CITY OF BALTIMORE

Disaster Preparedness and Planning Project

A COMBINED ALL HAZARDS MITIGATION AND CLIMATE ADAPTATION PLAN

OCTOBER, 2013

Mayor's Message

Baltimore Disaster Preparedness and Planning Project

Adopted by the Baltimore Disaster Preparedness and Planning Project Advisory Committee
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Executive Summary

Vision Statement

Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Baltimore is highly vulnerable to many natural hazards, ranging from coastal storms and flooding to extreme heat and high winds. There is strong consensus that these types of extreme events will increase, both in frequency and intensity, over the coming years. Furthermore, Baltimore's climate is changing. In the past century, the City has observed shifting trends in weather patterns and climate conditions. The increase in natural hazards, combined with climate change, create impacts that will notably affect the City's residents, businesses, infrastructure, and natural systems, and threaten regionally significant assets.

The Federal Emergency Management Agency (FEMA) requires that every local jurisdiction in the United States develop and adopt All Hazards Mitigation Plan (AHMP) as a condition to be eligible for disaster-related assistance, and requires jurisdictions to update their AHMPs every five years. In 2012, the City of Baltimore adopted a Climate Action Plan, which calls for the creation of a city-wide Climate Adaptation Plan. While an AHMP and a Climate Adaptation Plan could individually provide the required or necessary guidance to deal with extreme natural hazard events and climate change, the City of Baltimore has chosen to do much more than a routine update to the AHMP, or a routine development of a Climate Adaptation Plan.

In 2013, The Baltimore City Department of Planning and Office of Sustainability created the Disaster Preparedness and Planning Project (DP3) as an effort to address existing hazards while simultaneously preparing for predicted hazards due to climate change. This project develops an integrated All Hazards Mitigation Plan (AHMP), floodplain mapping, and Climate Adaptation Plan program that link research, outreach, and actions to assure implementation of a comprehensive and new risk-preparedness system for addressing existing and future impacts. Integrating hazard mitigation planning, which focuses on past events, with climate adaptation planning, which focuses on what will likely happen in the future, offers a positive, win-win solution for Baltimore City.

Flooding on the Jones Falls Expressway *Source: Baltimore Sun*

In order to determine the most feasible and effective mitigation and adaptation recommendations for Baltimore, natural hazards which threaten the City had to be identified and defined. In Baltimore, the following hazards were considered to pose a significant threat:

- Flooding
- Coastal Hazards- Tropical Storms and Hurricanes, Nor'Easter, Sea Level Rise, and Storm Surge & Coastal Inundation
- Precipitation Variability- Precipitation, Winter Storms, Drought, Dam Failure
- Extreme Wind- Associated with Storms, Derechos, Tornados
- Extreme Heat
- Air Quality
- Additional Hazards- Earthquakes, Lightning and Hail, Tsunamis

The project included the creation of a 47 member DP3 Advisory Committee and working groups which provided guidance, support and feedback in the development of goals, strategies and actions based on information provided by the detailed natural hazards inventory, risk assessment and vulnerability analysis that were completed at the beginning of the project. The Advisory Committee working groups and DP3 Plan focus on the four sectors: Infrastructure, Buildings, Natural Systems, and Public Services.

INFRASTRUCTURE

One of the most pressing challenges facing states and municipalities today is the quality and capacity of built public **infrastructure**—the water systems, schools and municipal buildings, transit systems, and other core assets upon which we all depend. Inadequate or failing public infrastructure will negatively impact the City's growth. Already, infrastructure in Baltimore has been proven vulnerable to unpredictable, extreme weather events. To increase the resilience of both new and existing infrastructure, we must be prepared to mitigate and adapt to the impacts of climate change.

BUILDINGS

Baltimore's **buildings**, some of which have been significant features in their communities for decades or even centuries, add vibrant charm to the City. In the past, Baltimore's building stock has been subject to weather-related risks. In particular, flooding associated with extreme precipitation events has caused a great deal of damage. Buildings may be destroyed — entirely or in part — or rendered unstable. Resilience of Baltimore's building stock is particularly important considering that many structures serve as refuge for City residents during severe storms and other extreme weather events. Similarly, critical emergency facilities — hospitals, fire stations, police stations, government buildings, and the like — perform essential functions during these events and increase the City's capacity to respond to, and alleviate, the impacts of a hazard.

NATURAL SYSTEMS

The City's **natural systems** will suffer adverse consequences as a result of climate change; however, this plan embraces nature for its potential as a hazard mitigation and climate adaptation tool. In many cases, natural features are capable of offsetting greenhouse gases and alleviating the severity of weather events, effectively reducing long-term risks from climate change and hazards. On the other hand, if not properly maintained, natural elements may themselves become a danger during an extreme weather event.

PUBLIC SERVICES

A major role of this plan is to expand Baltimore's preparedness for future hazards. Without a strategy for conveying information about the risks and vulnerabilities associated with these hazards, its message will fall on deaf ears. Therefore, strategies relating to **public services** are concerned with distributing information, building resources, improving communication, and establishing response plans. Additionally, strategies are set in place that will prevent or limit health risks — including disease outbreak, physical exhaustion, and respiratory conditions, to name a few — that are triggered by extreme events

The DP3 Advisory Committee and staff have created a plan that encompasses four sectors, 50 goals and 233 actions. Key examples of strategies and actions from the Disaster Preparedness and Planning Project Plan are:

- Integrate resiliency, redundancy, and structural stability into the City's drinking water system to ensure safe and reliable water storage and distribution
- Protect and enhance the resiliency and redundancy of electricity system
- Strengthen City zoning, floodplain and construction codes to integrate anticipated changes in climate
- Develop and implement hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.
- Create an interconnected network of green spaces to support biodiversity and watershed based water quality management
- Increase and enhance the resilience and health of Baltimore's urban forest
- Designate community leaders and organizations that can assist and provide support during hazard events
- Integrate climate change and natural hazards planning into all City and community plans

Protecting Baltimore and its residents from natural hazards, and adapting to a future affected by climate change will be challenging. The City of Baltimore is committed to addressing these issues, and this plan does so in a forward thinking, comprehensive manner. The Disaster Preparedness and Planning Project plan develops a unified approach to hazard mitigation, and climate adaptation, and provides clear guidance to City government and our citizens. The DP3 Plan supports Baltimore's sustainability and resilience, and will assist the City in achieving economic, equitable, and environmental growth.

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Chapter 1

Introduction

Overview of the Project

Recognizing the City's current vulnerability to the impacts of severe hazard events, Baltimore has undertaken a thorough, forward-thinking approach to the hazard mitigation planning process. Baltimore's Disaster Preparedness and Planning Project (DP3) was created by the Department of Planning as an effort to address existing hazards while simultaneously preparing for predicted hazards due to climate change. This project develops a program that integrates hazards mitigation planning, floodplain mapping, and climate adaptation planning. DP3 links research, outreach, and actions to create a comprehensive and new risk-preparedness system for addressing existing and future impacts.

Integrating hazard mitigation planning, which focuses on past events, with climate adaptation planning, which focuses on what will likely happen in the future, offers an innovative solution for Baltimore City. Completing a detailed inventory of natural hazards, a risk assessment, and a vulnerability analysis, informs actions to mitigate hazards and adapt to predicted climate impacts. This provides clear guidance and a unified strategy that supports Baltimore's sustainability and resilience.

In 2000, the President signed into law the Disaster Mitigation Act of 2000 (DMA 2000) in order to reduce the damages associated with natural hazards. The Federal Emergency Management Agency (FEMA) requires that every local jurisdiction in the United States develop and adopt an All Hazards Mitigation Plan (AHMP) as a condition to be eligible for disaster-related assistance. While FEMA requires that local governments update their AHMPs every five years, this plan is much more than a routine update.

Hazard mitigation can be described as the process of developing strategies that will reduce or eliminate loss of life and/or property damage resulting from natural hazard events. Baltimore's hazard mitigation planning process identifies the various hazards which the City faces, either currently or potentially, and assesses the potential risks and vulnerabilities associated with those hazards.

Both human and natural activities are causing the Earth's atmosphere to experience changing conditions. Because of climate change, many of the natural hazards now facing Baltimore may become even more dangerous, while new hazards could at the same time begin to present themselves. Regardless of how quickly or stringently cities are able to reduce greenhouse gas (GHG) emissions, impacts related to climate change will continue to be felt now and into the future. In the past, societies have generally been able to adapt to weather extremes and climate variability. Climate change, however, continues to produce new conditions which are beyond the scope of previous experiences. As a result, historical records are quickly becoming inadequate models for future planning and risk preparedness.

Considering this, the City of Baltimore has recognized the need to pursue a proactive approach to planning for natural hazards and climate change. Building upon the City's previous All-Hazards Mitigation Plan (2006), Baltimore is integrating various mitigation and adaptation programs into a comprehensive plan that addresses both existing and future impacts. This plan provides a framework for the City to identify strategies and actions for mitigating the impacts from natural hazards and adapting to changing conditions. Combining an all-hazards mitigation approach with climate adaptation will proactively strengthen Baltimore's resiliency.

Baltimore's proactive approach includes incorporating strategies that will increase the City's Adaptive Capacity. Climate adaptation recommendations are intended to reduce vulnerability to the impacts of climate change. This approach has a number of benefits. Most significantly, preemptive action offers tremendous cost savings. This project assures that adaptation-related recommendations are included in capital and operating budget decision-making and prioritized in planning processes. Federal efforts to strengthen a city's preparedness for hazards, for instance, costs only a fraction of what governments typically spend to repair the damage from a hazard after the event. In fact, for every dollar spent on disaster prevention, the federal government spends more than $6 in recovery efforts.[1]

Storm Surge in Baltimore after Hurricane Isabel, 2003 *Source: Baltimore Sun*

While proactive efforts should be increased, Baltimore still intends to enhance its response and recovery capacity. The City must be able to withstand the impacts of more frequent and intense extreme weather events and quickly bounce back from any disruptions. For Baltimore to become more resilient, the City must focus on improving essential infrastructure and buildings, protecting people and property, and embracing its natural systems. Most importantly, Baltimore must not wait for a crisis to transpire before acting. Implementing the strategies and actions listed herein will take time; and it is vital that the City act today in order to ensure a future for Baltimore that is sustainable and growing.

The DP3 plan addresses and reviews the natural hazards affecting the City. This process includes:

- Profiles and historic occurrences of hazard events;
- An assessment of geographic extent and Baltimore's risk and vulnerability for each hazard;
- A review of the potential impact of each hazard on community and critical assets; and
- Hazard-specific loss estimations in terms of economic damage;

Scope & Purpose of the Plan

Climate change is a global issue and the DP3 plan addresses not only the potential impact of natural hazards and climate change to Baltimore City, but also looks beyond Baltimore City's borders recognizing that hazard events do not stop at the City's edge.

Climate-related impacts are already affecting Baltimore; therefore the DP3 plan was created to address existing hazards, as well as hazards that are being predicted in Baltimore's future. The plan identifies changes which can be made to better prepare Baltimore to respond to new climate conditions, thereby reducing harm and taking advantage of opportunities. Heat waves, sea level rise, and flooding due to more extreme precipitation events are all projected to impact the City's environmental, social, and economic systems more intensely than they have in the past. Building adaptation into this plan will allow Baltimore City to reduce risks associated with natural hazards and increase overall resiliency.

Relationship to the Sustainability Plan

Baltimore's Sustainability Plan was adopted in March, 2009. It was created to serve as a guide for the City in its efforts to move towards sustainability, and identified various goals and strategies for doing so. The purpose of the Sustainability Plan is to:

- Engage the Baltimore community in a comprehensive discussion on sustainability;
- Inventory existing programs, organizations, and resources;
- Articulate and prioritize sustainability goals for the Baltimore community;
- Serve as a road map for future legislation, public/private partnerships, programs, and educational campaigns.

The Sustainability Plan promotes 29 priority goals with strategies to realize a clean, healthy, efficient, green, mobile, aware and invested community. While the Baltimore Sustainability Plan is a broad, comprehensive strategy, the DP3 Plan is a targeted effort to address various components of sustainability. Many of the goals, strategies and actions contained with the DP3 Plan relate to strategies within the Sustainability Plan. Direct connections between the plans will be identified using the tri-colored symbol above.

Relationship to the Climate Action Plan

The City of Baltimore adopted and released the Baltimore Climate Action Plan (CAP) in 2012 with the goal of achieving a target of a 15 percent emissions reduction by 2020. Chapter four of the CAP focuses on climate adaptation. It explores ways that Baltimore can efficiently manage risks and protect vulnerable populations from the anticipated impacts of climate change. Key recommendations from the CAP document include integration of climate adaptation into the AHMP update, in addition to conducting vulnerability and risk assessments. The DP3 Plan acts as a vehicle for accomplishing these recommendations, providing further detail of action and comprehensive implementation steps for both hazard mitigation– and climate adaption–related CAP measures. Measures that address energy savings and conservation, land-use and transportation, and the protection of Baltimore's natural systems are explicitly highlighted in the CAP as having the co-benefit of climate adaptation.

The CAP also considers the importance of assessing Baltimore's response capacity. Likewise, this is a priority for addressing hazard mitigation, and many DP3 strategies identify methods for strengthening emergency response activities. Similarly, as the CAP prioritizes the development of a Communications Plan, DP3 considers strategies and actions for establishing more robust and comprehensive methods for increasing awareness of climate change, climate adaptation, and natural hazards. Throughout this document, specific strategies that overlap with the CAP will be identified using the sun and cloud symbol above.

The Baltimore Sustainability Plan

The Baltimore Sustainability Plan was adopted in 2009.

Baltimore Climate Action Plan

The Climate Action Plan was adopted in 2012.

Relationship to Emergency Operations Planning

Emergency Operations Plans (EOPs) designate agencies and individuals who will be responsible for what — as well as when, with what resources, and by what authority — before, during, and immediately after an emergency. Alongside local hazard mitigation plans, which help to facilitate Federal funding and actions during and after hazard events, EOPs are tools for establishing a framework to execute emergency response activities.

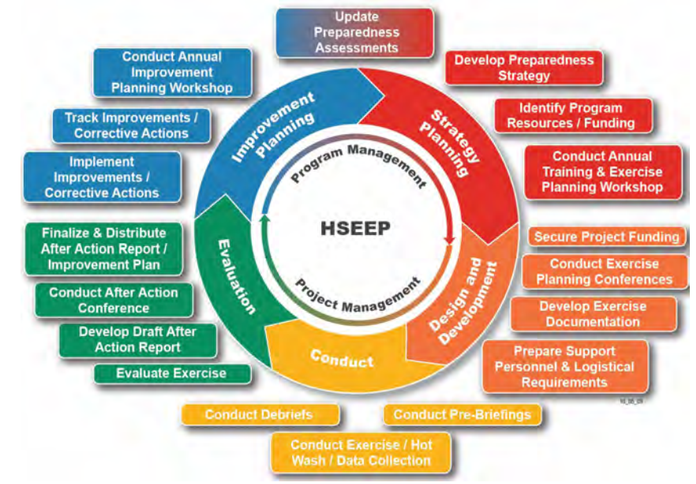


Figure 1–1 Hazard Preparedness Planning Process

Baltimore's EOP, maintained by the Mayor's Office of Emergency Management, includes annexes for each hazard and for all Emergency Support Functions (ESFs). Emergency Support Functions represent services, or sets of services, that are likely to be needed during a hazard event or incident (e.g. the Baltimore City Police Department, the Baltimore City Fire Department, etc.). The services provided by ESFs are Baltimore's EOP is coordinated with—and incorporates—all other City plans, policies, and procedures that pertain to emergency response and recovery, including DP3 and the previous AHMP. When defining strategies and actions, the DP3 process considered various EOP and ESF overlaps, which are indicated in Chapter 5 of this document.

Building Connections with Surrounding Counties and Cities

The City of Baltimore has a variety of strong partnerships at the local, state and federal level. The City understands how important collaboration with surrounding communities is to achieving its mitigation and adaptation goals. As part of this planning process, city staff participated in regional working groups, national and international conferences, and hazard-related forums to integrate regional considerations and cooperation into the DP3 efforts.

Regionally, DP3 planners participated as active consultants in the Maryland Climate Communication Consortium as both core consortium members and panelists at the Maryland Climate Summit. Planners also worked with the Baltimore Metropolitan Council to build relationships with surrounding Counties (Baltimore, Howard, Anne Arundel, and Carroll) to ensure collaboration in implementation efforts. Additional regional efforts include planning meetings and information sharing with surrounding urban areas such as Washington DC and Philadelphia.

Nationwide, city planners presented at and attended conferences related to climate adaptation to facilitate information sharing and networking with other cities working on mitigation and adaptation. Planners also actively participate in climate and sustainability networks such as the Urban Sustainability Directors Network (USDN) and the American Society of Adaptation Professionals (ASAP)

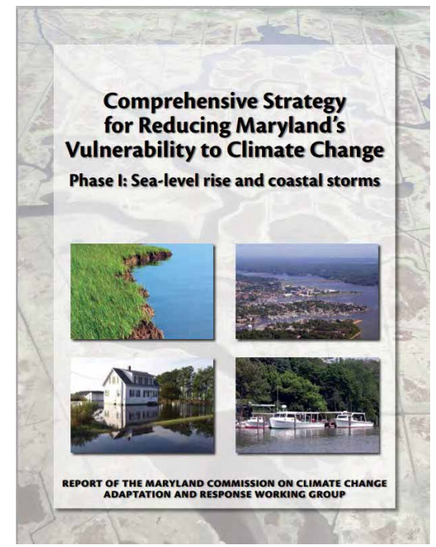
The purpose of mitigation planning is to identify policies and actions that can be implemented over the long-term to reduce risk and future losses associated with natural hazards. Baltimore City's DP3, informed by the previous AHMP, serves as the foundation for mitigation efforts. In addition to the hazard mitigation plan requirements and procedures outlined by FEMA, the DP3 is directly informed by other recent and ongoing efforts — both locally and nationally — that address climate change, adaptation, and mitigation.

Hazard mitigation and climate adaptation efforts are produced at range of scales and geographic levels. The National Climate Assessment (NCA), for instance, is an assessment produced by the U.S. Global Change Research Program (USGCRP) and a key resource for understanding climate change science and for conveying potential changes in climate systems and trends across the United States. The First and Second NCAs were published in 2000 and 2009 respectively, and the Public Comment Draft of the Third National Climate Assessment is currently under review. The Draft National Climate Assessment is overseen by a 60-person Federal Advisory Committee (The "National Climate Assessment and Development Advisory Committee" or NCADAC), which is supported by the National Oceanic and Atmospheric Administration (NOAA). NOAA is a Federal agency that conducts research in order to better understand and predict changes in climate, weather, oceans, and coasts—providing resources and services to share this information. NOAA provides a significant contribution of knowledge that helps cities to understand how and why climate conditions are changing and how to prepare. Many local hazard mitigation plans, including the DP3 plan, are guided by the climate data and information produced by NOAA.

The President's Climate Action Plan was published in June 2013 under the Obama Administration. Much like Baltimore's CAP, the President's Climate Action Plan outlines initiatives to cut carbon pollution and slow the effects of climate change. The President's Plan draws a clear connection between the Climate Action Plan and recent weather and climate disaster events, citing the far-reaching consequences and quantifiable economic costs suffered as a result. The President's Plan identifies three key pillars, which aim to (1) cut carbon pollution in America; (2) prepare for the impacts of climate change, and (3) lead international efforts to combat global climate change and prepare for its impacts. The President's Plan, through pillars two and three, directly incorporates climate resiliency, adaptation and mitigation efforts, recognizing the role of federal government in supporting local preparedness and resiliency efforts.

In Maryland, other initiatives still have been implemented and explored. The Maryland Department of Natural Resources (MDNR), as a means to adapt to a changing climate, has considered solutions for protecting resources and citizens from extreme events, rising sea level, and higher temperatures. In doing so, it developed two strategies (phases) that are currently being used to guide and prioritize state-level activities with respect to both climate science and adaptation policy. First, the Phase I Adaptation Strategy addresses sea level rise and coastal storms. Phase II identifies a strategy for reducing vulnerability to climate change and outlines a collection of steps that should be taken to address changing climate patterns.

At the same time, the Maryland Emergency Management Agency had been developing the 2011 Maryland State Hazard Mitigation Plan Update. The Maryland Plan facilities local governments in their efforts to reduce human and economic costs of natural hazard events, providing a framework for connecting pre- and post-disaster mitigation planning efforts with mitigation planning projects and initiatives for a comprehensive approach. The Maryland Plan investigated Baltimore's previous AHMP to evaluate measures being taken locally, and also determined key areas of exposure within Baltimore City.



This past summer, at the July 25th Climate Change Summit, Governor O'Malley announced a new state plan for cutting greenhouse gas emissions.[2] The Greenhouse Gas Reduction Action Plan was mandated by — and will advance the target identified within — the Greenhouse Gas Emissions Reduction Act of 2009, which effectively required Maryland to reduce GHG emissions by 25 percent of the 2006 baseline by the year 2020. The plan identifies more than 150 programs and initiatives to help the State meet the 25 percent reduction target. Greenhouse gas emissions reductions, as will be discussed throughout the DP3 plan, complements hazard mitigation and climate adaptation measures as through anticipated benefits such as higher air quality, improved environmental health, and reduced dependence on non-renewable energy, to name just a few. Addressing climate change, the Greenhouse Gas Reduction Action Plan — along with other federal, state, and local initiatives — help to progress Baltimore's efforts to become a more resilient City.

Climate Change

General Overview

Climate Change refers to any significant change in the measures of climate lasting for an extended period of time. This includes major changes in temperature, precipitation, wind patterns, or other effects, that occur over several decades or longer. Over the past century, Maryland's average temperatures have risen by 1.8°F and are projected to continue rising. These rising temperatures have already led to changes in weather and climate including more extreme weather events, longer and more frequent heat waves, and a rise in sea level to name a few.

We are already seeing the local effects of climate change around the world. While models of the potential impact of climate change have primarily been developed at global and regional scales, climate change is beginning to impact Baltimore residents, businesses and visitors through events such as higher, prolonged summer temperatures and intense storm events. These changes have the capacity to impact the economy, environment, public health and lifestyle of people throughout Baltimore.

Climate vs. Weather

Climate and weather are two terms that are sometimes misunderstood and used incorrectly. While similar, the difference in meaning rests in the period of time being described. "Weather" refers to what changes we experience on a day-to-day basis or over a short period of time, whereas "climate" describes the long-term trends of atmospheric conditions in particular regions. Weather may describe current temperature, humidity, precipitation, wind, or other similar conditions. A weather forecast may predict conditions for the coming week, while a climate prediction consolidates weather patterns over a period, typically 30 years, to determine expected changes in averages, called "climate normals."

	Climate	Weather
Definition:	Describes the average conditions expected at a specific place at a given time.A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere.[1]	Describes the atmospheric conditions at a specific place at a specific point in time. Weather generally refers to day-to-day temperature and precipitation activity
Components:	Climate may include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms over a long period of time.	Weather includes sunshine, rain, cloud cover, winds, hail, snow, sleet, freezing rain, flooding, blizzards, ice storms, thunderstorms, steady rains from a cold front or warm front, excessive heat, heat waves and more
Forecast:	By aggregates of weather statistics over periods of 30 years	By collecting meteorological data, like air temperature, pressure, humidity, solar radiation, wind speeds and direction etc.
Determining factors:	Aggregating weather statistics over periods of 30 years ("climate normals").	Real-time measurements of atmospheric pressure, temperature, wind speed and direction, humidity, precipitation, cloud cover, and other variables
About:	Climate is defined as statistical weather information that describes the variation of weather at a given place for a specified interval.	Weather is the day-to-day state of the atmosphere, and its short-term (minutes to weeks) variation
Time period:	Measured over a long period	Measured for short term
Study:	Climatology	Meteorology

Current and Most Recent Science

Looking to the most reliable scientific resources for climate data, the DP3 has utilized recent climate projections for Baltimore, Maryland, the Mid-Atlantic Region, and for the Country as a whole. This data conveys what Baltimore's future may bring, and what hazards the City may soon face.

Key sources that were utilized to better understand future climate change impacts included the National Oceanic and Atmospheric Administration (NOAA); NOAA's National Climatic Data Center (NCDC); NOAA's National Weather Service (NWS); the National Climate Assessment (NCA) reports produced by the U.S. Global Change Research Program (USGCRP); the Maryland Department of Natural Resources (MDNR); the Federal Emergency Management Agency (FEMA), in addition to the Maryland Emergency Management Agency (MEMA); MADECLEAR, a regional climate change institute; and the Intergovernmental Panel on Climate Change (IPCC); among other sources.

Chart: Climate Science Projections

Overview of Methodology

Documentation of the process to create the plan

The DP3 has utilized the following process throughout plan development:

1. Identify and profile existing hazards.
2. Conduct an inventory that identifies all assets such as hospitals, schools, etc.
3. Utilize modeling to identify risk from existing hazards and predicted climate impacts.
4. Complete a vulnerability analysis of identified assets and critical facilities. Identify exposure, sensitivity and adaptive capacity.
5. Identify actions and recommendations to deal with existing hazards and predicted impacts.
6. Develop implementation plans for these actions, as well as recommendations for stakeholder involvement and funding strategies.

In order to jointly determine what shared values and potential solutions work best for the greater Baltimore community, sustainability and resilience will be incorporated into all natural hazards decision making.

In an effort to amalgamate the hazards mitigation and adaptation processes, the City of Baltimore has utilized two methods to frame this plan. First, the Federal Emergency Management Agency's (FEMA's) Local Multi-Hazard Mitigation Planning Guidance and Crosswalk planning tool (Figure 1–2), and also the ICLEI-Local Governments for Sustainability's Climate Resilient Communities Five Milestones framework.

LOCAL HAZARD MITIGATION PLAN REVIEW CROSSWALK **FEMA REGION VIII**

Jurisdiction: Wheatland County, Montana

Instructions for Using the Plan Review Crosswalk for Review of Local Mitigation Plans

Attached is a Plan Review Crosswalk based on the ***Multi-Hazard Mitigation Planning Guidance Under the Disaster Mitigation Act of 2000***, published by FEMA, dated March 2004. This Plan Review Crosswalk is consistent with *44 CFR Part 201 – Mitigation Planning, Interim Final Rule* (the Rule), in accordance with the *Stafford Act* (42 U.S.C. 5165), and *44 CFR Part 78.5 – Flood Mitigation Plan Development*, in accordance with the *National Flood Insurance Act of 1968 (42 U.S.C. 4104c et seq)*.

