, because land in Massachusetts is naturally subsiding, by the end of the century, it is expected to rise by another one foot (IPCC, 2007). In addition, the magnitude of sea level rise is predicted to be compounded by thermal expansion of the oceans, the melting of ice on land (such as Greenland) and the collapse of the West Antarctic Ice Sheet. By the end of this century, under the IPCC high emissions scenario with ice melt, it has been suggested that sea level rise resulting from all these factors could reach six feet (Pfeffer et al., 2008). Since a large percentage of the state's population, development, and infrastructure is located along the coast, the impact of this change will be significant, putting the Massachusetts economy, health, natural resources, and way of life at risk.

Higher temperatures, especially the higher incidence of extreme heat days, will have a negative impact on air quality and human health. In general, impacts from climate change on human health can include respiratory illnesses, exacerbation of allergies and asthma, an increase in vector borne diseases, and degraded water quality. Floods from surges of coastal waters and high intensity precipitation events also threaten the state. If these events occur with greater intensity and frequency, as is predicted by many climate change models, the damage could be more severe and cumulative, straining local and state resources and the ability of government agencies to adequately respond.

The Scale and Scope of the Challenge

The issue of climate change, and in particular climate change adaptation, is multi-sectoral and complex. As it plays out in coming years, it will span geographical scales, with greater impacts predicted in areas along the coast and in floodplains. Climate change will also vary temporally—some of the impacts may not be felt for another 30 years or further in the future, while others are already upon us. It may also come in bursts and manifest itself as extreme weather events, with the frequency of such events predicted to increase over time. Massachusetts may experience large-scale catastrophic events, similar to Hurricane Katrina in New Orleans (2005) and the ice storm in Massachusetts (2008), or may see smaller but incremental changes that could have long-term impacts on freshwater resources, fisheries, food crops, coastal properties, and the economy.

The Costs and Risks Associated with Climate Change

While the costs of making changes and actively managing the built and natural environments to buffer the impacts of climate change may be substantial, the cost of inaction may be far higher. A sea level rise of 0.65 meters (26 inches) in Boston by 2050 could damage assets worth an estimated $463 billion (Lenton et al., 2009). Evacuation costs alone in the Northeast region resulting from sea level rise and storms during a single event could range between $2 billion and $6.5 billion (Ruth et al., 2007).

Common Strategies Across All Sectors

Several themes and climate change adaptation strategies that resonate across multiple sectors became evident during meetings of the Advisory Committee and through the development of this report. These strategies represent broad approaches that can shape and inform many climate change adaptation efforts in Massachusetts.

Some solutions to address climate change adaptation can also be considered mitigation strategies because, in addition to contributing to increased resilience and preparedness to climate change, they concurrently achieve reductions in greenhouse gas emissions that contribute to the problem.

The need to perform risk and vulnerability assessments was widely recognized across all sectors. These assessments determine levels of susceptibility and exposure to and impacts of climate change among people, physical structures and assets, natural resources and the environment, economic conditions, and other resources and interests. Areas needing thorough risk and vulnerability assessments include existing critical infrastructure and facilities, vulnerable natural habitats and ecosystems, vulnerable groups or populations, community- or region-specific hazards and threats, water supplies, businesses, homes and other structures, and social and cultural resources. Strongly connected to these assessments is the need for accurate and robust data, because better data collection leads to more accurate risk assessments and more informed decision-making.

Although the state already has data and information to initiate many of the adaptation strategies outlined in this report, more up-to-date and accurate information, models, and decision-support tools representing future climate change predictions and estimates are necessary. These include increased monitoring and observations of key climate parameters, creation or use of models and climate assessments down-scaled to be Massachusetts-specific, collection and use of high-resolution land elevation topography and near shore seafloor bathymetry, collection of improved and expanded socio-economic, epidemiological and demographic information, and development of key decision-support tools.

Once the risks and vulnerabilities are properly assessed through the use of this information, their impacts must be minimized through effective planning and management. For example, future risks and costs can be reduced for new development and redevelopment through the careful siting and inclusion of design, engineering, construction and maintenance standards that account for higher sea levels, increased temperatures, more intense coastal storms, and inland flooding. Also, sound land use decisions—guided by regulation and standards, incentives, and technical support—will help local communities adapt to and withstand climate change impacts.

Another important set of cross-cutting strategies identified during the development of this report include measures that preserve, protect, and restore natural habitats and the hydrology of watersheds. These strategies not only benefit natural resources and habitat, but can also play a critical role in protecting and increasing resilience of key infrastructure sectors, human health, and the local economy.

Finally, effective emergency response systems will be critical in preparing for climate change impacts and extreme weather events. These will especially be needed at the local level, where the first responses typically originate. Government officials and emergency response crews at all levels should assess and enhance emergency management tools and capabilities such as the State Risk Assessment Inventory, the State Comprehensive Emergency Management Plan, the State Hazard Mitigation Plan, and mapping and information systems in order to respond to climate change.