SCORING SYSTEM

N – Needs Improvement: The plan does not meet the minimum for the requirement. Reviewer's comments must be provided.

S – Satisfactory: The plan meets the minimum for the requirement. Reviewer's comments are encouraged, but not required.

Each requirement includes separate elements. All elements of a requirement must be rated "Satisfactory" in order for the requirement to be fulfilled and receive a summary score of "Satisfactory." A "Needs Improvement" score on elements shaded in gray (recommended but not required) will not preclude the plan from passing.

When reviewing single jurisdiction plans, reviewers may want to put an N/A in the boxes for multi-jurisdictional plan requirements. When reviewing multi-jurisdictional plans, reviewers may want to put an N/A in the prerequisite box for single jurisdiction plans.

States that have additional requirements can add them in the appropriate sections of the *Multi-Hazard Mitigation Planning Guidance* or create a new section and modify this Plan Review Crosswalk to record the score for those requirements.

Optional matrices for assisting in the review of sections on profiling hazards, assessing vulnerability, and identifying and analyzing mitigation actions are found at the end of the Plan Review Crosswalk.

The example below illustrates how to fill in the Plan Review Crosswalk.

Example

Assessing Vulnerability: Overview

- **Multihazard Requirement §201.6(c)(2)(ii):** *[The risk assessment **shall** include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description **shall** include an overall summary of each hazard and its impact on the community.*
- **FMA Requirement §78.5(b):** ***Description of the existing flood hazard and identification of the flood risk, ..., and the extent of flood depth and damage potential.***

Element	Location in the Plan (section or annex and page #)	Reviewer's Comments	SCORE Stafford N	SCORE Stafford S	SCORE FMA N	SCORE FMA S
A. Does the plan include an **overall summary** description of the jurisdiction's **vulnerability** to each hazard?	Section II, pp. 4-10	The plan describes the types of assets that are located within geographically defined hazard areas as well as those that would be affected by winter storms.		✓		✓
B. Does the plan address the **impact** of each hazard on the jurisdiction?	Section II, pp. 10-20	The plan does not address the impact of one of the five hazards addressed in the plan. **Required Revisions:** • Include a description of the impact of earthquakes on the assets. **Recommended Revisions:** • This information can be presented in terms of dollar value or percentages of damage.	✓			✓
		SUMMARY SCORE	✓			✓

Figure 1–2 FEMA Crosswalk Planning Tool

Advisory Committee

The Department of Planning assembled a group of experts from around the City and State to help gather essential data and draft recommendations for the DP3 plan. The purpose of the Advisory Committee was to bring together stakeholders from key agencies, institutions, businesses, and neighborhoods in order to identify actions and recommendations for the plan.

The Advisory Committee consisted of city directors from Department of Public Works, Department Of Transportation, Baltimore City Health Department, Mayor's Office of Emergency Management, Fire, Police and Department of General Services, community leaders, business leaders, climate scientists and representatives from Federal Emergency Management Agency, Maryland Emergency Management Agency, Maryland Department of Natural Resources, local Universities, the Port, and Baltimore Gas & Electric. The Advisory Committee met four times throughout the winter and spring of 2013, beginning in February of 2013. Additionally, members participated in subcommittees based on their specific areas of expertise.

DP3 Advisory Committee Meeting, March 2013 *Source: Kristin Baja*

Public Meetings

Throughout plan development, community input was solicited and encouraged. Two Town Hall events were held in spring 2013 and served to educate the public about the DP3 process and request their feedback regarding natural hazards affecting Baltimore. Additionally, representatives from Baltimore's Department of Planning attended community association meetings to explain the impacts of specific hazards and have intimate discussions with community members about their understanding of natural hazards and hazard mitigation planning.

DP3 Town Hall Meeting, July 30th, 2013 *Source: Kristin Baja*

Scope and Content

This document outlines the DP3 development process and strategies and actions that will help the city achieve its hazard mitigation and climate adaptation goals.

Chapter 2: Mitigation and Adaptation This chapter defines hazard mitigation and climate adaptation and highlights why Baltimore City decided to combine these two plan development processes. It explains the structure of a risk assessment and how risk is determined throughout the next two chapters.

Chapter 3: Hazard Identification This chapter identifies and defines natural hazards that threaten the City of Baltimore. It includes the severity, probability and location of each historical hazard and reports on the damages and consequences experienced by each. This chapter also integrates predicted changes due to climate change in order to address the need to adapt.

Chapter 4: Risk and Vulnerability Assessment This chapter builds upon the hazard identification process to further inform the risk assessment by assessing vulnerability. This chapter evaluates the potential losses associated with a given hazard and estimates the degree to which property damage, economic loss, physical injury, or death are likely to occur. It will highlight why Baltimore is at risk and where that risk is greatest.

Chapter 5: Strategies and Actions This chapter explores ways that Baltimore can best manage risks, protect people and property, and pro-actively plan for the current and future impacts of climate change. It explains the vision and goals for the plan and provides key strategies and actions divided into four sectors areas: infrastructure, buildings, natural systems and public services.

Chapter 6: Implementation, Monitoring and Evaluation This chapter identifies how implementation of the DP3 strategies and actions will begin. It identifies lead agencies, stakeholders, timeline, financing options and policy mechanisms for each action.

Appendices: Detailed appendices provide information on the DP3 Advisory Committee, the public process, critical facilities, health impacts assessments, engineering studies, and all HAZUS-MH modeling data.

Vision, Goal and Objectives for the plan

Vision:

Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Goals:

Goal 1 Protect the health, safety and welfare of Baltimore City residents and visitors

Goal 2 Prevent damage to structures, infrastructure, and critical facilities

Goal 3 Build resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private)

Goal 4 Enhance the City of Baltimore's adaptive capacity and build institutional structures that can cope with future conditions that are beyond past experience

Goal 5 Promote hazard mitigation and climate adaptation awareness and education throughout the City of Baltimore

Goal 6 Become a Community Rating System (CRS) classified community

Community Rating System (CRS)

Overview of the City of Baltimore

History and Geography

The City of Baltimore, Maryland, is located on the eastern seaboard in the Mid-Atlantic region (also referred to as the Northeast, or Northeastern, region of the United States). Situated on a natural harbor near the mouth of the Patapsco River where it empties into the Chesapeake Bay, the City features 60 miles of waterfront land within four major watersheds.

Founded in 1729, the City of Baltimore is a major U.S. seaport. Baltimore's port has been considerably successful. One particular economic advantage is that Baltimore is situated closer to major urban markets in the Midwest than any other major seaport on the East Coast. Additionally, the depth of Baltimore's harbor has continually provided access to the larger ships traveling from the Panama Canal. Today, Baltimore is one of only two East Coast port facilities that are deep enough to accommodate the new, substantially larger ships that will arrive following the Panama Canal expansion in 2014.

Baltimore's Inner Harbor was once the second leading port entry for Immigrants to the United States and a major manufacturing center. After a decline in manufacturing industries in the 1970s and 80s, Baltimore shifted to a service sector-oriented economy. Now, Johns Hopkins University, Johns Hopkins Hospital, and the University of Maryland are the city's largest employers.

The port and waterfront remain extremely important assets in Baltimore, providing an abundance of job opportunities as well as some of the City's strongest property tax base. Today, the Inner Harbor is home to Harborplace, a festival marketplace that opened in 1980. Recognized as an international model for urban waterfront development and revitalization, Harborplace transformed Baltimore's Inner Harbor and is now a shopping, entertainment, and tourist destination that also features attractions like the National Aquarium in Baltimore and the Maryland Science Center. Daily visitors number in the hundreds of thousands, adding up to more than 20 million visitors each year. In fact, summer tourist season sometimes swells the City population to over 1 million.

Pier Four Power Plant adaptive reuse *Source: thecitrusreport.com*

Baltimore City's 80 square miles of land encompass the most heavily developed area within the State of Maryland; the City is characterized by brick row houses, office centers, and university campuses, to name a few key features.

Population, Households, Employment, Property Values and other Demographics

Baltimore is one of the nation's largest cities. According to Census Data, Baltimore reported a population of 620,961 residents in 2010. Since the 1950's, Baltimore has lost about one-third of its population due, generally, to the suburbanization of the region. However, the latest Census data indicates that Baltimore's population is stabilizing. In 2012, the Census Bureau Population Estimates indicated that the City's population was 621,342, a small increase.

In Baltimore, the median age is 34 years, and there are slightly more females (at 52.9 percent) than male residents.

Data from the 2010 Census indicated that 64 percent of the population identified themselves as black and 29.4 percent as white. Both demographic groups, however, experienced a decline in numbers since 2000, while smaller demographic groups experienced significant increases. The percent of Baltimore's population that identify as Asian, for instance, increased 45.7 percent, while those who noted they were "some other race" increased by 159.1 percent. Additionally, the number of residents who indicated they were Hispanic increased 134.7 percent; with the largest increase — 161.9 percent — in Mexican Hispanic residents.

Hazards and Historic Assets

Baltimore is an historic port city, with its oldest communities located on or near the waterfront. These intact maritime communities, such as Fells Point, Federal Hill, and Locust Point, are particularly threatened by sea level rise and storm surges. While the threat of climate change and coastal hazards are great in these coastal communities, other aspects of climate change threaten historic resources across the city.

The city has over 80,000 historic properties designated on the National Register of Historic Properties individually or contributing to a district, or locally designated as a Baltimore City Landmark or contribution to a Baltimore City Historic District. The city also possesses significant historic landscapes, sites, and archaeological sites. These historic resources play a defining role in our city's heritage and are a vital part of its economy.

Historic structures, landscapes, and sites are non-renewable resources, making it of the utmost importance to proactively plan for their protection and resiliency. Many historic resources in Baltimore have already survived significant climatic changes in the past, and may demonstrate resiliency in the future. However, future climate hazards will likely affect more historic resources than ever before. It is possible that future impacts to historic resources may cause irreparable damage or lead to the loss of the cultural or economic benefits of these resources. There is also the potential that poorly designed climate adaptation and mitigation responses could damage or destroy the significance and integrity of these historic resources as well. Thus, it is critical that consideration of historic resources to be integrated into any hazard or climate change planning.

It is important to look to federal standards and the best practices in the field in planning for hazards and climate change and impacts to historic resources. This includes engaging with other maritime communities that are involved in innovative planning measures for their vulnerable historic resources, such as the City of Annapolis, and other partners such as the National Trust for Historic Preservation, federal and state preservation agencies, non-profits, and other partners. Other actions include:

1. Develop and implement a hazard mitigation planning strategy for the city's historic resources. Integrate a variety of tools, such as engineering surveys, to determine neighborhood-specific adaptation strategies.

2. Prioritize all historic resources vulnerable to climate change and climate hazards based on their significance and level of threat, and develop a schedule to complete investigations of all priority sites that have had little or no previous investigation.

3. Protect historic sites and buildings in place where financially and technically feasible using a variety of measures.

4. Create financial incentives for historically-sensitive adaption strategies that increase the resiliency of historic buildings.

5. Promote the use of historic preservation tax credits or other funding sources to offset costs of retrofits or other adaptation strategies where they are appropriate.

6. Develop guidelines and requirements for the potential displacement of vulnerable historic resources when preservation in place is not a feasible strategy for permanent protection.

7. Develop a Historic Property Resiliency Toolkit for property owners.

8. Explore the greater utilization of legislative and legal tools, such as historic designations and easements in the effort to protect historic resources.

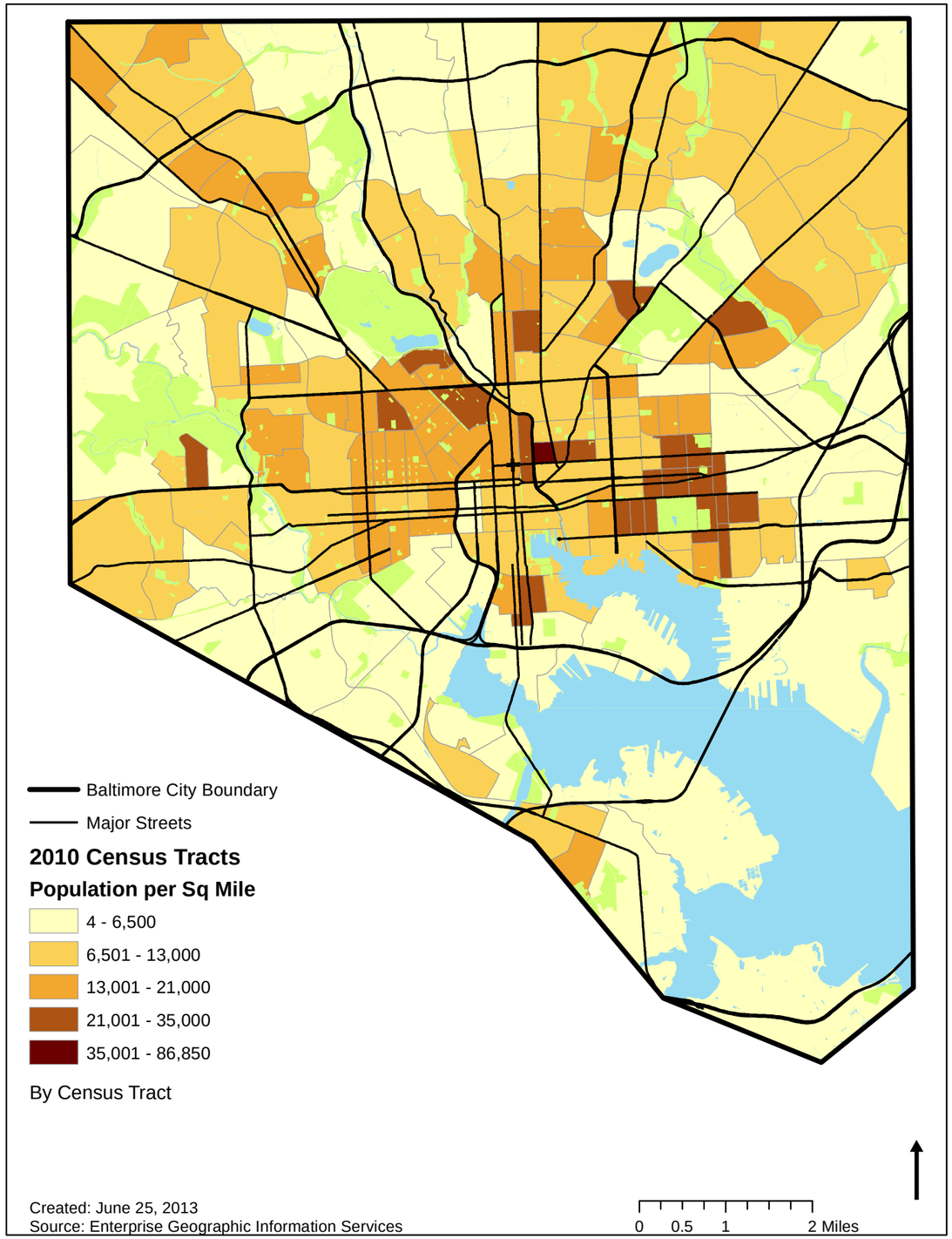


Figure 1–3 Population Density

As the map here (Figure 1–3) illustrates, Baltimore's population density is dispersed differently throughout the City. Concentrations of population groups with distinct demographic characteristics — including age, ethnicity or primary language, poverty status, individuals and families receiving federal assistance, and educational attainment levels — may be distributed in clusters (Maps showing demographic concentrations of populations by these characteristics may be found in Appendix X).

When certain populations are grouped together, the impacts from natural hazards may unequally impact some individuals more significantly, increasing vulnerability to certain hazards of one cohort more than others. Environmental justice ensures the fair treatment and the equal protection of an individual — regardless of race, ethnicity, or income — from environmental and health hazards, as well as uniform access to planning and decision-making processes which provide residents with a healthy environment in which to live, earn, play, and learn.[3] This plan attempts to provide disaster preparedness and planning opportunities for more vulnerable populations.

Table 1–1 BALTIMORE HOUSEHOLDS

	Number	Percent
Total households	249,903	100
Family households (families)	134,038	53.6
With own children under 18 years	55,848	22.3
Husband-wife family	60,293	24.1
With own children under 18 years	20,963	8.4
Male householder, no wife present	14,156	5.7
With own children under 18 years	5,412	2.2
Female householder, no husband present	59,589	23.8
With own children under 18 years	29,473	11.8
Nonfamily households	115,865	46.4
Householder living alone	90,092	36.1
Male	39,916	16
65 years and over	8,138	3.3
Female	50,176	20.1
65 years and over	17,095	6.8

Source: 2010 Census

Households

Baltimore is often referred to as a "City of Neighborhoods" for its many unique districts and communities. The characteristics of each neighborhood can vary greatly across the City, influencing the levels to which one community may or may not be vulnerable to various events.

In 2010, there were 249,903 households in Baltimore City (Table 1–1, left), 47.7 percent of which were owner-occupied (Figure 1–4, left), an 8.2 percent decrease since 2000. Family households in Baltimore City fell 8.9 percent in 2010, constituting 53.6 percent of all households. In 2010, the Median Household Income (Figure 1–5) grew to an estimated $50,046, up from just $39,368 in 2000 (2010 adjusted dollars) (2010 ACS 1-Year Estimates).

Comparing 2010 ACS 1-Year Estimates with 2000 SF3 Census data reveals that poverty status decreased, both for families — down from 18.8 percent in 2000 to 11.3 percent— and for all residents — from 22.9 percent in 2000 to 15.3 percent in 2010.

Interestingly, according to 2010 American Community Survey 1-Year Estimates, although Pre-K through 12th grade enrollment levels fell across the board, the number of high school graduates rose 2.3 percent and residents with college-level or higher educational attainment increased by 23.2 percent. Residents with similar education attainment levels are generally living in concentrated areas. The map below (Figure 1–6), for instance, shows that north Baltimore neighborhoods have high concentrations of residents with a high school diploma or greater. In this map, the darkest brown indicates areas where between 91 and 100 percent of residents had received a high school diploma or above, with the lightest yellow indicating areas where only 46 to 50 percent of residents had done so.

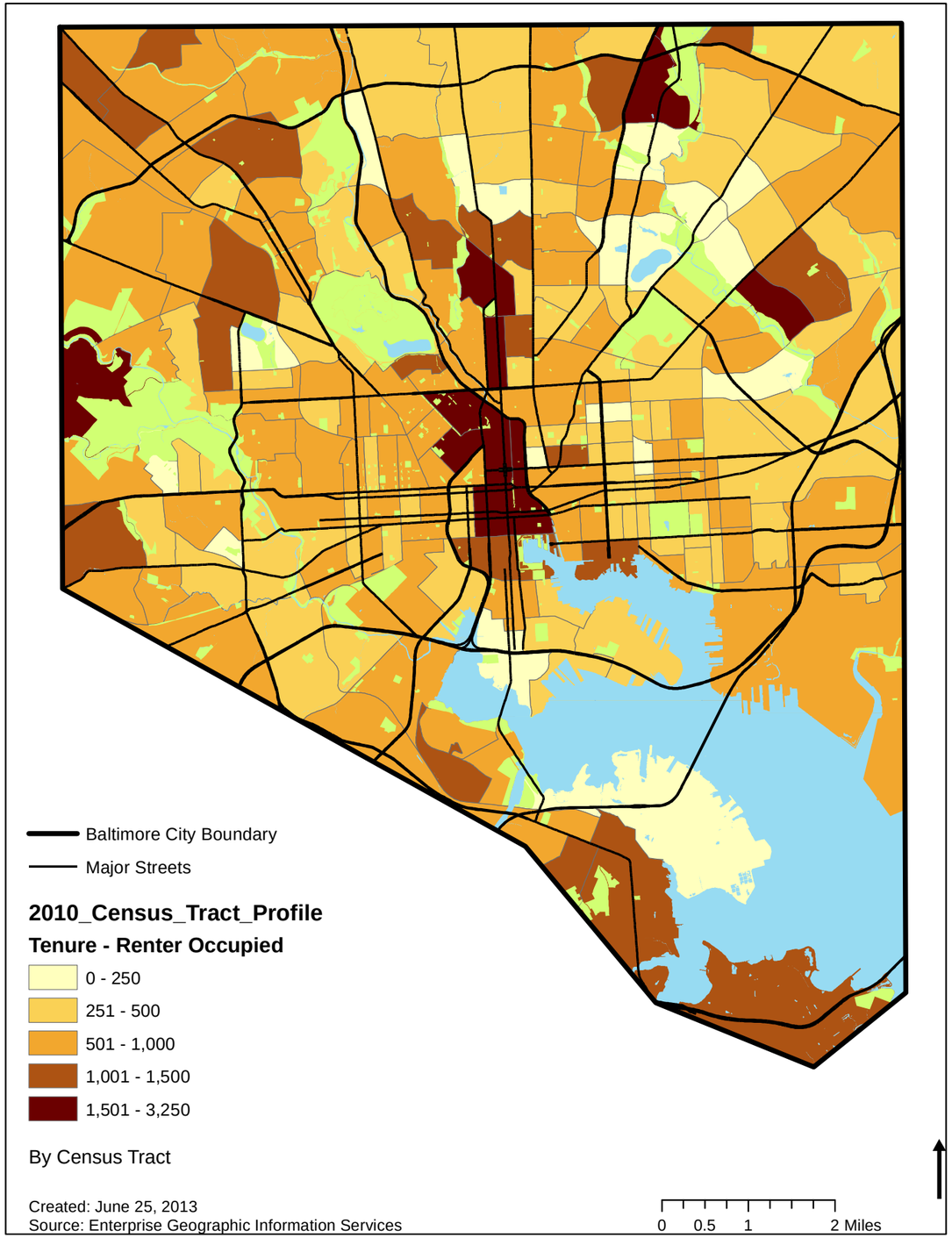


Figure 1–4 Baltimore City Tenure

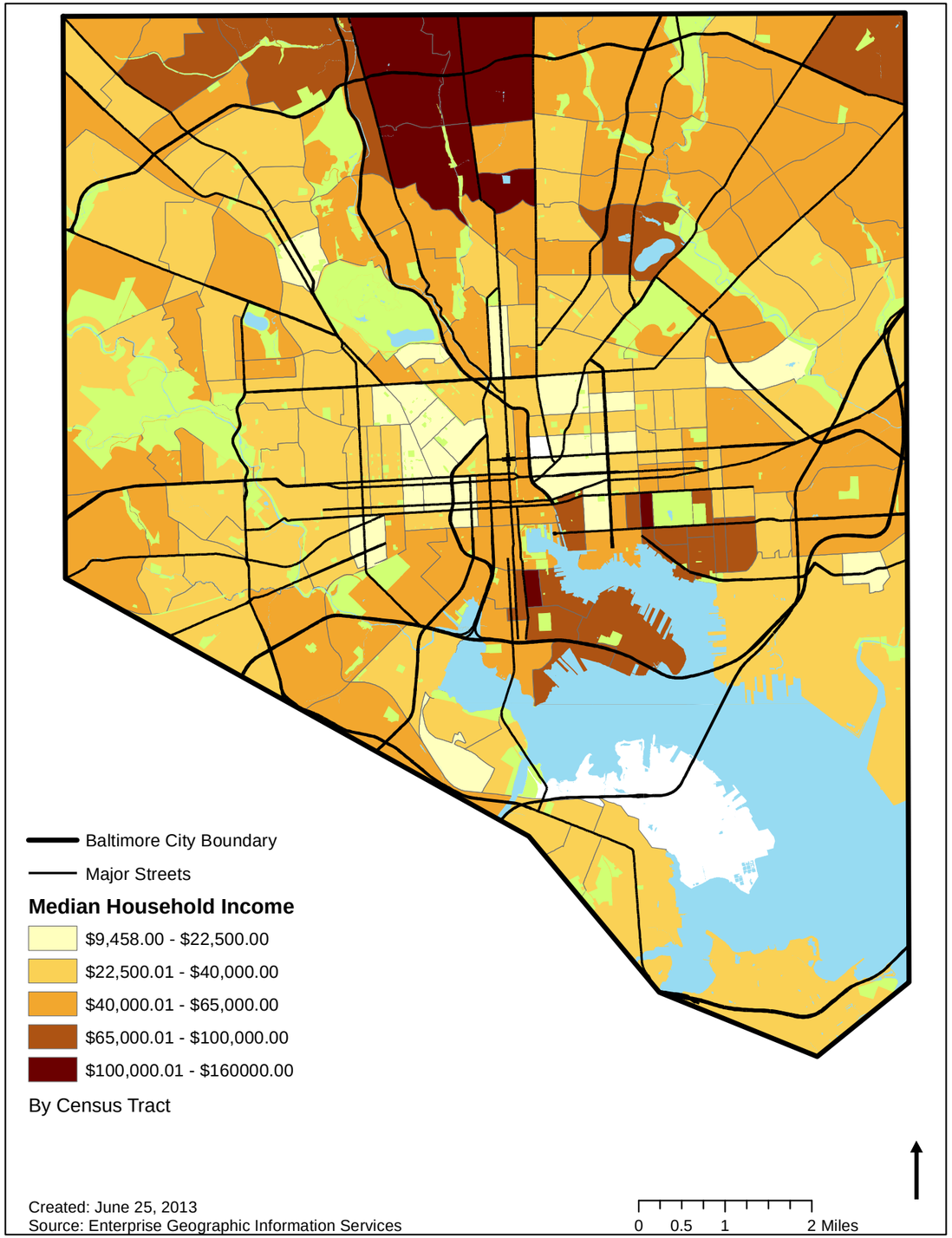


Figure 1–5 Median Household Income

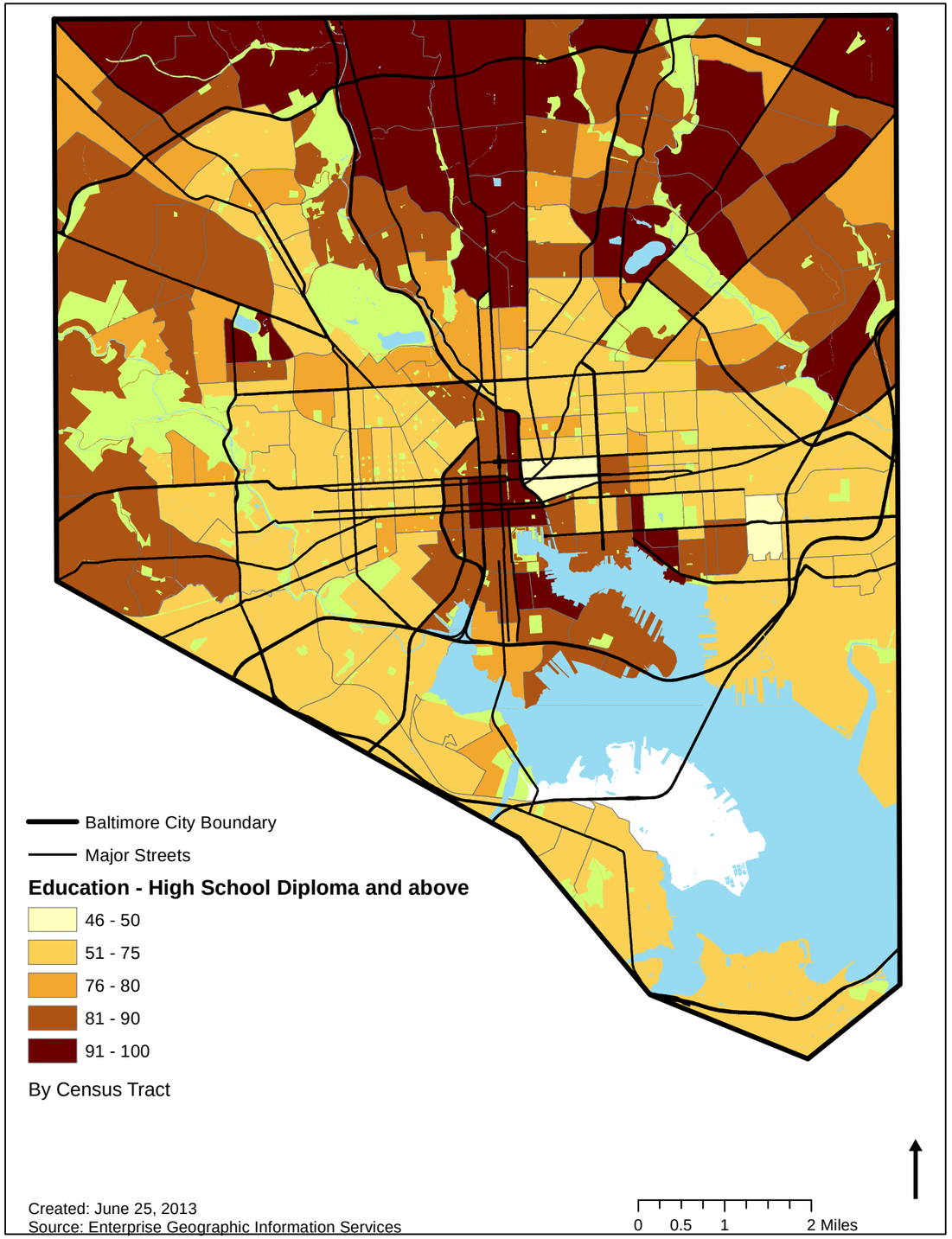


Figure 1–6 Educational Attainment

Table 1–3 Baltimore Top Revenue Generating Companies with More than 1000 Employees

Employer	Number of Employees	Neighborhood
Abacus Corporation	1000 and over	Pulaski Industrial Area
Baltimore Sun	1000 and over	Mount Vernon
Bon Secours Hospital	1000 and over	Penrose/Fayette Street Outreach
Broadway Services	1000 and over	Orangeville Industrial Area
Helix Health System	1000 and over	Loch Raven
Johns Hopkins Bayview Medical Center	1000 and over	Pulaski Industrial Area
Johns Hopkins Health System	1000 and over	Pulaski Industrial Area
Johns Hopkins Hospital	1000 and over	Dunbar-Broadway
Johns Hopkins University	1000 and over	Charles Village
Kennedy Krieger Institute	1000 and over	Middle East
Loyola College	1000 and over	Loyola/Notre Dame
Maryland General Hospital	1000 and over	Mount Vernon
Mercy Hospital	1000 and over	Downtown
Mv Contract Transportation	1000 and over	Curtis Bay Industrial Area
St Agnes Hospital	1000 and over	Violetville
Sinai Hospital	1000 and over	Levindale
T Rowe Price Associates	1000 and over	Inner Harbor
University Of Maryland Medical System	1000 and over	University Of Maryland

Economic Development, Land Use and Zoning

The top five, largest industries in Baltimore are Education and Health Services (23.2 percent), Retail Trade (11.7 percent), Professional (10.6 percent), Manufacturing (10.4 percent), and the Arts (9.2 percent) (ACS 2010 1-Year Estimates). As Baltimore's population has declined, however, the total number of City jobs has also fallen (Table 1–2).

Historically, Baltimore's economic activity has largely centered on waterfront development and redevelopment. Baltimore's waterfront includes a wide variety of land uses, including industrial, commercial, recreational, and residential development.

Additionally, Baltimore features high revenue-generating companies. Table 1–3, below, lists top revenue-generating companies in Baltimore which have 1,000 or more employees. While these, and other leading industries, are dispersed across the City, some neighborhoods have high concentrations of these major employers. For instance, about 35 percent of Baltimore's major employers are located within the Inner Harbor and Downtown Baltimore neighborhoods, together, which are major economic centers in the City (Figure 1–7).

Table 1–2 Jobs in Baltimore City 1970-2010

1970	1980	1990	2000	2005	2010	2013*
533,697	503,343	508,534	446,406	397,852	386,532	363,100

Source: 1970-2010 Data from the U.S. Bureau of Economic Analysis.
**2013 numbers, reported as of March 2013: http://www.bls.gov/ro3/cesqbalt.htm#ro3qcesbalt*

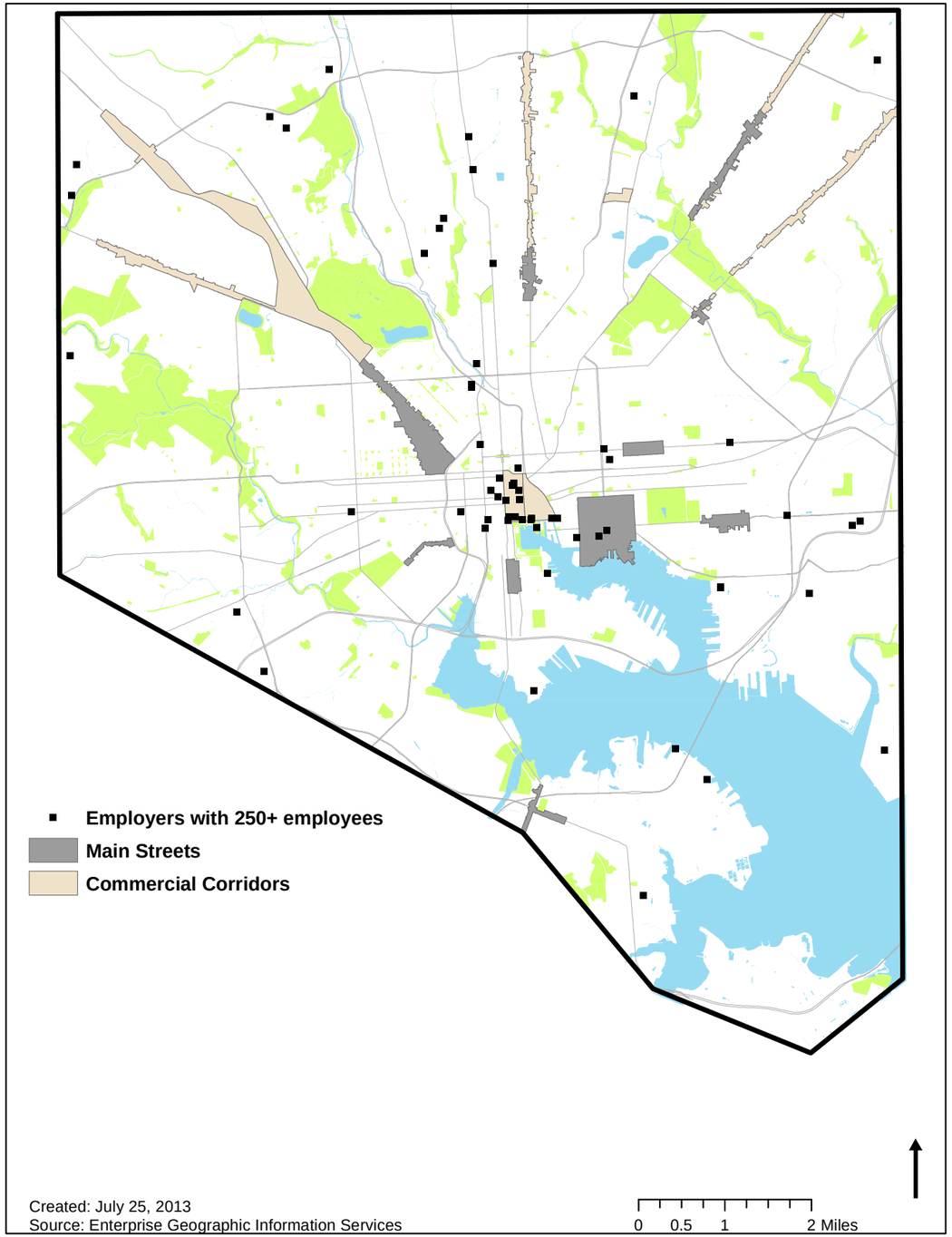


Figure 1–7 Economic Centers

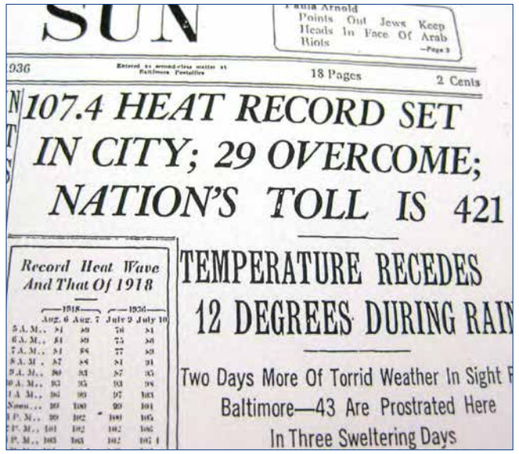
Climate of Baltimore

Baltimore has a temperate climate and experiences four, distinct seasons each year. Baltimore's winters are cool and damp, with limited snow fall. Summers are warm and humid. In Baltimore, an average annual rainfall of 41.99 inches has been measured. Average annual temperatures in Baltimore are measured at 55.1°F, and the City is generally warmer than the surrounding Counties due to an urban heat island effect (discussed in more detail in the "Extreme Heat" Hazard Profile in Chapter 3).

Baltimore is vulnerable to many natural hazards, including coastal storms, flooding, extreme heat and high winds. In the past, natural hazards like these have damaged property and infrastructure, and have resulted in the injury or fatality of Baltimore residents (Baltimore's history of natural hazard events will be discussed in more detail in Chapter 3 Hazard Assessment).

Additionally, the City's risk of experiencing natural hazards is expected to rise with projected changes in climate, which Baltimore has already begun to experience. Consider, for instance, some of the significant trends observed over the last century:

- Average temperatures have increased by 1.8°F in Maryland.[4]
- At BWI Airport, the most recent 30-year average (normal) temperature has increased by 0.5°F since the 1970-2000 measured normals.[5] (Typically, however, actual Baltimore City temperatures are a few degrees warmer than temperatures measured at BWI.)
- There has been a general increase in the number of heat waves.
- Average precipitation has increased by 10% in most of Maryland.[6] Meanwhile, intense precipitation events have increased by 20% over the last century.[7]
- Extreme weather events increase in intensity and frequency; in the case of hurricanes, storms are less frequent, yet there has been more intensity and damage associated with each storm.
- Relative sea level has risen 13 inches in Baltimore between 1902 and 2006, or at a rate of about 0.125 inch each year.[8] The global average is 0.08 inch/year.[9]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Fanny Arnold Points Out Jews Keep Heads In Face Of Arab Riots

18 Pages 2 Cents

107.4 HEAT RECORD SET IN CITY; 29 OVERCOME; NATION'S TOLL IS 421

Record Heat Wave And That Of 1918

TEMPERATURE RECEDES 12 DEGREES DURING RAIN

Two Days More Of Torrid Weather In Sight F

Baltimore—43 Are Prostrated Here In Three Sweltering Days

1936 Article in the Baltimore Sun *Source: marylandweather.com*

These trends are likely to continue throughout this century (Table 1–5 Local Climate Projections) and into the future. For instance, scientists predict:

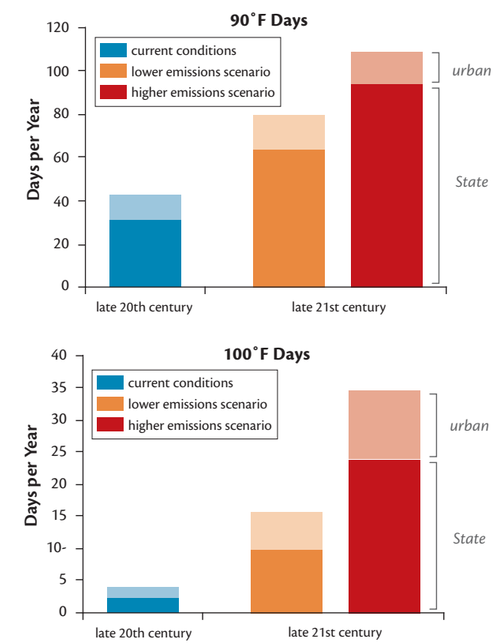
- Maryland's average annual temperatures will increase 3-8°F by the end of the century.[10]
- By 2100, average annual temperatures are expected to increase 12°F in Baltimore — which will at that point feel more like New Orleans, LA.[11]
- As many as 95% of summer days could reach extreme maximum temperatures by the end of the century.[12]
- Projected increases in average precipitation typically hover around 10%. At the same time, heavy storm events are expected to increase in frequency; winter precipitation is likewise expected to increase by an estimated 40%, although more of that precipitation will be rain as opposed to snow.[13]
- In Baltimore, relative sea level is expected to rise another 13 inches by 2050; while Maryland sea level could rise to between 24 and 48 inches by the end of the century.[14]

Table 1–5 Local Climate Projections

Maryland	2012	2025	2050	2100	Notes
Annual Average Temperature(°F)	55.1°	57.1°	58.1°	58.1-63.1°	
Higher Temperatures (summer days reaching maximum temperature extremes)	75 – 90%	80 – 95%	85 – 95%	90 – 95%†	*Foot, Rich. (2013, June).*
Increase in Annual Precipitation	40.76"	42.8"	43.53"	45" – 45.9"	
Sea Level Rise	n/a	--	.6' – 1.3'	2.7' – 3.4'	
Baltimore	**2012**	**2025**	**2050**	**2100**	**Notes**
Annual Average Temperature(°F)	54.6°	56.6°	--	66.6°	
Higher Temperatures (summer days reaching maximum temperature extremes)	75 – 90%	80 – 95%	85 – 95%	90 – 95%†	*Foot, Rich. (2013, June).*
Increase in Annual Precipitation	41.94"	44"	44.8"	46.3 – 47.2"	*Using statewide projections*
Sea Level Rise	n/a	--	13"	--	

† Projection for the year 2090.

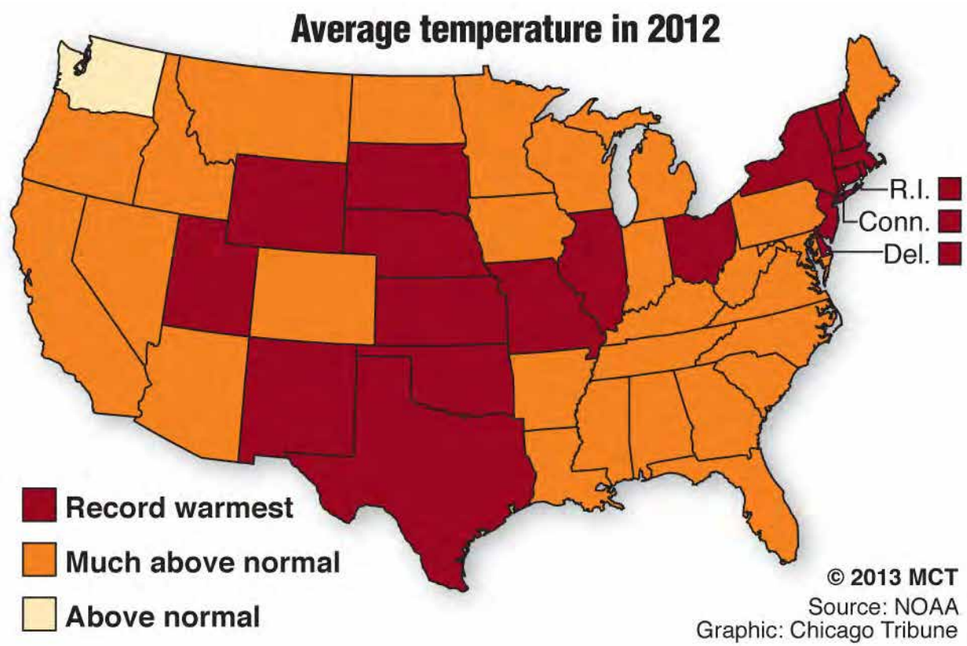
Table 1–4 Projected Number of Days with High Temperatures Reaching or Exceeding 90°F and 100°F in the Late 21st Century. This image compares recorded temperature measurements over the 20th Century with projected rises in temperatures based on both low and high emission scenarios. Note how temperatures are and will be even greater in urban areas.



Source: Figure 4.4 of the Maryland Commission on Climate Change, 2008: Ch. 2, Pg. 17.

United States Heat Wave of 2012

2012 was the warmest year on record for the contiguous 48 states



Changing trends continue to set new records. In 2012, more than 3,500 monthly weather records were broken across the country. Extreme weather events, like droughts, large wildfires and Hurricane Sandy, devastated communities. It was the warmest year on record, according to the National Oceanic and Atmospheric Association (NOAA). In Baltimore, residents experienced a winter warm spell, intense heat waves, and a significant derecho storm (see a description of derechos in the Wind Hazards Profile). With continuing climatic shifts, frequency and severity of natural hazard events are expected to increase significantly. Furthermore, with a projected rise in sea level of more than one foot, impacts will be spread over a much larger area of the City and threaten regionally significant utilities such as sewage treatment plants and a Baltimore waste-to-energy facility.

It is essential, therefor, to mitigate hazards and to adapt to changes in climate that we're already seeing, as well as other changes we can anticipate. This means ensuring the protection of Baltimore's residents, landscape, and the facilities and services upon which the City depends.

Existing Hazard Mitigation and Adaptation Projects

Baltimore City has an ever-growing record of important programs and actions which are centered on mitigation and adaptation. Although many will be expanded upon through the DP3 Plan, there are a few processes recently completed which will assist in these efforts.

Climate Committee

Through the Commission on Sustainability and recent adoption of the City's Climate Action Plan, the City's first Climate Committee was developed in early 2013. This committee is tasked with prioritizing climate-related strategies, identifying funding sources, and overseeing implementation. Although climate mitigation efforts related to reduction in CO2 emissions is the Committee's primary focus, climate adaptation strategies and actions

Sustainability Commission Meeting, 2013 *Source: Office of Sustainability*

Heat-Related Projects

The Urban Heat Island Mitigation Project is funded through the Public Service Commission Customer Investment Fund. This program supports the planting of additional trees and installs reflective roofs in low income communities identified as suffering from extreme heat. This project compliments existing initiatives in the Baltimore City Recreation and Parks Forestry Division which have prioritized development of an extensive tree inventory and tree planting and maintenance program.

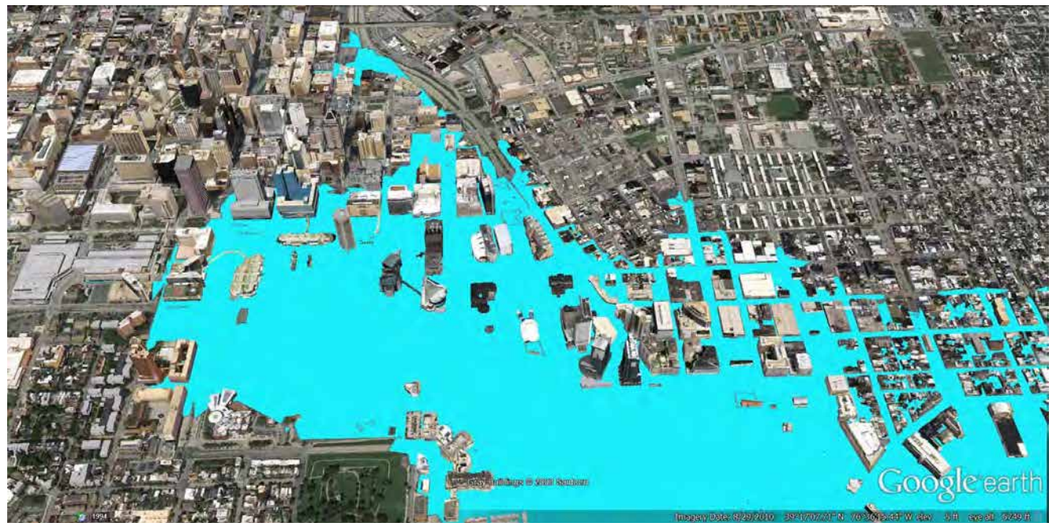
Flood Map Changes

In 2012, the City digitized its floodplain maps which allow integration of floodplain information with existing GIS resources. In addition to this upgrade, the City also updated and adopted its non-tidal floodplain maps which will assist with both mitigation and adaptation efforts. Expanding upon this effort, staff is working with State and Federal assistance to further refine non-tidal studies in key redevelopment areas and will adopt new tidal floodplain maps in spring, 2014.

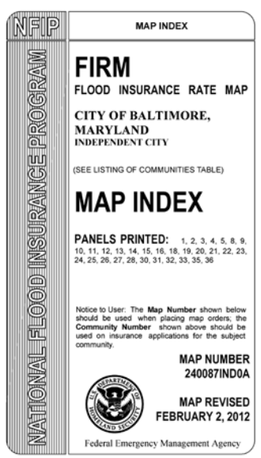
Tree Planting at local school *Source: Office of Sustainability*

The Baltimore City Health Department plays a vital role in heat-related hazard mitigation and adaptation. The Code Red Alert System was developed in ___. The purpose of the program is to prevent heat-related hospitalizations and deaths by allowing the health commissioner to declare a Code Red Heat Alert during periods of extreme heat.

Mitigation and adaptation efforts related to emergency response and recovery are also being addressed through plans and initiatives in the Mayor's Office of Emergency Management.



Utilizing new technology to display flood information *Source: Google Earth*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NATIONAL FLOOD INSURANCE PROGRAM

MAP INDEX

FIRM
FLOOD INSURANCE RATE MAP

CITY OF BALTIMORE,
MARYLAND
INDEPENDENT CITY

(SEE LISTING OF COMMUNITIES TABLE)

MAP INDEX

PANELS PRINTED: 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 35, 36

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
240087IND0A

MAP REVISED
FEBRUARY 2, 2012

Federal Emergency Management Agency

Left is Baltimore's Flood Insurance Rate Map (FIRM) Index Panel cover sheet. These maps are officially adopted by the City and are used for both flood insurance and regulatory development controls.

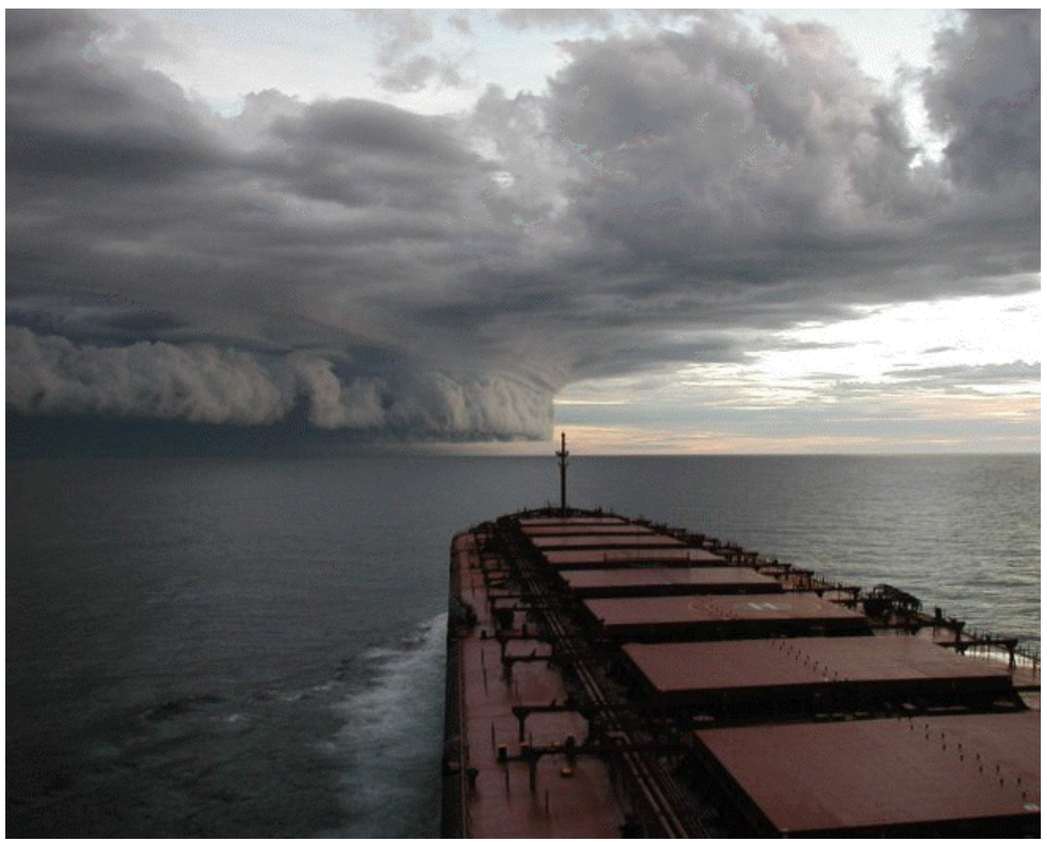
On February 2, 2012, the City adopted a new set of maps (i.e. FIRM) replacing the September 30, 1988, FIRM. The new FIRM is also a digital product. This is a significant advancement in bringing the flood insurance and regulatory program into the 20th century

The above map is an example of the future in displaying flood information. The image was created with Google Earth (February 2, 2012, FIRM 100-year flood). Google Earth allows City Planners to import digital files that will reflect a 3-dimensional representation. Some of the buildings in this image are not properly sized but the image shows the extent of waters from the Hurricane Isabel Flood in 2003. This type of graphic resonates with the public and will be used in our future campaigns to promote private sector preparedness.