Regarding infrastructure, the most significant vulnerability of existing structures stems from the fact that they were built based on historic weather patterns, not taking into account future predicted changes to sea level, precipitation, or flooding. This puts the infrastructure at increased risk of future damage and economic costs. Therefore, having more accurate maps and surveys—such as LiDAR (Light Detection and Ranging) elevation surveys—will help update current conditions, identify vulnerable facilities, and improve predictive capability. Incorporating these changes into the repair and upgrade of existing infrastructure, as well as into the improved siting and design of future infrastructure, will help minimize the anticipated impact of climate change effects on the infrastructure network. Key strategies include bolstering infrastructure resources by increased conservation, efficiencies, reuse of resources, and timely maintenance; building system redundancies; updating land use, siting, design, and building standards to include climate change projections; using natural systems for enhanced protection; and increasing resilience of infrastructure and the built environment.

Sector-Specific Strategies

Various adaptation alternatives, opportunities, and measures are available to address vulnerabilities arising from climate change. Strategies vary by type, scale, scope, and institutional responsibility.

An analysis of natural resources and habitat identifies potential strategies to enable the four broad ecosystem types in Massachusetts—forested, aquatic, coastal, and wetland—to adapt to climate change. These include protecting ecosystems of sufficient size and across a range of environmental settings, maintaining large-scale ecosystem processes and preventing isolation, limiting ecosystem stressors, and maintaining ecosystem health and diversity. These also include using nature-based adaptation solutions, embracing adaptive management, and developing a unified vision for conservation of natural resources, which can be carried out on a collaborative basis.

Predicted impacts of climate change on human health include the potential for increased heat stress; increased respiratory and heart diseases; elevated levels of ozone and particulate matter; higher pollen counts; increased vector-borne diseases; more outbreaks of water-borne diseases; and degraded surface water quality and increased shellfish pathogens. Extreme weather events can disrupt power, sanitary and health care services, and access to safe and nutritious food, while damaging homes and property. The public and private healthcare systems can address climate change-related demands by going through a network-wide climate change needs assessment that examines enhancing regionalization efforts to address non-emergency situations, developing and increasing responsive capacity through collaboration and improved coordination, and potentially relocating vulnerable health care facilities. In addition, there is a need to improve capacity to adequately detect and treat against pests and diseases, achieve and maintain ambient air quality standards, increase outreach to and support for vulnerable populations, and improve indoor air quality.

Climate change is also expected to affect many aspects of Massachusetts' economy and all levels of government. Climate change impacts will put greater stress on governments by increasing demand for emergency and other services. Among industries expected to be affected are weather-dependent activities such as agriculture, forestry and fisheries, and other industries such as manufacturing (which includes computers, electronic equipment, fabricated metal, and machinery) and service industries, such as real estate management, tourism and recreation, and health care. Examples of impacts include increased flooding, which can affect all sectors of the economy; less winter precipitation in the form of snow, which could adversely affect recreation; and higher temperatures adversely affecting outdoor workers, agricultural

output, the maple syrup industry, and fisheries populations.

Strategies to prepare and enable these industries to become more resilient to climate change include establishing redundant supply routes and sources; developing local and renewable sources of energy; examining possible changes in insurance markets that better capture future climate-related risks; assessing, and protecting facilities and cultural sites that are particularly vulnerable to flooding and sea level rise; and revising bank finance formulas to reflect risk over the duration of mortgages. Strategies for local, state, and federal governments—such as enhancing essential services, engaging in long-range local and regional planning, and developing guidelines, regulations, and standards—can help society better cope with predicted changes in climate.

Coastal resources, including residential and commercial development, ports, and infrastructure; coastal engineering for shoreline stabilization and flood protection; and coastal, estuarine, and marine habitats, resources, and ecosystem services are especially susceptible to increasing sea level rise, flooding, storm damage, and erosion. The ability to address changes in the coastal environment is reliant upon access to strong planning, management, and collaboration among various public and private entities. By incorporating climate change projections into existing strategic, management, and fiscal plans, resiliency in the face of climate change can be enhanced.

Conclusion

The time to address climate change is now. It is clear that while some climate change adaptation strategies are new, many are simply extensions or modifications of existing programs and efforts to practice good environmental stewardship, protect public health, and preserve public safety. The ability to adapt to climate change will be improved through robust science, data collection and analysis; inclusion of climate change in the criteria and evaluation of programs; application of a climate change lens to current planning efforts; examination of regulations, as needed, to take climate change into account, and; continuation of current efforts to increase resilience and decrease vulnerabilities in a wide variety of public and private assets.

Planning for and managing impacts of climate change before they occur are preferable to reactive decision-making after an impact takes place. This approach has the potential to reduce costs, minimize or prevent impacts to public health and safety, and minimize damage to crucial natural resources and built infrastructure. Both management and planning should be flexible, dynamic, and adaptive, and strategies must be continuously revisited and revised.

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