Flood Insurance Rate Map *Source: City of Baltimore*

Chapter 2

Hazard Mitigation and Climate Adaptation



Hurricane Isabel approaching the East Coast, 2003 *Source: cargolaw.com*

Importance of Planning to Mitigate Natural Hazards and Adapt to Climate Change

Baltimore's Disaster Preparedness and Planning Project (DP3) is a forward-thinking alternative to the standard All Hazards Mitigation Plan (AHMP). The Federal Emergency Management Agency (FEMA) requires that local governments update their AHMPs every five years. This plan, however, is much more than a routine update. In an effort to address existing hazards while simultaneously preparing for predicted hazards due to climate change, the City of Baltimore has chosen to develop an integrated AHMP, floodplain mapping, and Climate Adaptation Plan that will introduce a new comprehensive risk-preparedness system.

What is Hazard Mitigation?

In 2000, the President signed into law the Disaster Mitigation Act of 2000 (DMA 2000). Part of this act requires local governments to develop and submit a hazard mitigation plan as a condition of receiving grant assistance for mitigation projects. According to FEMA, **HAZARD MITIGATION** is any sustained action taken to reduce or eliminate long-term risks to people and their property from hazards. The purpose of hazard mitigation planning is to identify long-range policies and actions that can be implemented to reduce current risks and future losses.

The planning process is just as important as the plan itself. Risk-based decision making guides communities become more sustainable and disaster-resistant by focusing efforts on hazards and disaster-prone areas, and by identifying appropriate mitigation actions. The process also ensures that priorities are identified along with anticipated costs. Communities have limited resources to address all concerns. The DP3 recommendations recognize and balance the expenditure of limited resources in the consideration of priorities and recommendations. As such, The DP3 acts as the foundation and clearinghouse for Baltimore's long-term strategy to reduce disaster losses, damage, and expenses. It recommends practical solutions that can be implemented by the City in partnership with businesses, non-profit organizations, community groups, volunteers, and other levels of local government. Additionally, the DP3 will follow all tasks and procedures required for local mitigation plans by FEMA.

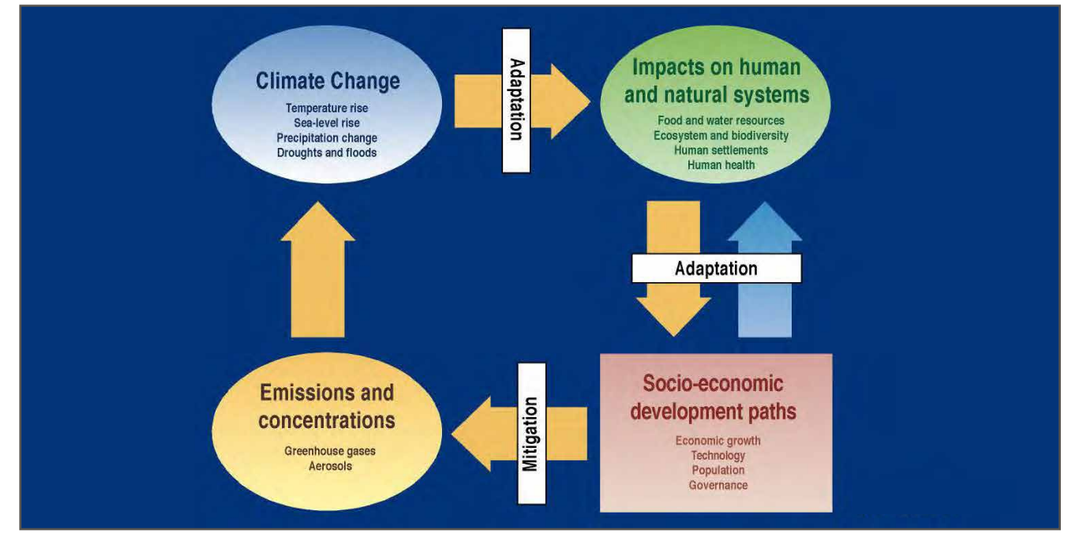
	FEMA How-to Series	Hazard Mitigation Grant and Pre-Disaster Mitigation Program (DMA 2000 Plan Criteria)
Planning Requirements	Phase 1 Organize Resources	Coordination among agencies
		Integration with other planning efforts
		Involve the public throughout the planning process
		State coordination of local mitigation planning
	Phase 2 Assess Risks	Identify all hazards
		Profile hazard events
		Assess vulnerability
		Estimate potential losses
	Phase 3 Develop the Mitigation Plan	Documentation of planning process
		Capability assessment
		Develop hazard mitigation goals
		Identification and analysis of mitigation measures
		Funding sources
	Phase 4 Implement and Monitor Progress	Adoption
		Implementation of mitigation measures
		Implementation through existing programs
		Monitoring, evaluation, and updating the plan
		Continued public involvement

What are Climate Change and Climate Adaptation?

CLIMATE CHANGE refers to any significant change in the measures of climate lasting for an extended period of time. Both human and natural activities are influencing changes in Earth's atmosphere, oceans and local governments. Changes include significant shifts in temperature, precipitation, wind patterns, and ecological effects which may occur over several decades or longer. For example, over the past century, Maryland's average temperature has risen by 1.8°F and is projected to continue rising. These rising temperatures have been accompanied by changes in local weather and climate, including more high-impact weather events, longer and more frequent heat waves, and a rise in relative sea level, just to name a few. A changing climate is now affecting many of the natural hazards that influence affect daily life, causing these events to become more extreme over time. Simultaneously, new hazards have been presenting which will introduce additional planning challenges for public safety and policy makers alike.

Nevertheless, many of the impacts associated with climate change may still be prevented by reducing greenhouse gas (GHG) emissions. Baltimore's Climate Action Plan (CAP) (discussed in Chapter 1 Introduction) is the City's most recent effort to establish policies and programs that focus on this task. The CAP highlights the GHG emission reduction measures that also have adaptation impacts and identifies priority strategies for this and other future adaptation planning strategies. While GHG mitigation initiatives continue to be essential to stabilizing the climate in the long-term, it will indeed take time for our planet to respond to GHG reductions. Consequently, GHG concentrations already present in our atmosphere commit us to a range of climate change impacts that we can expect to face in the near future.

Baltimore cannot entirely prevent the changes in climate which have already been set in motion. Without taking additional measures, a reduction in GHG emissions will not be a sufficient response. Instead, it is increasingly accepted that we must learn to live with, or adapt to, a modified climate. **CLIMATE ADAPTATION** is a process that intends to reduce long-term risks from hazards associated with climate variability and climate change. More specifically, adaptation refers to changes that are made to better respond to new climate conditions, thereby reducing harm and taking advantage of present opportunities. Climate-related impacts are already affecting Baltimore residents. Heat waves, relative sea level rise, and flooding due to more extreme precipitation events can impact the City's environmental, social, and economic systems. Building adaptation measures into this plan allows Baltimore to reduce risk to people and property while increasing resiliency of our communities and businesses.



How are Hazard Mitigation and Climate Adaptation Connected?

We must remember that climate change is going to happen over the foreseeable future and that development lasts for decades. It takes time to see the results of successful proactive planning. For decades to come, the City may continue to experience risks associated with elevated GHG emissions. While these changes cannot be prevented, Baltimore can prepare by incorporating the anticipated risks associated with climate change into hazard mitigation planning efforts. Integrating hazard mitigation planning, which focuses on past events, with climate adaptation planning, which focuses on what will likely happen in the future, offers a positive, win-win solution for Baltimore City. Both processes require a risk assessment which includes a detailed inventory of natural hazards and a vulnerability analysis. These efforts then inform actions to mitigate hazards and to adapt to predicted climate impacts. This provides clear guidance and a unified strategy that supports Baltimore's sustainability and resilience goals.

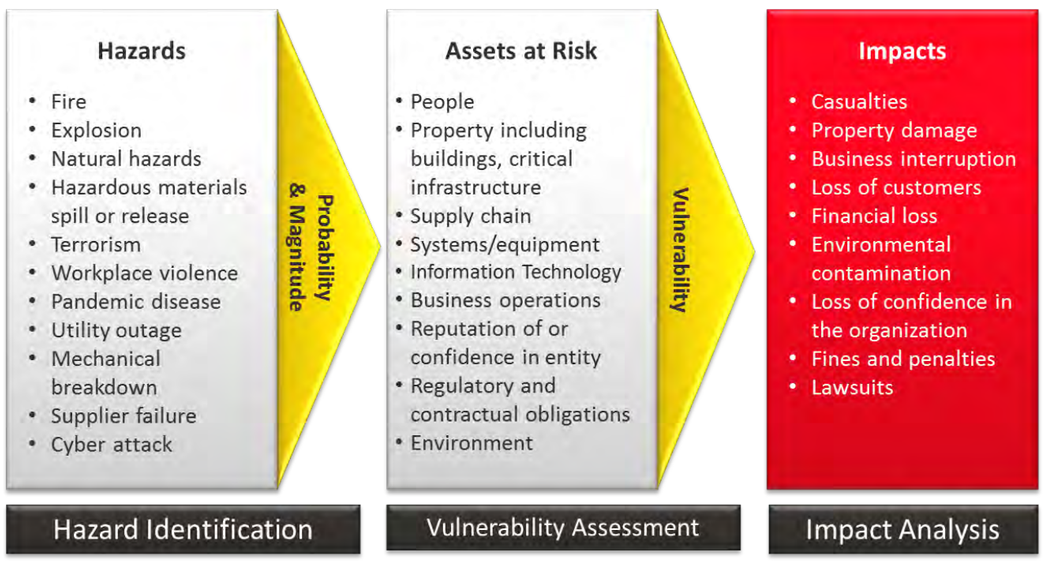
We must also recognize that it takes a significant amount of time to reach our long-term goals. Therefore, we must act now and prepare for the future by proactively mitigating natural hazards and adapting to climate change. Proactively planning for a hazard is much more effective than responding to impacts following a disaster. Additionally, a proactive method can provide significant cost savings. For instance, every dollar FEMA spends on natural hazard mitigation will produce, on average, $4 in future benefits.[1] More importantly, proactively planning for hazard mitigation and climate adaption protects the health and well-being of Baltimore's residents, and supports a sustainable, growing City.

What is a Risk Assessment?

Risk Assessment

The purpose of an AHMP is to identify policies and actions that can be implemented over the long term to reduce risk and future losses. In order to do so, a major component of the AHMP is a risk assessment. This process is a necessary first step for DP3, identifying the nature, location, intensity and probability of a threat, and then determining Baltimore's vulnerabilities and exposure to those threats while considering the capacities and resources available for the City to address or manage threats. Baltimore's risk assessment comprises the bulk of the DP3 report, with the individual steps of this analysis divided between the coming chapters.

The first step in a **RISK ASSESSMENT** is the identification of all natural hazards that have impacted, or may impact, the City. The **HAZARD IDENTIFICATION** process helps highlight the historical nature and extent of natural hazards that have impacted the City of Baltimore, considering the unique characteristics and potential consequences of each. This process also incorporates the magnitude associated with each hazard and the probability of the hazard occurring in the future. Chapter 3 Hazard Assessment discusses the historical and contemporary impacts and extent of individual hazards, using this recorded data alongside scientific projections to estimate the probability of future occurrences.



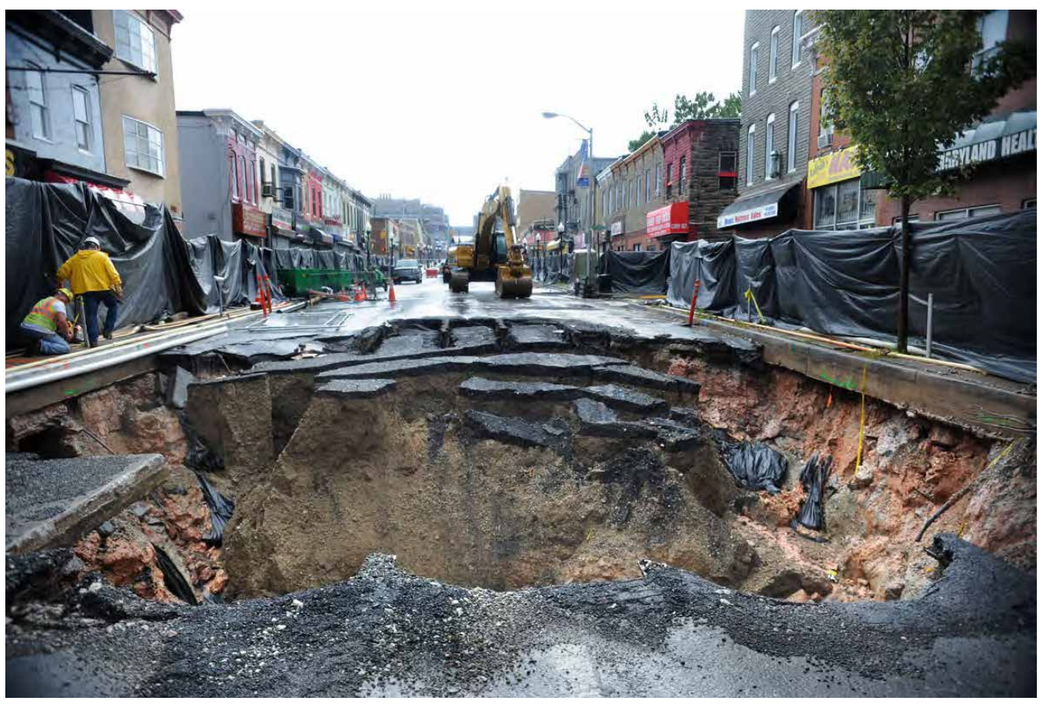
A **VULNERABILITY ASSESSMENT** complements the hazard identification process. Chapter 4 Risk and Vulnerability Assessment, further develops the risk assessment by examining Baltimore's current exposure (measure(s) of defense), sensitivity (degree to which the City could be affected), and adaptive capacity (ability for the City to recover). After addressing general, city-wide concerns for Baltimore City as a whole, the Risk and Vulnerability Chapter evaluates key areas of exposure, sensitivity, and adaptive capacity with regards to each individual hazard. Additionally, by looking ahead, the vulnerability assessment explores what, specifically, may be vulnerable (i.e. what assets — including community assets (vulnerable populations, economic assets, etc.) and critical facilities — could be at risk) to the future impacts of climate change. The vulnerability assessment includes an inventory of assets which identifies, where possible, what specific properties and resources may face greater impact, considering precisely how severe that impact may be during future events.

The initial elements examined in the vulnerability assessment lay the foundation for the **IMPACT ASSESSMENT.** This assessment identifies the degree to which, and in what manner, hazards will impact Baltimore's people, places, and economy. The impact assessment determines, for instance, how many people will be impacted, and how so. In other words, the impact assessment identifies what stands to be damaged due to a hazard event, and the cost of such a loss.

Hazard identification and vulnerability assessments are the first stages of the risk assessment. Once the possible impacts are identified, investing in appropriate hazard mitigation and climate adaptation methods can reduce the risk. To this end, the information discovered in each stage of the risk assessment (hazard identification, vulnerability assessment, and impacts analysis) is utilized in the decision-making process, and contributes to the development of the strategies and actions identified in Chapter 5. The recommendations in this report, through an understanding of the information revealed in the course of the risk assessment, aim to mitigate any risk and prepare the City to adapt to any projected changes in Baltimore's climate.

Chapter 3

Hazard Assessment



Hazard identification is the process which identifies and defines natural hazards that threaten the City of Baltimore. The hazard identification process looks at past hazard events—including an analysis of current hazards in addition to predicted threats due to climate change—and integrates damages and/or consequences that result from each hazard such as the destroyed homes, damaged trees, and compromised utility systems. Hazard identification includes the extent (severity) and probability (likelihood of occurrence) of each hazard, as well as the location of each hazard. Additionally, the process incorporates a brief explanation for hazards that are not particularly relevant for Baltimore's specific geography. For example, volcanic eruptions are not a hazard that the City of Baltimore faces now or in the near future.

In order to determine the most feasible and effective mitigation and adaptation recommendations for Baltimore, natural hazards which threaten the City had to be identified and defined, and their historical impacts analyzed. This chapter provides the following:

- Identification of hazards likely to affect the City of Baltimore;
- Profiles of the extent and severity of hazard events that have occurred in the City;
- Maps of specific locations where hazards occur; and
- Identification of predicted changes due to a changing climate.

Identification and Profile of Current Natural Hazards in Baltimore City

The process of identifying hazards included a variety of considerations and sources. The Federal Emergency Management Agency (FEMA) and the Maryland Emergency Management Agency (MEMA) provided Baltimore City with a preliminary list of natural hazards for this assessment. Based on historical data, as well as information provided by the National Oceanic and Atmospheric Administration (NOAA) and the State regarding anticipated climate impacts, city planners developed a draft list of hazards for consideration. Members of the Advisory Committee also provided input with regard to analysis of NOAA climate and weather data as recorded in the past 100 years. This was used as a baseline for comparison to changes in local climate projected to occur over the next 25 to 50 years. The analysis also incorporated most probable temperature and precipitation scenarios for the City through the year 2100 as synthesized from the most recent projections contained in the 2012 Intergovernmental Panel on Climate Change (IPCC) Report.

Further consideration was given to the apparent increase in frequency of high-impact, "no-notice" weather events to affect Baltimore and the State of Maryland since 1990. Relative to time periods prior to 1990, Baltimore has experienced a rise in frequency of high snow-accumulation winter storms, increasing frequency of severe weather outbreaks, as well as a rising number of higher average temperature readings on days that record highs are observed. The following table lists each hazard addressed in the preliminary investigation and identifies which hazards will be covered in this plan.

"NO-NOTICE" INCIDENTS:

A no-notice incident is one that occurs unexpectedly or with minimal warning. Incidents with typically predictable patterns can also become no-notice incidents when their behaviors or patterns differ from what had been predicted or expected. Due to the nature of no-notice events, the ability of emergency responders to react in a timely manner may be challenged.

List of Hazards:

Table 3–1 Preliminary Investigation

Identified Hazard	Comments	Treatment in Plan
Avalanche	Lack of mountainous terrain makes hazard improbable in Baltimore City.	Not included in the plan
Air Quality	Baltimore has very poor air quality which significantly affects residents	Addressed in "Extreme Heat" hazard profile
Coastal Erosion	Many of the city's shorelines have been bulkheaded or do not have the wave action that lead to erosion.	Not included in the plan
Coastal Storm	Past experience has shown the hazard is a threat to Baltimore City.	Addressed in "Coastal Hazards" hazard profile
Dam Failure	Baltimore City owns and operates several dams.	Addressed in "Flooding" hazard profile
Drought	Baltimore City has had experiences with drought.	Addressed in "Precipitation Variability" hazard profile
Earthquake	Interview with Maryland Geological Survey indicated that hazard may affect Baltimore City.	Addressed in "Land" hazard profile
Expansive Soils	Interview with Maryland Geological Survey indicated that hazard does not significantly affect Baltimore City.	Not included in the plan
Extreme Heat	Past experience has shown the hazard may significantly affect Baltimore City.	Addressed in "Extreme Heat" hazard profile
Flood	Past experience has shown the hazard may significantly affect Baltimore City.	Addressed in "Flooding" hazard profile
Hailstorm	Past experience has shown the hazard may significantly affect Baltimore City.	Addressed in "Precipitation Variability" hazard profile
Hurricane	Past experience has shown the hazard may significantly affect Baltimore City.	Addressed in "Coastal Hazards" hazard profile
Land Subsidence	Interview with Maryland Geological Survey indicated that hazard does not significantly affect Baltimore City.	Not included in the plan
Landslide/Land Slump	Interview with Maryland Geological Survey indicates that land slump may affect Baltimore City.	Addressed in "Land" hazard profile
Severe Winter Storm	Past experience has shown the hazard may significantly affect Baltimore City.	Addressed in "Precipitation Variability" hazard profile
Tornado	Past experience has shown the hazard may significantly affect Baltimore City.	Addressed in "Wind" hazard profile
Tsunami	According to MEMA tsunamis are of concern along the East Coast of the United States.	Addressed in "Coastal Hazards" profile
Volcano	Interview with Maryland Geological Survey indicated that hazard does not significantly affect Baltimore City	Not included in the plan
Wildfire	While Baltimore has some forests, they are not huge, uninterrupted tracts of wildland. Baltimore does not have other elements that generate or spread wildfires, like arid climate, softwood/ conifer trees, large expanses of steep slopes (>40%), or prolonged drought.	Not included in the plan
Windstorm	Past experience has shown the hazard may significantly affect Baltimore City.	Addressed in "Wind" hazard profile

This Plan will address the following natural hazards by analysis of impacts on Baltimore City and recommendations for mitigation and adaptation strategies:

Flooding: Flooding and Dam Failure

Coastal Hazards: Tropical Storms and Hurricanes; Sea Level Rise; and Storm Surge/Coastal Inundation; Tsunami

Precipitation Variability: Precipitation; Thunderstorms, with Lightning and Hail; Winter Storms and Nor'Easters; Drought

Wind: Associated with Storms; Derechos; Tornados

Extreme Heat: Heat and Air Quality

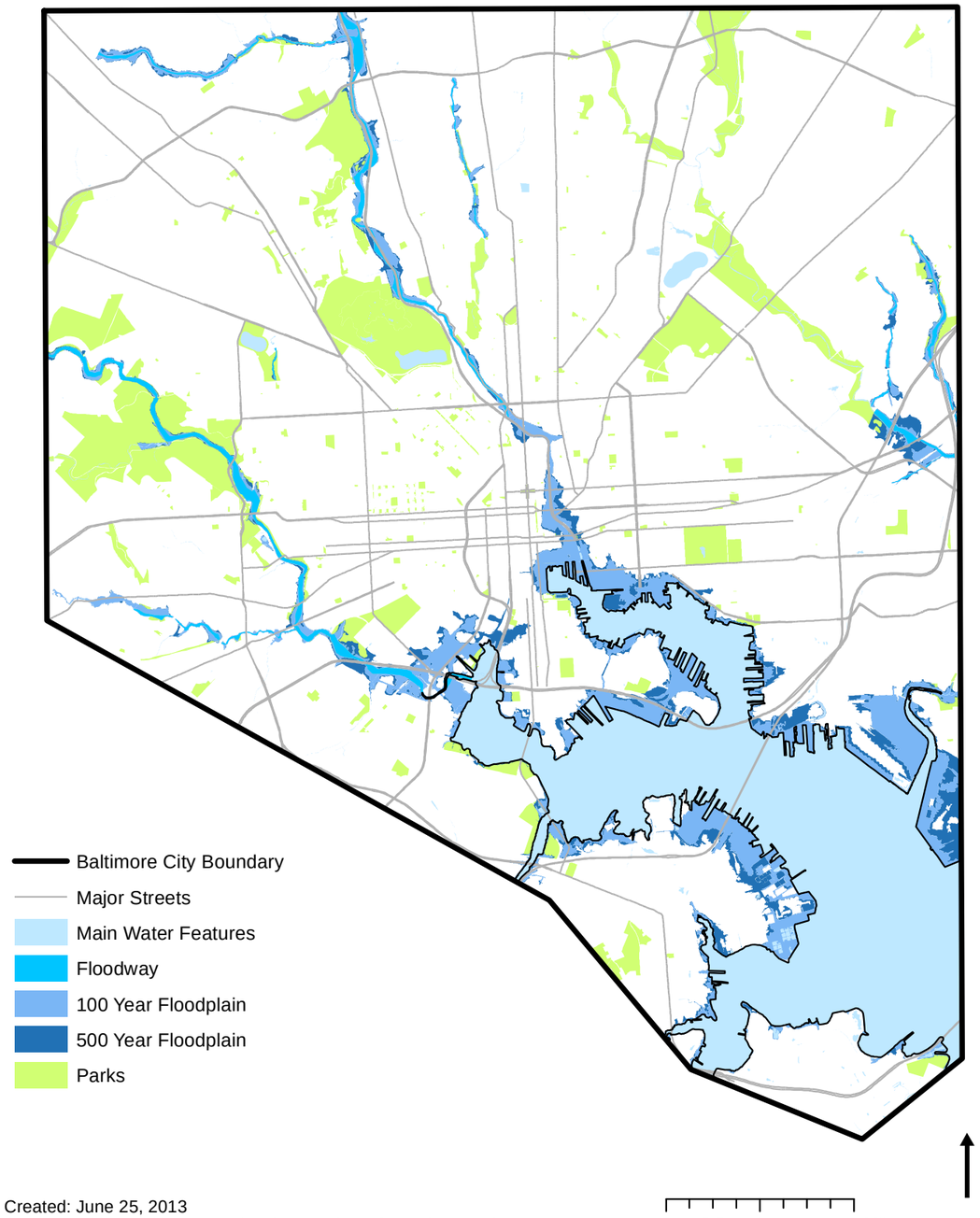
Land: Earthquakes; Landslides; Karst/Sinkholes

Figure 3–8 Image of flooding and subsequetnt damage in Colorado

Flooding

Flooding occurs when rivers, creeks, streams, ditches, or other hydrological features receive too much water. Three categories of flood are common in the State of Maryland: flash, riverine, and coastal. In Baltimore, major flooding events are the result of riverine flooding along the stream tributaries of the Patapsco River — including the Gwynns Falls and the Jones Falls, as well as their own tributaries — or from tidal flooding in the Northwest Harbor and Middle Branch of the Patapsco River.[1] Riverine flooding, usually from persistent rain or snowmelt, forces excess water beyond the water body and into the adjacent floodplain.[2] According to the 2012 FEMA Report, *Flood Insurance Study* (FIS) for the City of Baltimore, riverine flooding in the City is most often attributed to the following factors: "urbanization, which creates more runoff from impervious zones and higher, sharper flood peaks; stream channel encroachments, which include structures within the floodplain and undersized railroad and roadway bridges; and inadequate storm sewer drainage." Along the City's waterfront, high tides amplify flooding events.[3] Figure 3–1 delineates the Baltimore City Floodway along with the FEMA-designated 100- and 500-year floodplain areas. 100-year floods are those which have a 1.0 percent chance of being equaled or exceeded in scale in any given year; whereas the 500-year flood designation relates to a flood with an approximate 0.2 percent chance of being equaled or exceeded.[4]

Most of Baltimore's recorded floods have been the result of either flash flooding during sudden, short-lived rainstorms, or localized flooding due to poor drainage and stormwater management. *The Flood Insurance Study for the City of Baltimore* indicates that major historic flood events occurred in 1817, 1837, 1863, 1868, 1933, 1955, 1972, and 1975. These floods led to the loss of human life and caused significant damage to dwellings, industries, and infrastructure. In August 1817, flooding along the Jones Falls swept away homes, bridges, and livestock. Floodwaters during this event were reportedly between 12 and 20 feet above normal levels.[5] Similarly, the Jones Falls rose 20 feet during the flood of July 1868, when the river claimed more than 50 lives and caused millions of dollars in damages, primarily in downtown Baltimore. In July 1923, recorded flood damage was even more immense; and the flood of 1966 took 39 lives.[6] A list of additional major flood events, dating back to 1952, is found in Table 3–2 Historic Floods in Baltimore City with Damage Information below.



Created: June 25, 2013
Source: Baltimore City Enterprise Geographic Information Services

Figure 3–1 Baltimore City Floodway

Table 3–2 Historic Floods in Baltimore City with Damage Information

Dates	Type	Location	Description	Cost
9/1/1952	Coastal, Flash, River	Regional	Hurricane Able cause major flooding and washed out the B&O Railroad in Baltimore. 11 barges were torn loose from their moorings in the harbor, and 21 vehicles were swept into the harbor.	$500,000
10/15/1954	Coastal, Flash, River	Regional	Hurricane Hazel killed 6 people in Maryland and dropped 5-6 inches of rain in 8 hours. Heavy winds caused 6 foot storm surge.	$28,000,000 in Maryland
8/13/1955	Coastal, Flash, River	Regional	Hurricane Connie caused wide-spread flooding throughout Maryland with 10 inches of rain in 72 hours and killed 16 people.	$33,900,000 in Baltimore City
8/1/1971 to 8/2/1971	Flash	Baltimore City and Baltimore County	Between 5 and 12.5 inches of rain over 8 hours. 16 deaths attributed to flooding. Storm closed major highways in the region, left 20,000 residents without power, and displaced hundreds.	Est. $1,000,000
6/23/1972	Coastal, Flash, River	Regional	Tropical Storm Agnes killed 21 throughout Maryland and dropped 8 inches of rain in one day.	$110,000,000 in Maryland, $3.5 Billion nationwide
9/22/1975 to 9/26/1975	Flash	Regional	The remnants of Hurricane Eloise stalled and combined with other storm systems, dropping 14 inches of rain in Westminster, MD between Sept. 22 and 26. 17 deaths attributed to flooding	Est. $300,000,000 throughout Mid-Atlantic
9/6/1979	Flash	Regional	Tropical Storm David spawned 8 tornadoes and multiple flash floods in the Baltimore area and killed 15 nationwide.	$320,000,000 nationwide
9/19/2003	Coastal, Flash	Regional	Hurricane Isabel caused extensive flash floods as well as a storm surge of 8 feet in Baltimore City. 15 businesses and 570 homes sustained major damage, and 100 structures collapsed. 8 deaths are attributed to the storm throughout Maryland.	$4,900,000 in Baltimore City, $945,000,000 nationwide
7/7/2004	Flash	Mt Washington along the Jones Fall	21 vehicles lost in water, 54 911 calls for flooded basements	Unknown
6/25/2006 to 6/28/2006	Flash	Mt Washington and Clipper Mill Rd.	The Jones Fall rose 9.8 feet in 4 hours and 15 minutes. 94 residents displaced.	Unknown
11/16/2006	Flash, Coastal	Regional	Mudslide on 295 NB near Waterview exit. I83 NB from Fayette to Chase St. closed due to flooding. Harbor Hospital sustained minor flood damage.	Unknown
7/23/2008	Flash, Coastal	Patapsco Ave.	Heavy rain and high winds left 27,000 customers in the region without power. In Baltimore City, Part of the Vietnam Veterans Memorial Bridge was flooded, and traffic was redirected. I83 closed at President and Monument Street due to standing water. Sinai Hospital emergency department sustained minor damage from flood waters.	Unknown
9/26/2008	Flash	Mt Washington, Union Ave., and Clipper Mill Rd.	Major storm system with 45 mph gusts and 2 inches of rain. 100 Residents displaced, 15 businesses sustained damage.	Unknown
8/12/2010	Flash, Coastal	Regional	Heavy thunderstorms hit the region during morning rush hour and left 9500 customers without power. Several roadways closed due to flooding, including: Eastern Ave. and Highland Ave., Fleet St. between Caroline and Bond, Pulaski Highway at Monument St. and Moravia, and the 200 block of N. Lakewood Ave.	Unknown
3/10/2011	Flash	Mt Washington, Union Ave., and Clipper Mill Rd.	2.5 inches of rain during evening rush hour forced evacuations and closed I83 near Penn Station. Runoff from storm water infiltrated sanitary sewer causing 10,000 gallons of untreated sewage to spill. Dozens of basements flooded.	Unknown
4/16/2011	Coastal	Regional	Large series of storms spawning 100 tornados from North Carolina through the Mid-Atlantic caused flooding in Fells Point and the Inner Harbor and left 17,000 customers without power in Baltimore City.	Unknown
10/29/2012	Coastal	Regional	Hurricane Sandy caused flooding along Fells Point and the Inner Harbor with a moderate storm surge and 5.5 inches of rain.	$65 billion nationwide

The Jones Falls, especially where it passes through the Mt. Washington neighborhood of Baltimore, has been a recurrent flood threat to the adjacent structures. The historic mills that were sited at the edge of the river have since been converted into mixed use buildings which are now home to residents and successful businesses. These properties continue to be flooded; in recent years, severe flooding in Mt. Washington has occurred most notably in 2004, 2006, and 2008. Properties which frequently suffer damage from floods are referred to as "repetitive loss properties." FEMA identifies repetitive loss properties as those which have experienced two or more flood insurance claims of at least $1,000 within a 10-year period since 1978. There are 52 such properties in Baltimore City, and currently only 17 of those properties are insured by FEMA. Close to $10 million dollars in flood insurance claims have been attributed to these properties. Due to privacy concerns associated with flood insurance, the type of information that can be shared regarding repetitive loss properties is restricted. This information is considered to be legally privileged and confidential, and use is protected under the Privacy Act of 1974, 5 U.S.C. Section 552(a). However, while detailed property information may not be discussed, the locational information may still be represented. Figure 3–2 Repetitive Loss Properties, below, notes the locations of Baltimore's repetitive loss properties. Note how these properties are clustered around the floodways and floodplains.

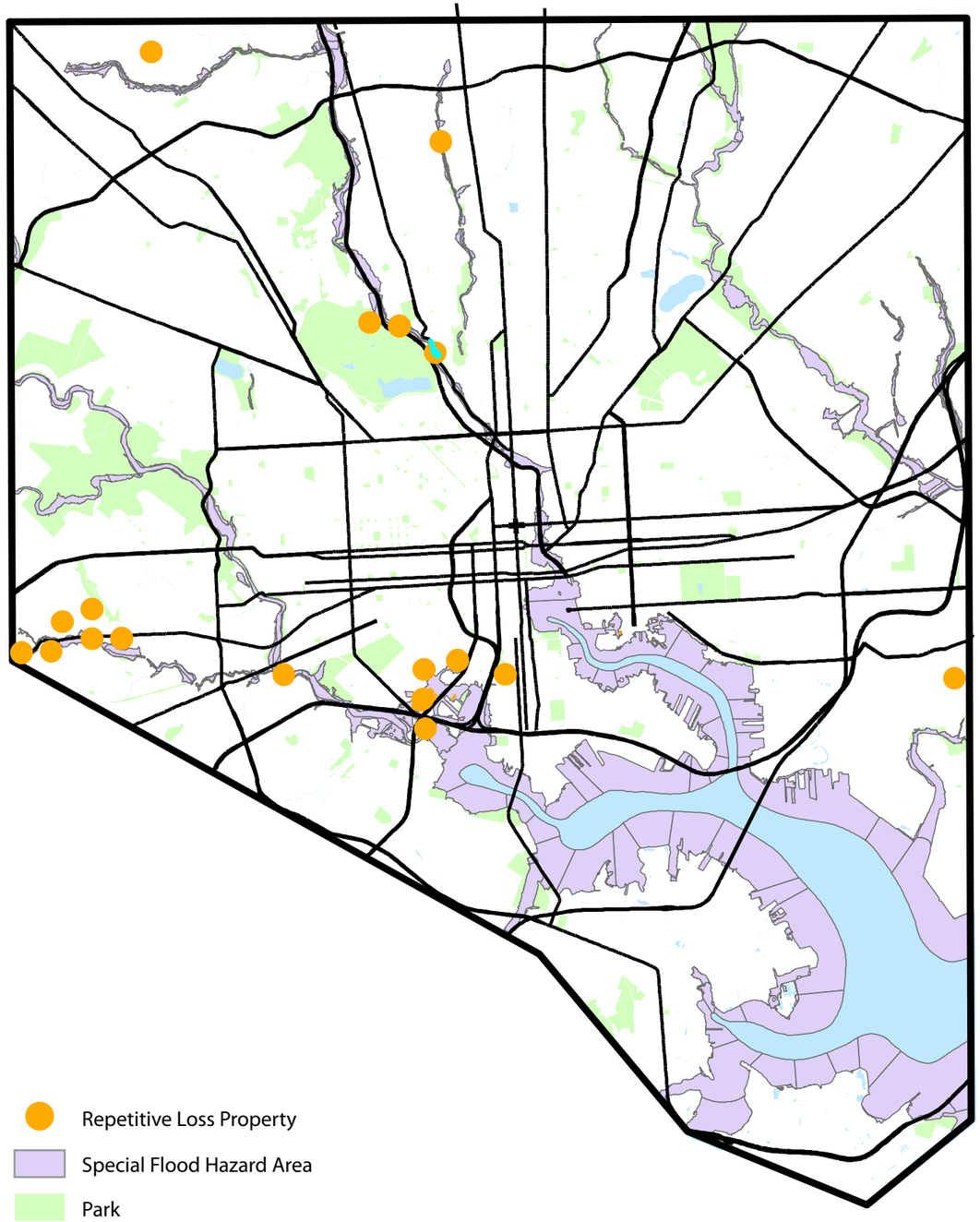


Figure 3–2 Repetitive Loss Properties

In Baltimore, tidal flooding usually occurs as a result of storm events, such as nor'easters or hurricanes (see Precipitation Variability Hazard Profile; see Coastal Hazards Profile). As an additional concern, flood maps indicate that some areas of tidal flooding are also affected by high velocity flooding. High velocity flooding, where floodwaters can move faster than five feet per second, can exacerbate flood damage. During the storm of 1933, downtown Baltimore was inundated by tides which arose 8.33 feet at Fort McHenry. Flooding during Tropical Storm Agnes, in June 1972, stands as one of Maryland's biggest natural disasters. In some areas, flood peaks were twice as high as the 100-year recurrence interval.[7] Statewide, Agnes caused $43 million in damages to public infrastructure and $66 million in damage to private property. Baltimore City alone suffered $33.9 million in losses.[8] More recently, in fall 2003, Hurricane Isabel hit Baltimore. At the time, the storm was referred to as the "perfect" 100-year tidal flood—meaning that floodwaters reached depths predicted for 100-year floods. The City's Flood Insurance Rate Maps reflected that the extent of Isabel's flooding corresponded to the adopted 100-year flood zone. The City was regulating development based on these maps. Fortunately, thanks to Baltimore City's freeboard requirements, buildings with first floors at or above the 1' freeboard elevation did not sustain major flooding damage, and only 16 flood insurance claims were filed. It is worth noting, that even through those maps reflect Isabel's impact as a 100-year storm, the new tidal floodplain analysis show that Isabel was a 500-year event.

Figure 3–3 The Jones Falls, Showing buildings that sit within the floodplain in orange

Floods in Baltimore have forced evacuation, displaced hundreds of residents, overwhelmed emergency communication lines, and negatively impacted businesses. Major storm events and floods become even more menacing when critical emergency facilities are impacted, as was the case in November of 2006 and July of 2008 when different hospitals were impacted by floodwaters; or in 2012, when Sandy flooded research facilities at Johns Hopkins (though it had little impact on patient care facilities). This vulnerability must be taken into account as the City looks to the future. In Baltimore, 5.19 square miles of property (6.4 percent of the City's total land area) currently rests within the flood zone, while 3 percent of Baltimore's overall land — primarily in the Inner Harbor and the Fells Point Historic District — is within the coastal floodplain. By the end of the century, approximately 180 square miles of dry land along Maryland's coastline is expected to be inundated. Coupled with more frequent and extreme precipitation events (See Precipitation Variability Hazard Profile) these conditions could present a regular hazard.

Dam Failure

As an aspect of flooding, risks associated with dam failure are considered in this plan. Dams are constructed to manage water storage, control flooding, and divert runoff into reservoirs upstream. Dams are sources of concentrated vulnerability and can lead to serious regional disasters when they fail. Dam failure is the collapse or breach of the dam structure, for which there is often either very little or no advance warning. While most dams in the Baltimore region have relatively small water volumes and failures would therefore have little or no repercussions, dams with larger storage volumes can have disastrous consequences should they fail.

Dam failures can be caused by any one or a combination of the following:

- Prolonged periods of rainfall and flooding (cause of most dam failures in the U.S.)
- Inadequate spillway capacity, resulting in excess overtopping flows.
- Internal erosion caused by embankment or foundation leakage or piping.
- Improper maintenance, including failure to remove trees, repair internal seepage problems, replace lost material from the cross section of the dam and abutments, or maintain gates, valves, and other operational components.
- Improper design, including the use of improper construction materials and construction practices.
- Negligent operation, including the failure to remove or open gates or valves during high flow periods.
- Failure of upstream dams in the same drainage basin.
- Landslides into reservoirs, which cause surges that result in overtopping.
- High winds, which can cause significant wave action and result in substantial erosion.
- Earthquakes, which typically cause longitudinal cracks at the tops of the embankments, thereby leading to structural failure (see the Land Hazards Profile).

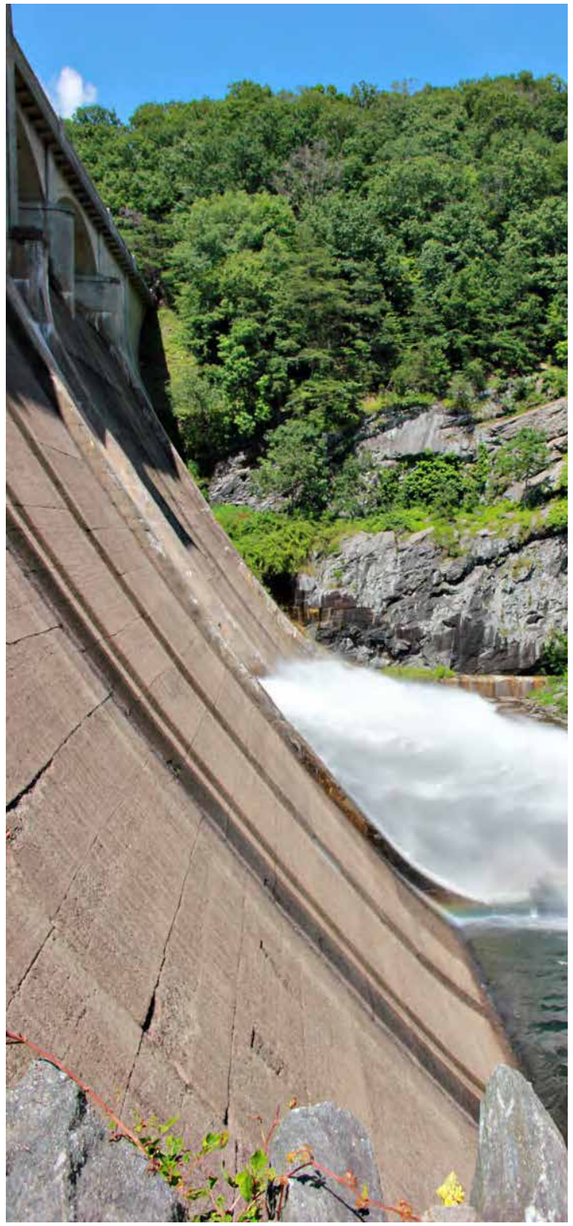


Figure 4–4 Prettyboy Dam
Source: m3liss.wordpress.com

Table 3–3 Baltimore City Dams by Waterway and Hazard Potential

Dam Name	Waterway	Hazard Potential Classification	EAP
Druid Hill Lake	Offstream-Jones Falls	H	X
Guilford Reservoir	Offstream-Stony Run	H	X
Hillen Road Water Supply Lake	Offstream-Herring Run	H	X
Lake Ashburton	Gwynns Run	H	X
Lake Montebello	Offstream-Herring Run	S	
Lake Roland Dam	Jones Falls	H	X
Liberty Dam	North Branch, Patapsco River	H	X
Loch Raven Dam	Gunpowder River	H	X
Montebello Waste Water Lake	Offstream-TR-Herring Run	L	
Old Loch Raven Dam	Gunpowder River	L	
Pecks Branch Dam (Ashburton)	Offstream-Gwynns Run	H	X
Prettyboy Dam	Gunpowder Falls	H	X
Pikesville Reservoir	Offstream – Gwynns Falls	H	X
Mays Chapel Reservoir	Offstream – Jones Falls	H	X
Towson Reservoir	Offstream – Jones Falls	H	X

National Inventory of Dams, http://crunch.tec.army.mil/nid/webpages/nid.cfm and Hal Van Aller, P.E. of MDE Dam Safety Division

In Maryland, most dams consist of an earthen embankment to retain water and a combination of spillways designed to convey water safely around or through the facility. The Baltimore City Department of Public Works owns and maintains the seven Public Works dams around the City. All of the City's dams are earthen (one is earthen with rockfill), and all but one are considered off-stream dams. The National Inventory of Dams, a database maintained by the U.S. Army Corps of Engineers, classifies one of the seven dams as being a low hazard, one as being a significant hazard, and five as high hazard dams. Low hazard potential dams are those where failure or improper operation would result in no probable loss of human life and low economic or environmental losses. Significant hazard potential dams are those where failure or improper operation would result in no probable loss of human life, but can cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns. High hazard potential dams are those where failure or improper operation will likely cause loss of human life. Table 3–3 Baltimore City Dams by Waterway and Hazard Potential details the names, associated waterways, and the hazard potential classification for all of the dams found within, or used and maintained by, Baltimore City. All Baltimore City dams classified as being high hazard potential have corresponding Emergency Action Plans (EAP).

Stanford University maintains the National Performance of Dams Program database which documents dam incidents. Incidents are defined as events that affect the structural and functional integrity of dams but which do not necessarily cause failure, and does not include ordinary maintenance and repair, vandalism, acts of war, recreational accidents, or sabotage. This database has no record of dam incidents for facilities in the City of Baltimore.

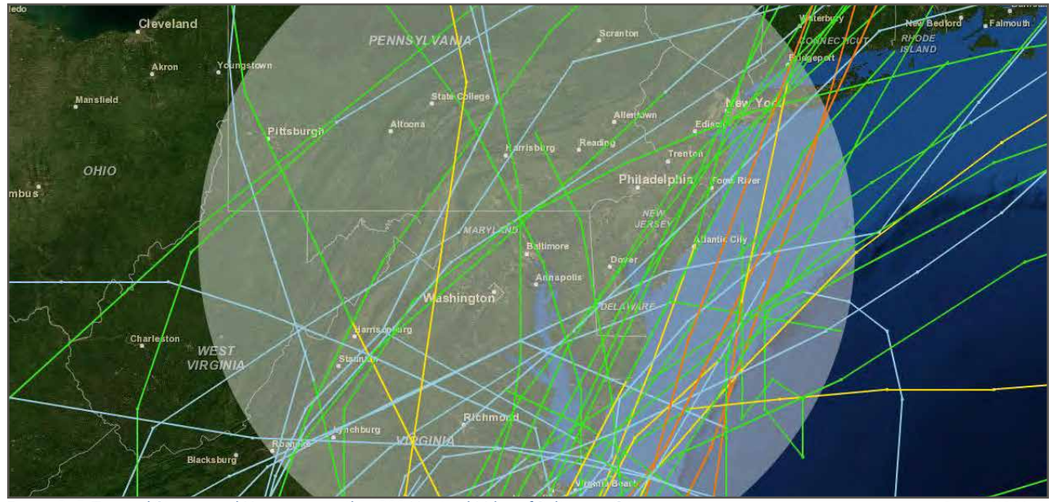


Figure 3–5 Tropical Storms and Hurricanes within 200 Nautical Miles of Baltimore City *Source: NOAA*

Coastal Hazards

Tropical Storms and Hurricanes

Tropical storms and hurricanes are very intense, low-pressure wind systems that form over tropical or sub-tropical waters. Both tropical storms and hurricanes are considered tropical cyclones; the distinction, however, is based on wind speeds and, typically, on the amount of destruction produced (i.e. the "impact"). Tropical storms are given a name when the maximum sustained wind speeds within the storm's eyewall reach or exceed 39 mph. If a tropical storm continues to grow in strength, and peak wind speeds reach 74 mph, it is then declared a hurricane.

The Saffir-Simpson Hurricane Intensity Scale (shown in Table 3–4 Saffir-Simpson Scale, right) categorizes intensities of hurricanes based on wind speed and the expected storm surge. A storm surge, one of the most damaging impacts of a coastal storm event, is an abnormal local rise in sea level, caused by deepening low pressure in the core of the storm that creates an extreme difference in barometric pressure between the tropical system and the atmospheric environment outside the system. As a result, a dome of water rises under the eye of the storm, and is eventually pushed onto the coastline as the storm makes landfall. The height of a surge is measured as the deviation (in feet) above average sea level. In extreme circumstances, storm surge can, and has exceeded a height of 25 feet in other areas around the world. Storm surge is especially damaging due to the combination of a high volume of water covering a large geographic area that is moving toward or across land at high velocity. According to NOAA, 9 out of every 10 deaths associated with coastal storms are caused by storm surge—demonstrating why this water phenomenon is often the greatest threat to life and property from a tropical system. As the scale demonstrates, when a storm grows more intense, the resulting storm surge is more likely to reach greater heights and bring more significant damage. Storm surge may also accompany significant coastal storms that are known along the east coast as "Nor'easters." (For a discussion of hazards associated with Nor'easters, see the Winter Storms and Climate Influences section below).

Figure 3–5 Tropical Storms and Hurricanes within 200 Nautical Miles of Baltimore City illustrates the paths of previous hurricanes that have come near the City, signifying storm magnitude by color. As it demonstrates, storms crossing directly through Baltimore are typically tropical or sub-tropical storms.

Coastal storm systems can persist for extended periods of time, and across great distances. As hurricanes are sometimes hundreds of miles across, their effects can be felt in areas that may be quite distant from the storm's center. Hurricane Agnes in 1972, for example, did not pass directly over Baltimore, but is still considered to be one of the most damaging hurricanes in Baltimore's history. At impact, Agnes was a Category 1 hurricane. Baltimore experienced widespread flash flooding and considerable riverine flooding. The State of Maryland reported 21 storm-related deaths and total public sector cost in excess of $110 million. In 2003, the region was hit by the Category 2 Tropical Cyclone, Isabel. In Baltimore City, Isabel's cost to the public sector totaled $4,883,364. Fifteen commercial properties and more than 570 homes were declared uninhabitable due to Isabel's major flood damage; while approximately 100 structural collapses occurred throughout the county. As an additional hazard, Tropical Storms and Hurricanes are also capable of spawning tornados. For example, in 1979, Tropical Storm David spawned 8 tornados in Maryland. Similarly, Hurricane Irene produced tornados near the Eastern Shore of Maryland.

As hurricanes and tropical storms near land, they may generate torrential rains, high winds, storm surge inundation, coastal flooding, and inland flooding. Hurricanes can also produce difficult-to-predict tornadoes within embedded rain bands (for a description of tornado hazards, see the Wind Hazard Profile). Depending on where a tropical system makes first landfall, coastal storms can lead to dangerous storm surges and inundation of low-lying land. In Baltimore, hurricanes and tropical storms have produced wind damage, riverine flooding along tributaries, and inundation of shorelines and harbors by way of intense storm surges.

Due to a combination of geographic and climatic factors, major hurricanes of Categories 3 and above generally begin to weaken upon reaching the Mid-Atlantic. Prior to making landfall, a storm may have rapid wind speeds — and may be classified as one or more categories higher, with much faster winds — than what is recorded once the storm makes landfall. 1969's Camille, for example, dropped from 165 mph to wind speeds of just 25 mph when passing over Baltimore. As they make landfall, however, wind speeds are diminished (1969's Camille went from 165 mph wind speeds to just 25 mph) and the category of storm often becomes lower. This change is demonstrated in Table 3–6 Tropical Storms and Hurricanes within 200 Nautical Miles of Baltimore City, which reveals key information about significant tropical storms and hurricanes that have passed within 200 nautical miles of Baltimore City since 1950. In the past 61 years, 51 hurricanes and other tropical

Table 3–4 Saffir-Simpson Scale

Category	Wind Speed	Storm Surge	Expected Damage
1	74-95 mph	4-5 ft.	**Very dangerous winds will produce some damage:** Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days
2	96-110 mph	6-8 ft.	**Extremely dangerous winds will cause extensive damage:** Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3	111-129 mph	9-12 ft.	**Devastating damage will occur:** Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4	131-156 mph	13-18 ft.	**Catastrophic damage will occur:** Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months
5	>157 mph	>18 ft.	**Catastrophic damage will occur:** A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Derived from NOAA National Hurricane Center: Saffir-Simpson Scale (http://www.nhc.noaa.gov/aboutsshws.php) and Understanding Your Risks, FEMA 386-2, 2-23

Table 3–6 Tropical Storms and Hurricanes within 200 Nautical Miles of Baltimore City

Storm	Year	Start Date	End Date	Wind Speed (KTS)	Max Wind Speed	Category
ABLE	1952	Aug. 18	Sep. 2	40	90	TS
BARBARA	1953	Aug. 11	Aug. 16	65	95	H1
CAROL	1954	Aug. 25	Sep. 1	85	85	H2
HAZEL	1954	Oct. 5	Oct. 18	110	115	H3
CONNIE	1955	Aug. 3	Aug. 15	45	125	TS
DIANE	1955	Aug. 7	Aug. 21	45	105	TS
CINDY	1959	Jul. 5	Jul. 12	40	65	TS
GRACIE	1959	Sep. 20	Oct. 2	60	85	TS
BRENDA	1960	Jul. 28	Jul. 31	45	50	TS
DONNA	1960	Aug. 29	Sep. 13	95	140	H2
UNNAMED	1961	Sep. 12	Sep. 15	35	35	TS
DORIA	1967	Sep. 8	Sep. 21	50	75	TS
CAMILLE	1969	Aug. 14	Aug. 22	25	165	TD
ALMA	1970	May. 17	May. 27	25	70	TD
DORIA	1971	Aug. 20	Aug. 29	50	55	TS
GINGER	1971	Sep. 6	Oct. 5	30	95	TD
AGNES	1972	Jun. 14	Jun. 23	45-60	85	TS
BELLE	1976	Aug. 6	Aug. 10	90	105	H2
SUBTROP:SUBTROP 3 1976	1976	Sep. 13	Sep. 16	20	40	TD
BOB	1979	Jul. 9	Jul. 16	20	65	TD
DAVID	1979	Aug. 25	Sep. 7	40	150	TS
FREDERIC	1979	Aug. 29	Sep. 14	35	65	TS
BRET	1981	Jun. 29	Jul. 1	40	60	TS
DEAN	1983	Sep. 26	Sep. 30	55	55	TS
BOB	1985	Jul. 21	Jul. 25	30	65	TD
DANNY	1985	Aug. 12	Aug. 20	25	80	TD
GLORIA	1985	Sep. 16	Oct. 1	75	125	H1
HENRI	1985	Sep. 21	Sep. 24	35	50	TS
CHARLEY	1986	Aug. 13	Aug. 29	65	70	H1
CHRIS	1988	Aug. 21	Aug. 30	20	45	TD
DANIELLE	1992	Sep. 22	Sep. 26	40	55	TS
BERYL	1994	Aug. 14	Aug. 18	15	50	TD
BERTHA	1996	Jul. 5	Jul. 17	60	100	TS
FRAN	1996	Aug. 23	Sep. 9	40	105	TS
DENNIS	1999	Aug. 24	Sep. 8	20	90	TD
FLOYD	1999	Sep. 7	Sep. 19	60	135	TS
GORDON	2000	Sep. 14	Sep. 21	25	70	TD
HELENE	2000	Sep. 15	Sep. 25	40	60	TS
ALLISON	2001	Jun. 5	Jun. 18	30	50	TD
ISABEL	2003	Sep. 6	Sep. 19	65	140	H1
BONNIE	2004	Aug. 3	Aug. 13	30	30	TD
CHARLEY	2004	Aug. 9	Aug. 15	40	130	TS
GASTON	2004	Aug. 27	Sep. 2	35	65	TS
IVAN	2004	Sep. 2	Sep. 24	25	140	TD
JEANNE	2004	Sep. 13	Sep. 29	35	105	TS
CINDY	2005	Jul. 3	Jul. 11	30	65	TD
ERNESTO	2006	Aug. 24	Sep. 4	40	65	TS
BARRY	2007	May. 31	Jun. 5	40	50	TS
HANNA	2008	Aug. 28	Sep. 8	45	75	TS
IRENE	2011	Aug. 21	Aug. 29	65	105	H1
SANDY	2012	Oct. 21	Oct. 30	80	95	H1

storms have passed within 200 nautical miles of Baltimore, an annual frequency of 0.8 hurricane events. This chart indicates the Categories and wind speeds of systems as they approached and impacted Baltimore, as opposed to what may have been recorded prior to a system making landfall. To demonstrate the severe change in speed over land, maximum wind speeds have also been noted.

Since 1950, Baltimore has not suffered a direct hit by any storm greater than a Category 1 hurricane (though higher intensity storms had still passed within 200 nautical miles of the City). However, as noted, storms like Agnes and Isabel have caused great amounts of flooding and damage. Due to the unpredictable nature of storms, Category designation does not always accurately reflect a storm's potential damage in Baltimore. Indeed, severe damage has occurred to property and natural coastlines from less-than-major Category hurricanes. This damage is caused by a remnant storm surge decreasing more slowly than expected following the weakening of the land-falling storm.

It is important to note, however, that a storm's weakening allows "accumulated cyclone energy" (ACE) to quickly affect a much larger area as the storm nears land at higher latitudes. Thus, the weakening storm will undergo an expansion of the wind field and, while maximum sustained winds in the storm's core usually decrease, the overall area that is significantly affected by tropical storm force or hurricane force winds becomes much larger.

Hurricane Sandy, in October 2012, is one example of this phenomenon: in the day prior to landfall, the wind field expanded to a diameter greater than 1,000 miles. On October 28-29, portions of the City of Baltimore observed maximum wind gusts of 63 mph, with brief periods of sustained winds near tropical storm force of 39 mph. These winds were accompanied by extremely heavy downpours of rain. At the time, the center of Hurricane Sandy was east of Baltimore in the western Atlantic Ocean. This is one example of how an expanding wind field, even from a weakening tropical system, can generate multiple hazards hundreds of miles from the storm's center.

Additionally, Hurricane Sandy produced a spike of more than 3 feet in tidal rise at the Inner Harbor within a short period of time as the storm was passing to the north and east of Baltimore. Were a storm like Sandy to occur in 2025, 2050 or 2100, it would more easily inundate low laying areas with a similar, or even smaller, surge. Taking into consideration recent projections for sea level rise in Maryland, which suggests relative sea level rise could increase by as much as 5.7 feet by the end of the century, storm surge hazards will require significant mitigation strategies.[9] On top of this projected rise, even a low-end tropical storm could produce water damage greater than that from Isabel if construction measures are not incorporated immediately.

Baltimore's extensive hurricane history and the mapped hurricane inundation areas show that hurricanes are a significant hazard to the City. Additionally, hurricanes have the potential to have a considerable impact on human health. Table 3–7 Coastal Hazards - Injuries and Deaths, below, indicates that a total of 200 injuries and 1 fatality were caused by coastal hazards in recent decades.

Table 3–7 Coastal Hazards - Injuries and Deaths

County/City	Total Injuries	Total Deaths
Baltimore City	200	1

Source: Table 3-37, Maryland Emergency Management Agency, 2011: 127-128.

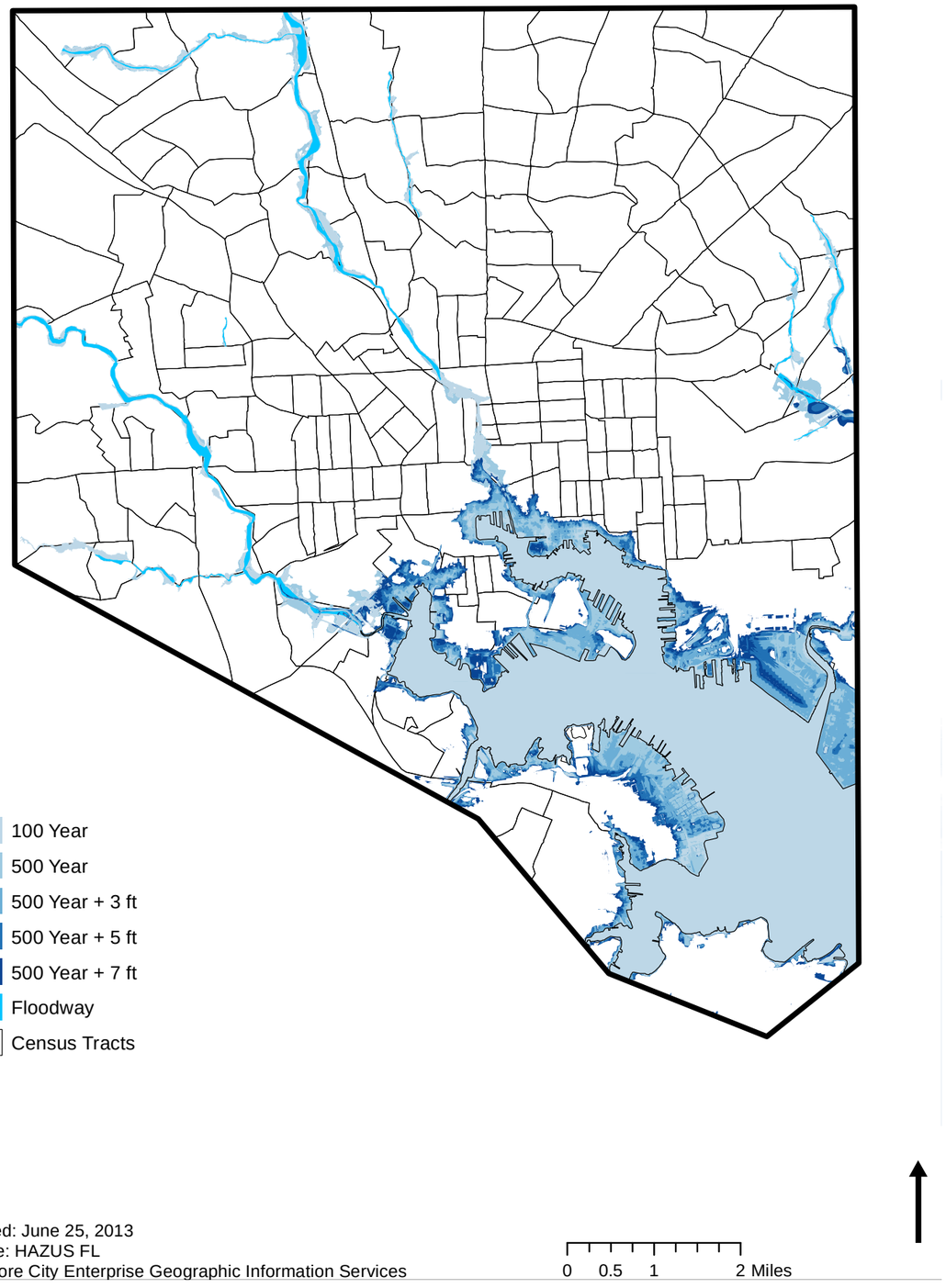


Figure 3–6 Baltimore City Flood Hazard Areas Showing 3ft, 5ft, and 7ft Sea Level Rise Scenarios

Sea Level Rise

For a number of reasons — including climate change and an anticipated increase in global temperature — the world's sea levels have been rising in the past 100 years. In Baltimore, NOAA sea level gauges at Fort McHenry, as well as other official reports, have shown that relative sea level in the Harbor area has increased by 12 inches since 1900. The most current sea level data from the Maryland State Climate Change Commission, and from the Intergovernmental Panel on Climate Change, indicate that sea levels in the Baltimore region could experience an additional rise of 1.5 to 3 feet in the next 50 years. Approximately 1.33 percent of Baltimore City land is within the projected sea level rise zone.[10]

Projections for global increases in sea level range from less than 1 foot for lower emissions scenarios to as much as 1.6 feet for higher emissions scenarios by the middle of the century. By 2100, these projections swell to between 1.7 and 4.6 feet. In Maryland, relative sea-level rise projections range from 0.9 to 2.1 feet by 2050 and 2.1 to 5.7 feet by 2100.[11] In fact, recent findings reveal that sea level rise is accelerating faster than previously projected due to rapid polar ice sheet melting. In particular, sea level rise has also been greater than anticipated along Mid-Atlantic coastlines, where the waters rise as the flow of Gulf Stream slows.[12]

Although relative seal level rise is a gradual process, Baltimore City may still experience acute impacts in the near term. Some examples include increased frequency of low-level inundation, storm-exacerbated floodwater rise that coincide with high tides or astronomical-influenced tides, increasing rates of coastal erosion in non-bulk-headed areas, and increased saltwater intrusion into underground utilities and infrastructure. Furthermore, scientists recommend planning for the higher range of projection values so as to take into account increased risks associated with flooding during storms.

When the temporal factor of sea level rise is coupled with the relative increase in land-falling the potential for tropical systems to cause extreme tidal flooding will increase. Baltimore's waterfront is densely developed and will continue to have development pressure for the foreseeable future. Coastal storm surges may be amplified by sea level rise, creating a greater threat. Figure 3–6 Baltimore City Flood Hazard Areas Showing 3ft, 5ft, and 7ft Sea Level Rise Scenarios, left, delineates the potential impact for a 100- or 500-year storm when accompanied with sea level rise (showing 3ft, 5ft, and 7ft SLR scenarios). This will impact current and future shoreline development. The impacts of rising sea level on Baltimore City will continue to present significant short- and long-term challenges to its waterfront communities.

Figure 3–7 Tsunami in Japan, 2011 *Source: telegraph.co.uk*

Tsunamis

As stated in the 2011 Maryland State Hazard Mitigation Plan (HMP) "A tsunami is a series of sea waves caused by the displacement of a large volume or body of water. Tsunamis may result from local or distant large-scale seafloor displacement, including seismic activity, volcanic activity or landslides that generate uplift or drop in the ocean floor." [13]

"Waves travel in all directions from the originating tsunami sources, building in height as the wave approaches the shore. The topography and geometry of the coastline, wave direction or path, and offshore topography influence the run-up (or terminal height) of the wave and therefore potential for damage."[14]

While the focus of hazard identification and mitigation planning in this document has centered on atmospheric- and surface-related natural hazards, recent oceanic events have introduced new concerns regarding potential vulnerability of coastal areas such as Baltimore to unusual hazards such as Tsunamis. This section will summarize existing analysis presented in the Maryland State Hazard Mitigation Plan regarding Tsunami risk, as well as discuss recent scientific research on potential risks and causes of East coast Tsunami events. A 2002 Tsunami Hazard Assessment by the National Geophysical Data Center concluded that "There is a substantial danger of tsunamis along the East Coast of the United States that may have been underestimated previously."[15]

On June 13, 2013, portions of the New Jersey coastline, recently ravaged by a 13-foot high storm surge from Hurricane Sandy in October 2012, experienced a Tsunami. Observers and local news media reported that on the afternoon of 6/13, the water level along the coast in central New Jersey rapidly rose as much as 6 feet in a matter of a few minutes.

This rare event was reported in local media and later examined closely by NOAA meteorologists and other scientists. NOAA later classified the event as a "meteo-tsunami" in a July 2013 report, stating

> *"Tsunami-like waves were observed along the US east coast during the afternoon of Thursday, June 13, 2013. Over 30 tide gages recorded the fluctuations with impacts noted along the New Jersey shore and in Massachusetts. In Barnegat Light, NJ, at least two people were swept off a breakwater and required medical treatment. The NOAA meteorologist from the JPWTS reported in the official account that "The event occurred in close conjunction with a strong weather system moving from west to east off the New Jersey coast which is labeled by the NWS as a low-end derecho."*

While a tsunami is traditionally caused by geological forces such as undersea landslides, earthquakes, volcanoes or other seismic influences, this occurrence could be considered an example of a "geo-atmospheric" type event that upon closer investigation, could present a significant new hazard planning concern for vulnerable high population areas such as Baltimore City and surrounding areas. This potential new hazard is being considered by the Disaster Preparedness and Planning Project Committee due to the concerns that;

1) A "meteo-tsunami" or similar wave-event could occur in the Chesapeake Bay at a critical time when large numbers of people are assembled near the water;
2) Policy-makers and infrastructure planners alike may need to make considerations for additional resiliency to no-notice coastal flooding in new construction as part of on-going coastal hazard mitigation strategies;
3) Geological research suggests that many areas of the continental shelf in proximity to the mouth of the Chesapeake may contain at-risk regions which can produce undersea landslides.

The 2011 Maryland State HMP denotes three primary causations of East coast tsunamis: "Inundation (the extent the water goes over the land), wave impact (from incoming and receding currents) and coastal erosion. While most tsunamis occur in the Pacific Ocean, which consists of subduction zones where vertical plate movement results in earthquakes. Conversely, the U.S. East Coast has been, until recently, considered in an area with reduced threat from tsunamis.

Among the potential causes of a significant tsunami event along the U.S. East Coast, and particularly the Mid-Atlantic, this report assesses the relative probability of different events pertaining to Baltimore:

- Tectonic activity: In the Atlantic Ocean, the Mid-Atlantic Ridge is a spreading center (a divergent plate boundary). The U.S. East Coast is a passive margin, characterized by minimal tectonic activity and a low sloping continental shelf. The majority of the Atlantic Ocean's tectonically active areas (seismic and volcanic) are concentrated near the Caribbean Islands and at the Scotia island arc chain. (MD HMP) For Baltimore, this tsunami causation is considered at the lowest probability.
- Volcanic, Subsurface or Meteoric: Other eastern seaboard tsunami sources include volcanic debris falls or catastrophic failure of volcanic slopes, explosive decompression of underwater methane deposits or oceanic meteor splashdowns such as the Chesapeake Bay Bolide which is believed to have produced a crater at the mouth of today's Bay. Peer-reviewed research in Geologic journals regarding methane deposits suggests this tsunami causation is still generally low probability, but a rising concern among oceanographers.
- Slumping and Submarine Landslides: Since subduction zones are absent around most of the Atlantic basin, tsunamis and tsunami-like waves along the U.S. East Coast are generally the result of slumping or landsliding associated with local earthquakes or with wave action associated with strong storms. In the past century, "no-notice" submarine landslide induced tsunamis have shown to produce damage to coastal areas of the Eastern U.S., Bermuda and the Caribbean. This observation places a higher hazard probability for Baltimore.

Overview of historical Tsunami events from the 2011 Maryland HMP which have occurred in the Atlantic Ocean basin and affected the U.S. East coast, including the Mid-Atlantic region include:

- Earthquakes in the Azores-Gibraltar convergence zone (e.g., Lisbon earthquake in 1755);
- Earthquakes along the Hispaniola-Puerto Rico-Lesser Antilles (Caribbean) subduction zone, in and around the Puerto Rico Trench or near the Leeward Islands;
- Large mass failure event, including the potential flank collapse of the Cumbre Vieja
- Volcano in the Canary Islands;
- Landslide tsunamis caused by Submarine Mass Failures (SMF) triggered along the East coast continental slope by moderate seismic activity. Significant geological and historical evidence (e.g., the 1929 Grand Bank landslide tsunami and the Currituck Slide off North Carolina and Virginia) suggests that SMF tsunamis pose the most significant tsunami hazard to the upper east coast, triggered on the continental slope by moderate seismic activity (magnitude 6.0 to 7.5).

"Although such near-field landslide tsunami sources are less energetic than co-seismic (e.g. earthquake induced) tsunamis, SMFs can occur at a shorter distance from shore and therefore cause significant run-up on small sections of the coast while offering little warning time, thus posing significant hazard to local, low-lying, coastal communities, such as Ocean City, MD and Worcester County. For example, SMFs with volumes of above 100 km3 can generate vertical extent of wave uprush on a beach or structure (run-up) of more than two meters."

While two of the three primary causes of Tsunamis are generally considered extremely low-probability events, the 2011 Maryland Plan outlined one particular scenario that could present a significant long term Tsunami hazard to Baltimore, as well as this hazard being counted in the "no-notice" category like that of derechos and other severe weather events. Among the two areas of highest concern for potentially high-impact tsunami events that could affect Baltimore include two East Coast off-shore areas currently being investigated for potential future large-scale submarine slope failure. These sites include:

- Large cracks discovered northeast of Cape Hatteras (off the coast of North Carolina and Virginia). The cracks are located on the outer shelf edge and exist as a series of "en echelon cracks" (Maryland HMP Figure 3-43).
- Submarine canyons located approximately 150 kilometers east of Atlantic City, New Jersey.

The North Carolina-Virginia site also contains evidence of a large submarine landslide, the Albemarle-Currituck Slide, which has been dated to approximately 18,000 years ago, with over 33 mi of material, moved seaward from the continental shelf, most likely causing a tsunami. These cracks may indicate a progression in slope failure and the potential for another submarine landslide to occur that could trigger a tsunami on the order of a few to several meters in height, similar to a storm surge resulting from a Category 3 or 4 Hurricane. Further, investigations suggest that the cracks are in areas of large deposits of methane hydrate and pressurized water, wherein sudden release of the water or methane may have produced the cracks and slope failure. (MD HMP)

Given the existing vulnerabilities of Baltimore City's coastal infrastructure and sensitive populations, this Tsunami Hazard Assessment was included to provide a starting point for future examination of appropriate preparatory and mitigation measures which can be undertaken as the City's plans develop.

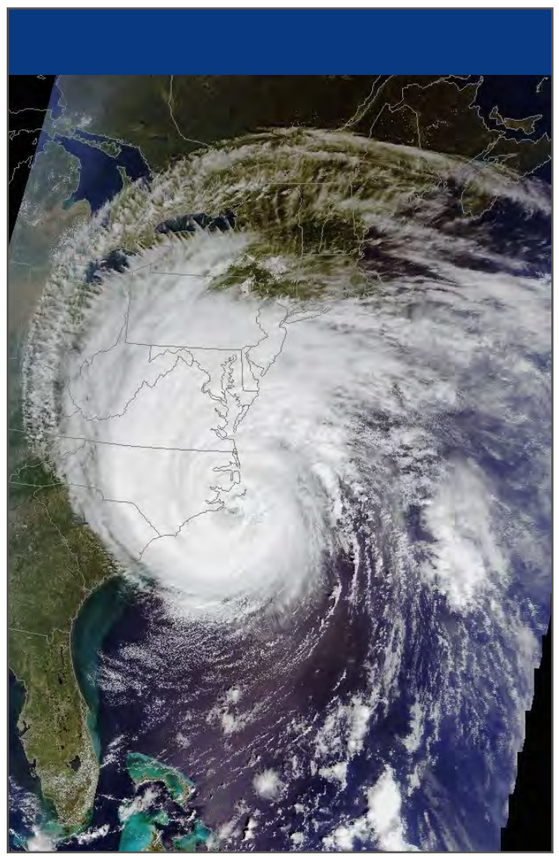


Figure 4–8 Hurricane Isabel over the East Coast on September 18, 2003 *Source: NASA*

Figure 3–9 Flooding from heavy precipitation shuts down a portion of the Jones Falls Expressway *Source: Baltimore Sun*

Precipitation Variability

The amount of precipitation that falls over an area will vary by large amounts as global temperatures increase. Precipitation events are likely to increase in magnitude in Baltimore City leading to increased flash flooding. Among the many harmful effects of climate change, increased stormwater runoff and demand for stormwater management are anticipated to be some of the greatest challenges facing cities.[16] Climate projections for the State of Maryland predict that the average annual precipitation will increase between 5-12 percent by the end of the century.[17] In Baltimore, studies suggest that precipitation could increase by as much as 227mm each year by the middle of the century.[18] At the same time, the Northeast Region is expected to experience more frequent heavy precipitation events — where more than 2 inches of rain falls within a 48 hour time period — while the intensity of heavy precipitation events is projected to increase by 12-15 percent.[19]

Most of Maryland's precipitation falls in the summer months but winter precipitation is expected to rise and the form of this precipitation is likely to be altered. While temperatures increase, more rain will fall in Maryland's winter months, with a projected 50 percent decrease in snow volume by the end of the century.[20] As precipitation frequency and intensity will increase, Baltimore will be more vulnerable to flash flooding events.

Heavy precipitation may, at times, be conveyed through what scientists refer to as "atmospheric rivers." These channels carry immense quantities of water across the planet, and contribute to the intensity of heavy precipitation events. Atmospheric rivers may cause both rainstorms and snowstorms. For instance, an atmospheric river was responsible for the "Snowmageddon" event that hit Baltimore in 2010.[21] Even more alarming, atmospheric rivers are likely to become stronger due to a warming planet and higher saturation levels of water vapor in the atmosphere. This increase could lead to an increase in both severity and frequency of rain- or snowfall, and contribute to significant flooding and other damage.

Thunderstorms

When atmospheric conditions combine to provide moisture, lift, and warm unstable air that rapidly elevates, a thunderstorm is formed. Thunderstorms can occur at any time of day and in all months of the year, but are most common during summer afternoons or evenings and in combination with frontal boundaries. Maryland experiences approximately 20-40 thunderstorm days per year and frequently occur in Baltimore. Thunderstorms are considered a significant hazard due to their ability to spawn tornadoes, hailstorms, strong winds, flash floods, and damaging lightning.

Table 3–8 Thunderstorm Property Damage 1956-2010

Property Damage (Total)	Property Damage (Annualized)
$49,257	$896

Source: Table 3-66, Maryland Emergency Management Agency, 2011: 180.

Table 3–9 Thunderstorm Injuries and Deaths 1956-2010

County/City	Total Injuries	Total Deaths
Baltimore City	1	2

Source: Table 3-65, Maryland Emergency Management Agency, 2011: 179.

Severe thunderstorms have varied characteristics and can inflict considerable damage. The National Weather Service classifies a thunderstorm as severe if it produces hail that measures at least one inch in diameter, winds of 58 mph or greater, or a tornado. Thunderstorms affect a smaller area compared with winter storms or hurricanes, but for a number of reasons, can be dangerous and destructive. Storms can form in less than 30 minutes, giving very little warning and can cause considerable damage.

Table 3–8 Thunderstorm Property Damage 1956-2010, above, notes measured economic costs and damage associated with thunderstorm events in Baltimore City from 1956 to 2010. In that time period, thunderstorms had been responsible for $896 in property damage annually. In that same period, thunderstorms in Baltimore City had killed two individuals (Table 3–9 Thunderstorm Injuries and Deaths 1956-2010, below).

Figure 3–10 Lightning striking the World Trade Center building in downtown Baltimore

Table 3–10 Damage from Hail in Baltimore, 1950 to 2012

Date	Time	Size (Inches)	Injuries	Fatalities	$ Loss (Millions)
8/12/1957	13:30:00	0.75	0	0	0
8/1/1963	16:00:00	1	0	0	0
6/18/1970	16:10:00	4.5	0	0	0
5/25/1979	18:10:00	1.75	0	0	0
4/24/1991	11:30:00	1	0	0	0
4/24/1991	11:52:00	1	0	0	0
11/8/1996	14:40:00	0.75	0	0	0
6/2/1998	17:29:00	1.75	0	0	0.005
7/30/1999	18:50:00	1.75	0	0	0
5/13/2000	14:40:00	1	0	0	0
7/14/2000	16:15:00	1.75	0	0	0
5/2/2002	14:10:00	1	0	0	0
5/13/2002	13:35:00	1	0	0	0
4/3/2006	17:50:00	0.75	0	0	0
7/10/2007	11:45:00	1	0	0	0
8/14/2012	20:07:00	1	0	0	0

Lightning

Every thunderstorm is accompanied by lightning; in fact, the actual sound of thunder is a direct result of lightning. The phenomenon occurs when water droplets are carried by the updraft of a thunderstorm to the upper parts of the atmosphere where they freeze and become charged. Lightning is the charged electrical channel that shoots downward toward the earth's surface. As this channel nears the ground, it is attracted to oppositely-charged channels which, once connected, create a powerful electrical current that produces a visible flash of lightning.

Lightning often strikes outside of areas where rain is actually falling, at times appearing as far as 10 miles away from rainfall. It can strike from any part of the storm, and may even strike after the storm has seemed to pass. Additionally, a lightning bolt can warm the surrounding air to temperatures as high as 60,000° Fahrenheit.[22] In Baltimore, lightning strikes have been the cause of significant property damage throughout the years, and have even taken the lives of City residents. As the frequency and intensity thunderstorms increases, so will the lightning associated with these storms.

Hail

Hail is another dangerous by-product of severe thunderstorms. Hail is formed in towering cumulonimbus clouds (thunderheads) when strong updrafts carry water droplets to a height at which they freeze. Eventually, these ice particles become too heavy for the updraft to support and they fall to the ground at speeds of up to 120 mph. When falling at such high speeds, the hail has insufficient time to melt in the warmer air and reaches the ground in the form of ice.

Hail falls along paths called swaths, which can vary from a few square acres to up to 10 miles wide and 100 miles long.[23] Hail larger than ¾ inch in diameter can inflict great damage to both property and crops. Some storms produce hail over 2 inches in diameter. In Baltimore, the largest size hail measured between 1950 and 2012 had been 1.75 (Table 3–10 Damage from Hail in Baltimore, 1950 to 2012). Although hail in Baltimore had not caused significant economic losses during this period, hail causes about $1 billion in damages annually in the U.S. Hail is already a known occurrence in Baltimore. Though climate scientists predict more frequent and intense severe storms in the future, it is difficult at this point to establish any long-range projections regarding the future impact of hail in Baltimore.

Figure 3–11 A Scene from Baltimore following a wave of heavy storms, dubbed "Snowmageddon"

Winter Storms and Climate Influences

Winter storms produce more than just snow. Winter weather can take many forms, including freezing rain, sleet, extreme cold and high winds. These conditions may occur singly or in any combination. Freezing rain is that which falls onto a surface where the temperature is below freezing, causing the rain to form a coating of ice. Conversely, sleet occurs as rain drops freeze into ice pellets in the cold air before reaching the ground. Like snow, freezing rain and sleet can create hazardous conditions for motorists. Even small accumulations of ice can make walking or driving extremely dangerous. Moreover, significant accumulations of ice can fell trees and utility lines, resulting in loss of power and communication.

Regarding winter weather projections, the noticeable uptick in major winter storm events in Baltimore since 1996 has been compared to the relatively snowy periods in the 1950s and 1960s. This suggests that although climate change has influenced average temperatures, it is also possible that the Baltimore region could experience increased precipitation in the form of snowfall due to increased moisture content driven by rising evaporation from warmer bodies of water. An April 2013 journal article from the Bulletin of the American Meteorological Society, titled *Monitoring and Understanding Trends in Extreme Storms* noted that "observed increases in extreme precipitation are "consistent with the observed increases in atmospheric water vapor, which have been associated with human-induced increases in greenhouse gases."[24] The article also points to findings relevant to concerns for Baltimore City's unique weather in recent years that "while the role of water vapor as a primary cause for the increase in extreme precipitation events is compelling, the possibility of changes in the characteristics of meteorological systems cannot be ruled out. There may also be regional influences from the temporal redistribution of the number of El Niño events versus La Nina events and from land use changes."

Table 3–12 Winter Storms and Freezes, right, notes sever winter storm events (storms and freezes) in Baltimore that caused considerable damage. The public sector cost of a blizzard in 1996, for instance, totaled $20 million in Maryland. Winter storm warnings are issued when snowfall is expected to accumulate more than 4 inches within 12 hours, or when a quarter of an inch or more of freezing rain will accumulate. Severe winter storms can significantly slow traffic, decrease commercial activity, lead to power outages, disrupt communications, and even force vulnerable buildings to collapse.

While winter storms are expected in Baltimore — and the City budgets and prepares for snow removal activities each year — winter storms occasionally reach a magnitude that overwhelms local response efforts. This stress may be placed on the transportation system as roads are unable to be efficiently salted or plowed, or it may be placed on electrical infrastructure. As a result of a 1994 ice and sleet storm, for example, the City of Baltimore experienced power and phone line outages, as well as rolling blackouts, due to increased use of electricity and natural gas. Some residents were left without power or heat for nearly two weeks.

Over the past decade, Baltimore City has experienced several strong winter storms that have disrupted regular activities and caused a number of automobile accidents and power outages. Climate averages for Baltimore denote 21.1 inches of snowfall annually for any given year. Table 3–11 Significant Winter Storms in Baltimore, MD, shows significant winter storms during which the region received more than the annual snowfall in a single snow event.

Years that bring several winter storms, frequent episodes of disruptive precipitation or extreme cold can tax the energy supply, raising the cost of heating homes, businesses and public facilities. In 2010, two severe winter storms took place just days apart. Following the 25 inches of snow that had fallen on February 5th, a second snowstorm on February 9, 2010, brought an additional 19.5 inches of snow, negatively impacting critical emergency facilities. Together, public sector cost for these two storms totaled nearly $35 million for the City of Baltimore alone.

Table 3–11 Significant Winter Storms in Baltimore, MD

Date	Inches of Snow and Ice
March 15-18, 1892	16.0 inches
February 12-14, 1899	21.3 inches
February 16-18, 1900	12.0 inches
January 27-29, 1922	26.5 inches
March 29-30, 1942	22.0 inches
February 15-16, 1958	15.5 inches
December 11-12, 1960	14.1 inches
March 5-7, 1962	13.0 inches
January 30-31, 1966	12.1 inches
February 18-19, 1979	20.0 inches
February 11-12, 1983	22.8 inches
January 22, 1987	12.3 inches
January 7-9, 1996	26.6 inches
January 25, 2000	14.9 inches
February 16-18, 2003	26.8 inches
December 18, 2009	18 Inches
February 5-6, 2010	25-29 Inches
February 9-10, 2010	19.5 inches

National Weather Service, www.nws.noaa.gov/er/lwx/winter/storm%2Dpr.htm

While major snow and ice storms may appear to be on the rise in the short term, according to the Intergovernmental Panel on Climate Change 2007 Fourth Assessment Report (AR4), a factor which may be driving this observation is an actual decrease in global snow and ice cover. The IPCC noted in AR4 that "observations show a global-scale decline of snow and ice over many years, especially since 1980 and increasing during the past decade, despite growth in some places and little change in others."[25]

While "most mountain glaciers are getting smaller, and snow cover is retreating earlier in the spring, Sea ice in the Arctic is shrinking in all seasons, most dramatically in summer."[26] The report notes that important coastal regions of the ice sheets are thinning in places like Greenland and West Antarctica, which is contributing to a sea level rise of at least 1.2mm globally just in the 10-year period between 1993 to 2003.

For Baltimore, the contrasting reduction in snow-cover and sea ice has been identified as an influential factor in altering weather patterns over the Northern Hemisphere. This climate contrast has produced extreme cold and snow in some regions — such as central and northern Europe from 2012 to 2013 — while leaving other regions, including the Mid-Atlantic in the U.S., with highly variable snowfall and winter temperatures from year to year. As average annual temperatures increase overall, winter temperatures will likewise become warmer. While winter temperatures have only slightly increased in Baltimore in recent decades, temperatures are projected to increase between 4-7° by 2025. Carrying this projection forward, winter temperatures could be an estimated 7.4-10.6° warmer by the end of the century.[27] For this reason, and due to high fluctuations in winter weather impacts, many eastern U.S. cities, including Baltimore, are actively preparing for winter extremes.

Winter storms may also significantly disrupt the ability of Baltimore residents to go about completing daily routines. Populations who are less mobile, or who have chronic illnesses or age-related limitations, are most vulnerable. For these residents, snow and ice will pose additional health hazards, including heart attacks from physical exertion after clearing a sidewalk of snow; inability to access vital medical services; or being trapped indoors.

Table 3–12 Winter Storms and Freezes

Date of Storm	Storm Type	Severity at Impact	Damages	Recovery Time	Public Sector Cost	Facilities Impacted	Historical Elements Impacted
2/11/1983	Snow Storm	22.8 inches					
2/10/1994	Ice and Sleet	3 inches of freezing rain/ice -28 degree wind chills 40+ MPH wind		People without power and heat for nearly 2 weeks			
1/8/1996	Blizzard of '96	26.6 inches			$20 million in Maryland		
1/25/2000 to 1/30/2000	Severe Winter Storms	14.9 inches	Rolling blackouts due to increased use of electricity and natural gas; tree loss due to heavy ice; power and phone line outages; Car accidents				
2/15/2003 to 2/18/2003	Severe snowfall	28.2 inches			$3,000,000		Roof collapse of B&O Railroad Museum
2/11/2006 to 2/12/2006	Snow Storm	13.1 inches	62,000+ People Lost Power				
12/18/2009	Snow Storm	18 inches			$2,191,670 (Baltimore)		
2/5/2010	Severe winter storm	25.0 inches	34,000 BGE Customers without power (region)		$34,783,976 (Baltimore)	Harbor Hospital, Oldtown Station, BPD Southern District, Stratford water pump station lost power	
2/9/2010	Severe winter storm	19.5 inches					
1/26/2011	Snow Storm	9.8 inches	Car accidents; JFX gridlocked; vehicles abandoned on roadways; 122,000 BGE Customers without power			3800 E. Biddle (garage), 6400 Pulaski Hwy (plow shop), 239 N. Calverton (substation)	

Nor'Easters

Some of the most significant winter storms that affect Maryland are known as "Nor'easters" because they are accompanied by strong northeast winds. These storms often form in the Gulf of Mexico, intensify, and then move up the East Coast. High pressure systems over the Maritime Provinces of Canada deliver the cold air to Nor'easters that result in winter precipitation. The cold air flowing from the north forms what actually looks like a wedge, bounded on the west by the mountains of Washington and Allegany Counties and by warmer winds coming off the Atlantic Ocean on the east. Meteorologists call this the "cold air dam" or "the damming effect." Moist air coming from the south flows up over this dam, producing heavy winter precipitation.

Often, the heaviest snow with a Nor'easter occurs in a band 50 to 100 miles wide, usually setting up over central or eastern areas of Maryland. Precipitation along this band typically changes from snow in the west, to a transition area of freezing rain and sleet, then finally to rain in the east. Areas receiving mostly snowfall can experience totals of greater than a foot of precipitation. In the most intense Nor'easters, thunder and lightning may also be observed. The distribution, intensity and type of precipitation associated with Nor'easters are highly dependent on the track of the center of the storm system. A system that tracks nearest the coast is more likely to produce rain along the coast and snowfall further inland. A system that tracks a bit further out to sea is more likely to produce mostly snowfall even along the coast.

Winter storms can also be life threatening events. From reports measured between 1993 and 2010, Winter Storms accounted for a total of 8 deaths and 166 injuries in Baltimore City (Table 3–13 Winter Storm Hazard - Injuries and Deaths, below).

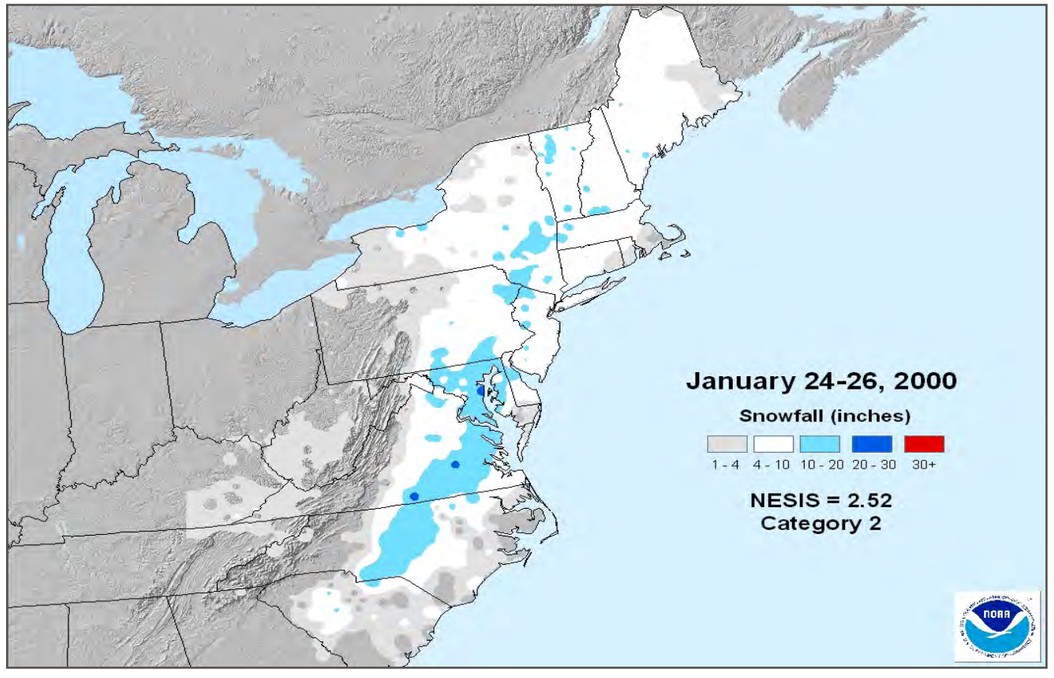


Figure 4–12 Map Showing January 2000 Nor'Easter; *Source: NASA*

Figure 3–13 Pretty Boy Reservoir during the drought of 2002 *Source: gunpowderfalls.org*

Drought

Droughts are extended periods of dry weather, caused by a natural reduction in the amount of precipitation over an extended period of time. Droughts may be classified as meteorological, hydrologic, agricultural, or socioeconomic events. Table 3–14 Drought Classification Definitions presents definitions for these different types of droughts:

While occurring less frequently in Baltimore City than in surrounding jurisdictions, meteorological and hydrologic droughts are natural hazards that present major threats to the City and regional water supply. Such droughts may ultimately evolve into socioeconomic droughts in which the City's ability to deliver water to residents or businesses becomes limited. Additionally, Baltimore provides public water to areas outside of the City's boundaries; therefore, a drought may greatly diminish water supplies that are available not only to the City of Baltimore, but also to the surrounding counties.

Droughts may vary greatly in their extent, duration, severity, and impact. Their conditions may be worsened by human activities, high temperatures, high winds, and low humidity. To mitigate the intensity of a drought's effects, the City may be forced to impose water rationing requirements upon households. This form of restriction has only been applied once in recent years; however, limits on car washing or other commercial/institutional uses have been more common. Such restrictions can have a negative economic impact on water-dependent businesses. During a prolonged drought event, land values can decrease, unemployment can increase, and certain industries or individuals may be impacted more than others. The agriculture industry, for instance, generally experiences the first and harshest effects of droughts (for a more detailed discussion about agriculture, see Extreme Heat Hazard Profile).

Table 3–13 Winter Storm Hazard - Injuries and Deaths

County/City	Total Injuries	Total Deaths
Baltimore City	166	8

Source: Table 3-76, Maryland Emergency Management Agency, 2011: 204.

Table 3–14 Drought Classification Definitions

Type	Definition
Meteorological	The degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales.
Hydrologic	The effects of precipitation shortfalls on streamflows and reservoir, lake, and groundwater levels.
Agricultural	Soil moisture deficiencies relative to water demands of plant life, usually crops
Socioeconomic	The effect of demands for water exceeding the supply as a result of a weather-related supply shortfall.

Multi-Hazard Identification and Risk Assessment, FEMA

Figure 3–14 Pretty Boy Reservoir during the drought of 2002 *Source: USGS*

A listing of significant Maryland droughts is presented in Table 3–15 Historical Droughts in Maryland. For each dry period, the table the region that had been affected, and notes the economic cost for two of the events. A drought recurrence interval is the average interval of time within which streamflow would be less than usual during a drought event. The U.S. Geological Survey (USGS) is able to determine annual departures from average streamflow and assign recurrence intervals to each drought. For Baltimore, the USGS identified five regional droughts which had significant extent and duration: (1) 1930 to 1932; (2) 1953 to 1956; (3) 1958 to 1971; (4) 1980 to 1983; and (5) 1984 to 1988. The drought from 1930 to 1932 was likely the most severe agricultural drought ever recorded in Maryland. Rainfall during that period was approximately 40 percent less than average, and 1930 was the driest year recorded since 1869. Total cost of crop losses during 1930 were estimated at $40 million in the region.[28]

Since 1930, droughts have occurred about once every 10 years, with mixed severity and duration. Recurrence intervals during the drought from 1953 to 1956 had generally been 10 to 25 years — with the exception of areas north and east of Baltimore, where recurrence intervals were less than 10 years. From 1958 through 1971, a 13-year regional drought with recurrence intervals greater than 25 years caused severe streamflow deficiencies throughout Maryland. Greatly exceeding regional losses during the 1930 drought, the 1986 to 1988 drought accounted for an estimated loss of $302 million.

Table 3–15 Historical Droughts in Maryland

Dates	Area Affected	Economic Cost
1930-1932	Regional	$40,000,000 in crop losses (1930)
1953-1956	Regional	
1958-1971	Regional	
1980-1983	Multi-State	
1984-1988	East MD	$302,000,000 in estimated agricultural losses (1986-1988)
2002	Central MD	

While long-term or water-supply droughts — where rainfall deficits of more than 14 inches persist for two years or more — currently occur less than 4 percent of the time in Maryland, that percentage is expected to increase to approximately 5 percent by the end of the century. Furthermore, the duration of annual dry spells in Maryland is projected to increase from the current average of 15 days to as many as 17 days.[29]

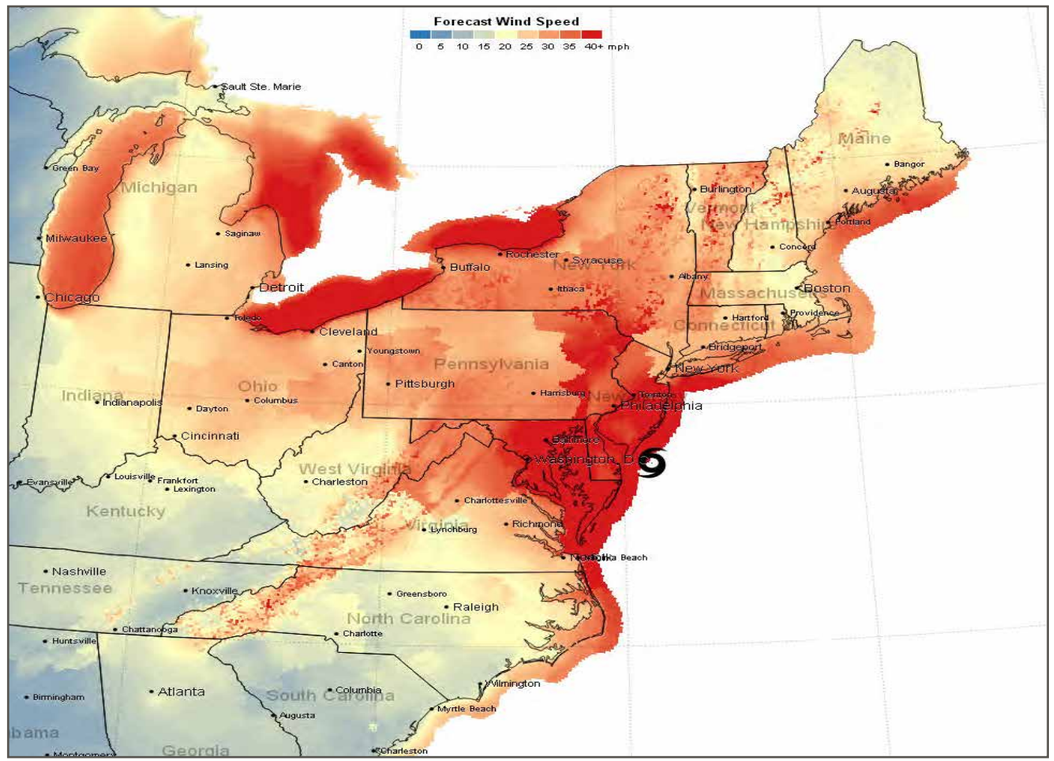


Figure 3–15 Map Showing Wind Speed During Hurricane Sandy

Wind

Wind is the motion of air past a given point caused by a difference in pressure from one place to another. Wind poses a threat to Maryland in many forms, including winds that are produced by severe thunderstorms and tropical weather systems. The effects of wind can include blowing debris, interruptions in elevated power and communications utilities, and intensified effects of winter weather. Harm to people and animals, as well as damage to property and infrastructure, may result.

In the mainland United States, mean annual wind speed is reported to be 8–12 mph, with frequent speeds of 50 mph and occasional wind speeds greater than 70 mph. In coastal areas, from Texas to Maine, tropical cyclone winds may exceed 100 mph. In the mid-Atlantic, high wind speeds are generally produced by severe thunderstorms and tropical storms/hurricanes. The most severe windstorms may produce tornadoes.[30]

Table 3–16 Wind Events in Baltimore, 1950 to 2012

Total Wind Events	Average Windspeed	Total Cost of Damage (Millions)	Average Cost of Damage (Millions)
116	29.8793	25.3715	0.2187198

Windstorms also have the capacity to cause considerable personal and property damage. From records of 116 high wind events measured between 1950 and 2012 (Table 3–16), the average wind speed was approximately 30 mph, at times reaching speeds of 78 mph. Fortunately, these events did not cause any fatalities in Baltimore; however, 21 injuries were recorded. Additionally, total recorded property damage exceeded $25 million, with an average of nearly $220,000 in damage for each event.

Destruction of trees and other vegetation may produce secondary impacts that damage structures and power lines, or block roadways and storm drainage systems. For instance, downed trees may topple power lines or cause property damage if they fall. Minor structural damage —to shingles, gutters, etc. — may also be sustained by some. Measured between 1956 and 2010, Baltimore City reported a total of 30 wind related injuries (Table 3–17). During the same time period, property damage from wind events totaled an average of $15,601 a year (Table 3–18).

Table 3–17 Wind related injuries and deaths per county, 1956-2010

County/City	Total Injuries	Total Deaths
Baltimore City	30	0

Source: Table 3-56, Maryland Emergency Management Agency, 2011: 168.

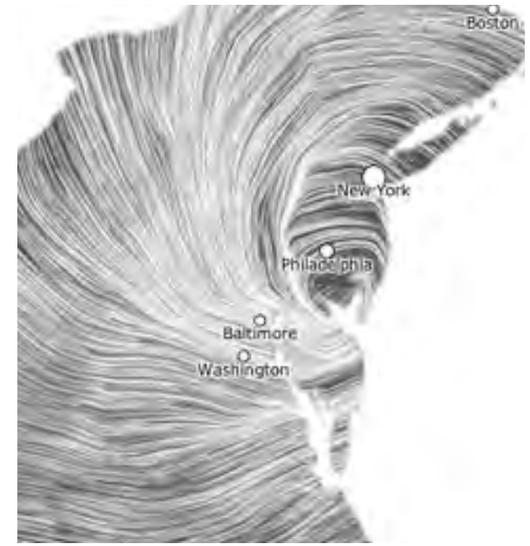


Figure 3–16 Wind During Hurrican Sandy

Table 3–18 Wind crop and property damages per county, 1956-2010

Property Damage (Total)	Property Damage (Annualized)	Crop Damage (Total)	Crop Damage (Annualized)	Total Damage	Total Damage (Annualized)
$858,078	$15,601	$ 1	$ -	$858,079	$15,601

Source: Table 3-60, Maryland Emergency Management Agency, 2011: 171.

Tornados

A tornado is a violent atmospheric disturbance characterized by one or more twisting and funnel-shaped columns, extending from a thunderstorm cloud toward the ground. Tornadoes can touch the ground with winds over 300 mph. While relatively short-lived, tornadoes are intensely focused and are one of nature's most violent storms.

Tornadoes are measured according to their wind speed on the Fujita Scale (F-Scale). Revised in January of 2007, the Enhanced Fujita Scale, illustrated in Table 3–19 Table X: Enhanced Fujita Tornado Intensity Scale, below, ranges from an EF0 to an EF5. The strongest tornadoes ever observed have produced winds over 200 mph. Different wind speeds may cause similar-looking damage from place to place or from building to building. Without a thorough engineering analysis of tornado damage in any event, the amount of damage from any given storm may be unpredictable.

Spawned by powerful thunderstorms or hurricanes, tornadoes are produced when a southwesterly flow of warm, moist air combines with both northwesterly and southwesterly flows of cool and dry air, thereby forcing the warm air to rise rapidly. Most damage results from high wind velocity and wind-blown debris. Tornadoes may range from just several yards to over two miles in width; and, although tornadoes normally only travel on the ground for short distances, tornado tracks of 200 miles or more have been reported.

Table 3–19 Table X: Enhanced Fujita Tornado Intensity Scale

Category	Wind Speed	Examples of Possible Damage
EF0	Gale Tornado (65 – 85 mph)	**Light damage**. Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage to sign boards.
EF1	Moderate Tornado (86 – 110 mph)	**Moderate damage**. The lower limit is the beginning of hurricane wind speed; peel surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads.
EF2	Significant Tornado (111 – 135 mph)	**Considerable damage**. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
EF3	Severe Tornado (136 – 165 mph)	**Severe damage**. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; cars lifted off ground and thrown.
EF4	Devastating Tornado (166 – 200 mph)	**Devastating damage**. Well-constructed houses leveled; structure with weak foundation blown off some distance; cars thrown and large missiles generated.
EF5	Incredible Tornado (over 200 mph)	**Incredible damage**. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 100 yards; trees debarked; incredible phenomena will occur.

Source: The Enhanced Fujita Scale (National Weather Service). http://www.crh.noaa.gov/arx/efscale.php

Table 3–21 Significant Tornado Events from 1950 to 2012

Event number	Date	Time	F/EF Scale	Injuries	Fatalities	$ Loss (Millions)
624	8/12/1957	13:30:00	0	0	0	0
249	6/11/1958	15:00:00	0	0	0	0
618	7/19/1996	14:30:00	0	0	0	0
1200	11/17/2010	0:35:00	1	3	0	0.25

Tornado season is generally noted to last from March through August — although tornadoes may occur at any time of the year — and more than 80 percent of tornado strikes happen between noon and midnight. Tornadoes are known to destroy almost everything in their path. Depending on the intensity and size of the tornado, damage may be as minor as a few broken tree limbs and downed power lines, or as devastating as the destruction of houses, businesses, and community vitality. Nationwide, tornadoes account for an average of 70 fatalities and 1,500 injuries each year. From events reported between 1950 and 2010, tornados in Baltimore produced a total of $203,617 in reported property damage, or $3,338 annually (Table 3–20 Tornado Hazard - Property Damage in Baltimore, below).

To date, the highest intensity tornado experienced in the Baltimore Region has been an F2. One such event on June 16, 1973 injured four people in the Towson area. In October 1990, another F2 tornado injured 59 Reisterstown residents. Less than twenty minutes later, this tornado was followed by a less powerful, F1 tornado. A more in-depth collection of significant tornado events in the Baltimore Region is listed in Table 3–21 Significant Tornado Events from 1950 to 2012.

Figure 3–17 Tornado over inner harbor, June 2013

Table 3–20 Tornado Hazard - Property Damage in Baltimore

Property Damage (Total)	Property Damage (Annualized)
$ 203,617	$ 3,338

Source: Table 3-73, Maryland Emergency Management Agency, 2011: 192.

Derechos

Derechos are large thunderstorm clusters that produce widespread and long-lasting winds which can be extremely damaging. The impact of a derecho is similar to that of a hurricane making landfall, and can be many miles wide and several hundred miles long. An event may be classified as a derecho if the swath of storms is more than 240 miles long and wind speeds of over 58 mph are maintained for at least six hours throughout the entire span of the storm front.

Derechos occur most often in the Midwest and Great Lakes region during the summer months. In the Mid-Atlantic region, derechos are less common — occurring once every two to four years in Maryland. Consequently, residents have typically been less familiar with this type of storm designation. The term, however, was recently marked in the memories of many Baltimore residents following the devastation of a June 29, 2012 Mid-Atlantic and Midwest derecho. According to the National Weather Service, this storm, which was exceptionally severe in the Baltimore/Washington region, brought gusts of wind between 65 and 75 mph. As a result, numerous overhead electrical units suffered damage, two individuals were electrocuted by downed power lines, and more than one million customers across the region were left without power. In some areas, efforts to restore power persisted for more than a week. Additionally, these strong winds disrupted communication with vital emergency response facilities, interrupting 911 services in Northern Virginia. Maryland declared a state of emergency as the National Weather Service Forecast Office of Baltimore/Washington received over 300 early reports of severe damage, and continued gathering reports in the weeks that followed.[31] In Baltimore City, public sector costs of the June 29th storm exceeded $2.5 million. A list of additional derechos in Maryland is collected in Table 3–22 Noteworthy Derechos Impacting the State of Maryland, above.

Table 3–22 Noteworthy Derechos Impacting the State of Maryland

Date	Description
June 6, 1977	Southern-Mid-Atlantic Derecho
July 4-5, 1980	"The 'More Trees Down' Derecho"
November 20, 1989	"The Mid-Atlantic Low Dewpoint Derecho of November 1989"
April 9-10, 1991	"The West Virginia Derecho of 1991"
August 4, 2004	n/a
May 21, 2004	n/a
July 10-11, 2011	"The Cross Country Derecho of July 2011"
June 29-30, 2012	"The Ohio Valley / Mid-Atlantic Derecho of June 2012"

Source: http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm

A number of other hazards may also be associated with derechos — including heat waves, tornados, and flash floods. As derechos occur in the summer months, they may indirectly lead to fatalities if power outages correspond with extreme heat waves. Indeed, this is a significant concern as derechos often appear on the fringe of heat waves due to favorable storm conditions created by extreme shifts in temperature. In the derecho of 2012, for example, Baltimore experienced a record setting heat wave, where temperatures measured at BWI Airport reached or exceed 90°F for 12 consecutive days.[32] This heat wave began on June 27—two days prior to the derecho event— and high temperatures endured for more than a week while hundreds of thousands of residents were deprived of power and/or air conditioning.

It should also be noted that the same conditions which foster the formation of a derecho are also favorable conditions for tornados. Furthermore, the immense downpour of precipitation associated with derechos and thunderstorms may lead to instances of flash floods.

Extreme Heat

An extreme heat condition is identified when prolonged temperatures are 10° or more above the average high temperature for a region. In Baltimore's past, between the 1950s and the 1970s, an average of 60 percent of summer days had met the maximum temperature extremes. In the 2000s, that percentage grew to approximately 75-90 percent of summer days reaching maximum temperature extremes. Studies predict that Baltimore may experience between 85-95 percent such days before the middle of the century, or between 90-95 percent by 2100.

These extreme heat predictions may be further evaluated by considering what temperature extremes are being met. Between 1981 and 2010, Baltimore experienced an average of 1.1 days a year with temperatures above 100°F. In 1930, Baltimore endured its longest stretch of 100 degree days, spanning a four-day period between July 19th and 22nd. A three-day stretch was experienced in 2011, between July 21st and 23rd.[33] Conservative projections for Baltimore City estimate that the number of days with temperatures above 100°F could increase to as many 1.6 days a by 2050, or 2 days a year by the end of the century. Similarly, in the Northeast region, low emissions scenario projections estimate a regional increase to as many as 9 days a year by the middle of the century.[34]

According to NOAA, Baltimore experienced an average of 31 days a year when temperatures met or exceeded 90°F in the years between 1981 and 2010. In 2012, the June 29th derecho occurred on the fringe of a major heat wave in Baltimore. For more than a week straight, temperatures soared above 90°F. In Baltimore, the number of days when temperatures reach or exceed 90°F are projected to increase to between 35 and 38 days by 2050, or to between 38 and 41 days a year by the end of the century. Similarly, according to the National Climate Assessment, regional climate model simulations suggest that Maryland could experience more than twice as many days per year over 95°F by mid-century — with an estimated 15 additional days above 95°F each year.[35] This is expected to severely impact vulnerable populations, infrastructure, agriculture and ecosystems. In the future, Baltimore expects that periods of extreme heat are likely to increase in frequency, duration, and intensity.

The summer season in Baltimore City is known to have frequent high temperatures accompanied by high humidity. On some summer days, urban air can reach temperatures up to 10°F warmer than surrounding suburban or rural areas — a phenomenon known as the "urban heat island effect." Densely developed, metropolitan areas tend to replace natural land cover

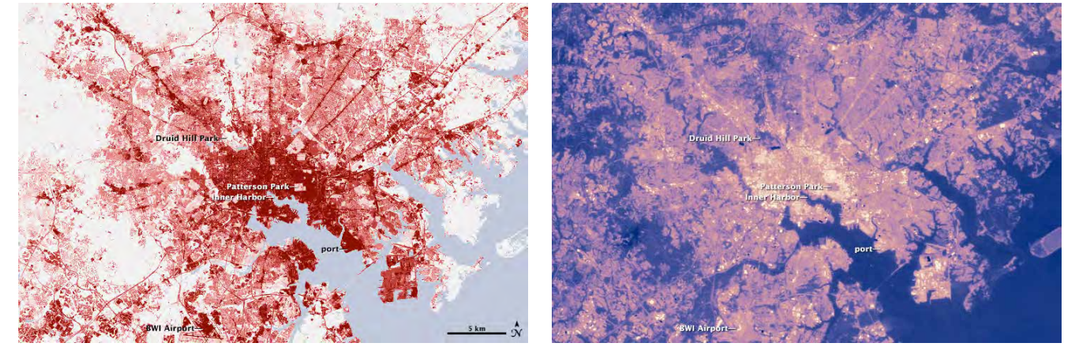


Figure 3–18 Urban Heat Island in Baltimore City
Side by side, these two images compare Baltimore City's developed land (left) with land surface temperature readings.
Source: earthobservatory.nasa.gov

with asphalt, sidewalks, buildings, and other hard infrastructure. As opposed to natural elements of an ecosystem, which can absorb the sun's heat and cool the surrounding air through evapotranspiration, these hard materials retain and radiate heat. The resulting warm urban temperatures can give rise to adverse public and environmental health problems, and can increase energy usage for summertime cooling.[36] The urban heat island effect is anticipated to become intensified as extreme heat events increase as a result of climate change.

The 2001 satellite images of Baltimore City (Figure 3–18) shown above illustrate how intensely developed land contributes to rising temperatures near the city center. The left image shows impervious surfaces in the Baltimore metropolitan area, where the darker red areas represent dense, highly developed land. When compared to the land surface temperature image on the right, these same areas correspond with the hottest surface temperatures. Cooler areas correspond with open spaces, and low density development. According to the NASA Goddard Space Flight Center, Baltimore's land surface temperature changes by as much as 10 degrees Celsius going out from the city center.[37] More densely developed areas typically contain more materials (asphalt for example) likely to absorb and retain heat than rural areas.

While air conditioning is far more common today than it was in the past, there are many Baltimore residents who live without this luxury, either because of the associated expense or a personal choice. Row home style housing, which is typical of Baltimore, can become extremely hot during 90+ degree days and nights. Older residents may recall traditions of sleeping out on rooftops or in City parks to find relief from the heat. Today, however, these options are seen by most residents as unsafe or undesirable.

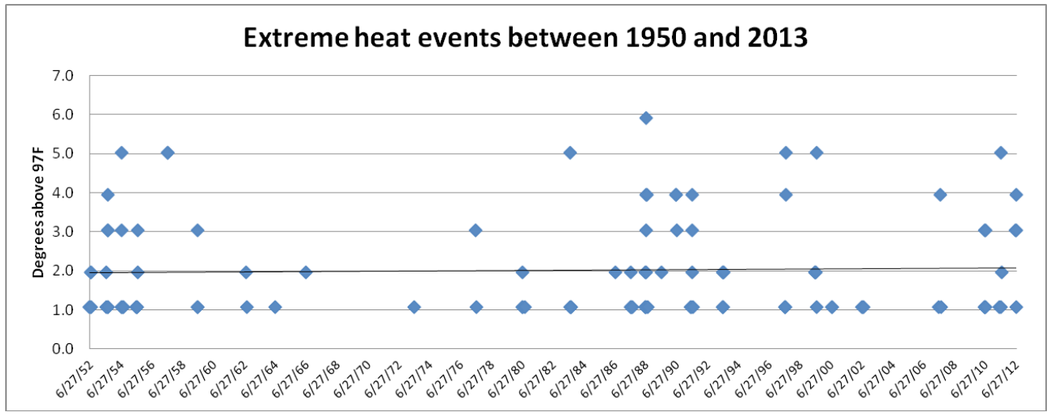


Figure 3–19 Extreme Heat Events in Baltimore Between 1950 and 2013

Over the past 50 years, average temperatures in the United States have increased more than 2°F. By 2100, Maryland's average winter temperature are projected to increase by 2-6°F and average summer temperatures are projected to increase by 3-9°F.38 Greenhouse gas (GHG) emissions will impact future scenarios; as GHG emissions continue to rise, so will average temperatures. Increases in average temperatures will lead to longer consecutive periods of 90°-100°F temperatures. Figure 3–19, above, shows that the short period between 1960 and 1980 characterized by fewer high heat days was disrupted in the late 1980s onward by years with more frequent days reaching temperatures above 97°F.

A significant increase in the number of extreme heat days could place people at a greater risk of suffering from heat-related health conditions, including heat stress, heat exhaustion, or heat stroke. These medical problems are a particular threat to the elderly population, young children, or people with respiratory difficulties. For instance, in the heat wave following the June 29, 2012 derecho, a total of 8 heat-related fatalities were reported in Baltimore City.[39]

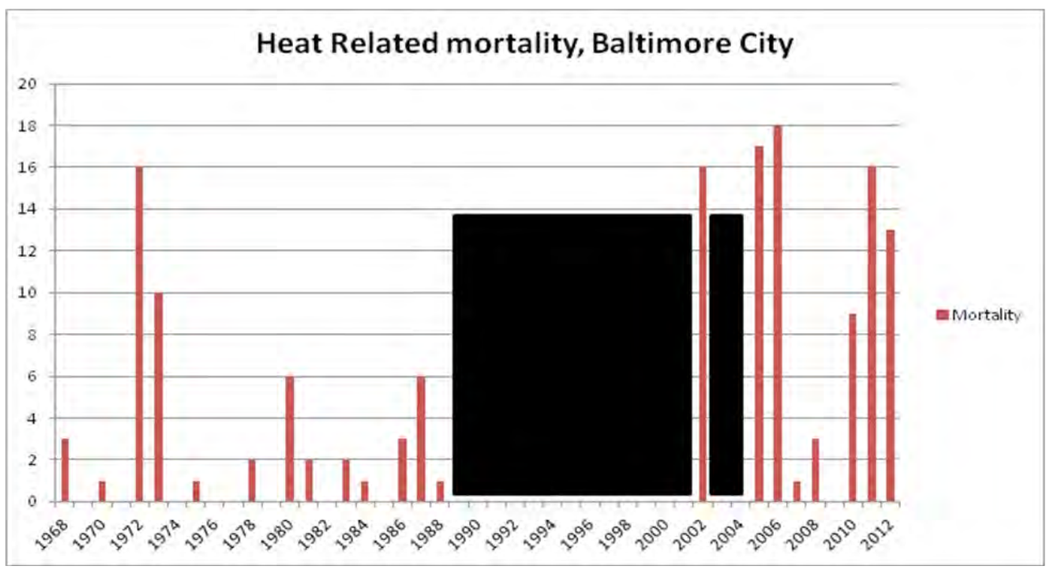


Figure 3–20 Heat Related Mortalities in Baltimore City

Heat Fatalities in Baltimore City (pre-2005 data is provided by CDC, but starting 1989, data is "suppressed" if less than 10 for privacy purposes. Data from 2005 onwards is from BCHD). Also presented is monthly heat mortality since 2005, with average monthly temperature.

Air Quality & Respiratory Illnesses

Health risks associated with heat — particularly risks that worsen symptoms triggered by respiratory diseases — are further provoked by diminished air quality. Trees and other vegetation cool the surrounding air and are shown to help to improve air quality. According to the American Lung Association, Baltimore City received a D Grade in the 2013 Air Quality Report Card.[40] The map below, Figure 3–21, utilized air quality trends to grade air quality in Maryland. The Baltimore region, highlighted in red, received an 'F'.

Acting as filters, trees gather find particles from the air, and scientists have long considered the capacity of trees to affect air pollution. Researchers with the U.S. Forest Service, studying a number of cities including Baltimore, were recently able to quantify one health benefit of the urban tree canopy. Their study found that trees in Baltimore remove approximately 14 tons of pollution each year.[41] Tying these findings to public health, this service is equated with one less premature death, nearly 140 fewer asthma attacks, and avoiding an estimated 240 cases of labored breathing. Other highly populated cities with denser tree canopies have shown even greater influence. In New York City, for example, the study estimated that the tree canopy could be credited with preventing as many as 8 deaths.

Summertime heat increases energy usage which, in turn, produces emissions that boost the concentration of harmful pollutants in the air. Furthermore, higher temperatures accelerate the chemical reaction that produces ground-level ozone, or smog. By the middle of the century, Baltimore is expected to endure a 28 percent increase in the average number of days exceeding 8-hour ozone standards.[42] Coupled with the possibility of higher pollen generation from plants due to a changing climate, air quality conditions may become a more considerable threat. Air pollution triggers asthma attacks, exacerbates allergies, and can lead to long-term health problems such as heart disease or stroke. Currently, asthma is the number one chronic disease among this nation's youth, afflicting one out of every 10 schoolchildren. Higher cases of these heat and air-quality induced conditions can place a stress on medical facilities.

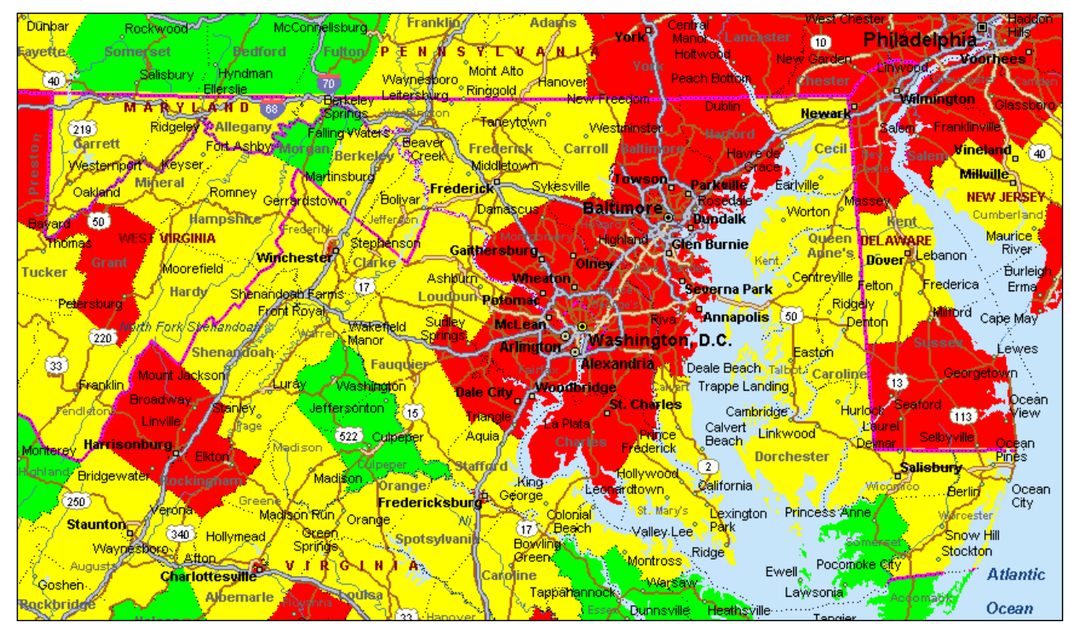


Figure 3–21 Maryland Air Quality; Source: http://creativemethods.com/airquality/maps/maryland.htm

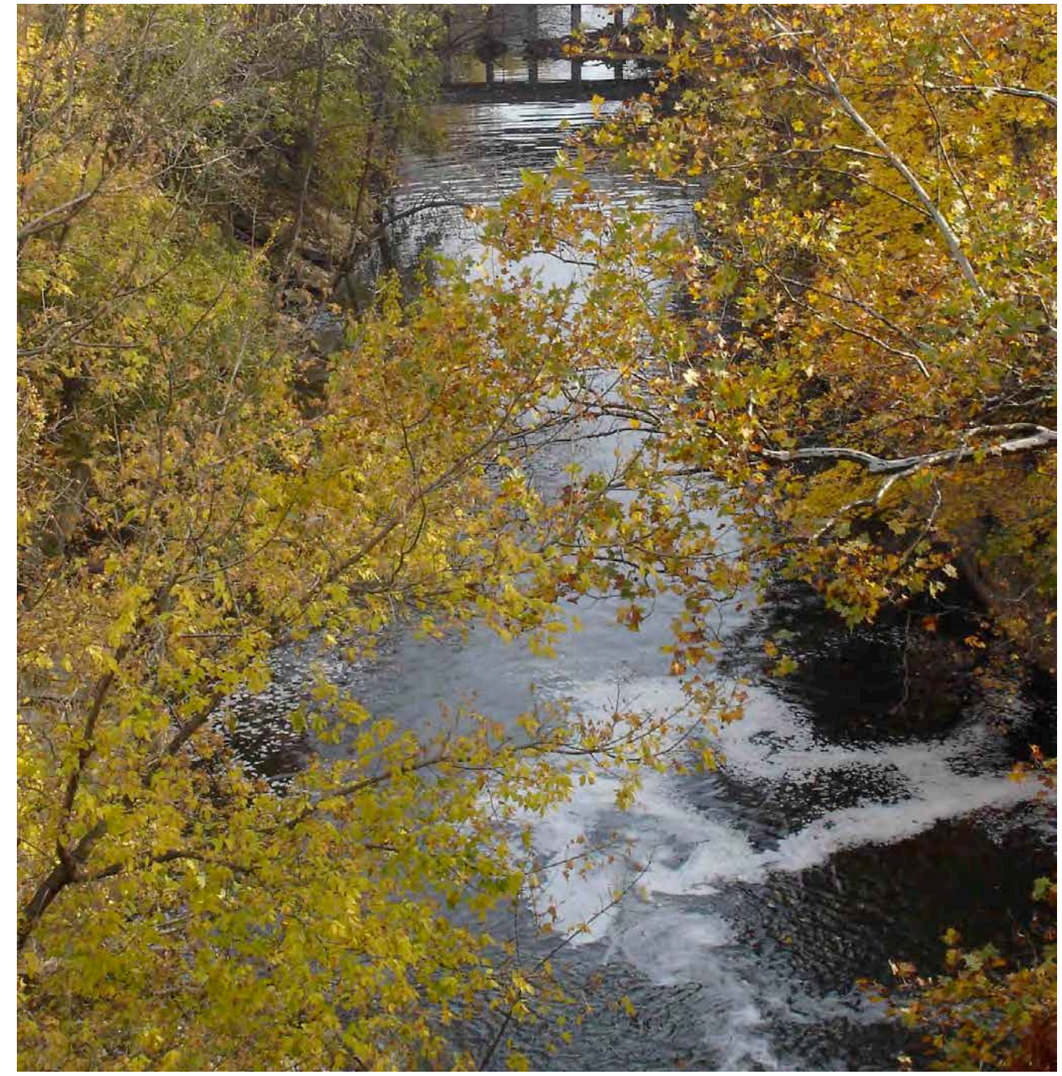
Vector-Borne Diseases

Warmer, wetter conditions help insects and diseases flourish. In a changing climate, increases in average temperature, precipitation, and humidity will enable disease-carrying vectors and pathogens to infiltrate urban environments more easily. These conditions create favorable environments, for example, for breeding mosquitoes, which are known carriers of disease. Already, Baltimore has experienced a growing population of the tiger mosquito, originally native to Southeast Asia.

According to the National Climate Assessment, shorter and warmer winters may increase survival and growth of disease-causing agents and parasites. Additionally, a changing climate may influence the distribution of diseases that are sensitive to temperature and moisture — including anthrax, blackleg, and hemorrhagic septicemia — and lead to increased incidence of ketosis, mastitis, and lameness in dairy cows.[43]

Extreme Heat Impacts on Infrastructure

Extreme heat in dense cities, as is typical of Baltimore City, can damage transportation and other infrastructure. Extreme heat damages transportation infrastructure, including streets, rail lines, and airport runways. Heat experiences may reduce the reliability and capacity of transportation systems. Extended periods with extreme heat can also tax the energy system, stressing or even damaging utility infrastructure.



Trees and the Ecosystem

As mentioned above, the overall climate of the Baltimore region will soon be quite different from what we now recognize. With changing patterns, Baltimore's current climate zone is expected to be altered significantly. Summer months may soon feel more like the climate that is currently typical of southern states. As the overall climate begins to change, there will be a major shift in habitat conditions. We may, therefore, anticipate new challenges for native wildlife and vegetation.

As new species of insects, plants, and animals invade the Baltimore region, native species are challenged to compete for survival. However, at the same time, their native habitats grow more harsh and unfriendly. Changing precipitation patterns, for example, can dehydrate trees which may be simultaneously exposed to outbreaks of pests or diseases. Coping with intense struggles on two levels will place tremendous stress on a species.

Impacts on Water Sources

While drought is one threat to water supply (see Precipitation Variability Hazard Profile), extreme heat is another; and it is possible that Baltimore could experience both conditions at the same time, amplifying the impact. Extreme heat may actually increase the frequency and likelihood of drought events. In spite of projections of moderate increases in annual precipitation in Maryland, increases in temperatures in climate models lead to decreases in soil moisture throughout the year. In Maryland, the number of days above 90°F is projected to more than double under a lower greenhouse gas emissions scenario and roughly triple under a higher emissions scenario by the end of the century. Extended heat waves (temperatures above 90°F for at least three consecutive days) are expected to be much more frequent and longer lasting, particularly under higher emissions scenarios.

Maryland's diverse geology and water resources affect its vulnerability to drought. Ground water is the most commonly used source of water supply and is obtained from both confined and unconfined aquifers. Public water suppliers rely on surface waters for their water supply. About two-thirds of Maryland's citizens regularly consume water that originates from a surface water source. In general, counties that have invested in water supply and distribution infrastructure are generally less vulnerable to drought. However, communities relying on the Potomac and Susquehanna Rivers and their tributaries for water are more vulnerable during a drought than those using the Chesapeake Bay. This is due to the lack of recharge from surrounding watersheds (Figure 3–22, below) that flow into the rivers.

Baltimore City and Washington, D.C. rely on the Susquehanna and Potomac Rivers respectively. The Baltimore City water system was designed over 75 years ago to provide a year-round supply of water. If that supply is ever depleted, Baltimore can pump water into the City from the Susquehanna River through an existing 120" diameter water main. This back-up system, however, has never been needed. Whether or not this system is still functional is actually unknown. Meanwhile, Washington, D.C. has less than a week's supply of water if the Potomac River were to dry up.

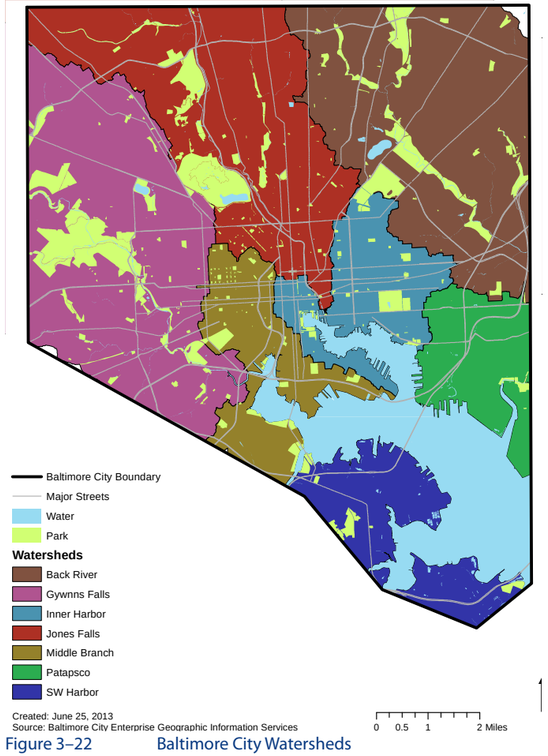


Figure 3–22 Baltimore City Watersheds

Agriculture and Aquaculture

Agriculture is Maryland's largest industry, and drought is a significant, recurring problem. While many factors can influence agricultural productivity, declines in crop yields are most closely linked to insufficient precipitation (see Precipitation Variability). Depleted soil moisture can also have a direct impact on agricultural productivity and can continue to affect yields even after normal precipitation levels return. While agricultural production is not as significant in Baltimore, many City residents do rely on surrounding agricultural operations for their food supply.

More than just precipitation and soil moisture, however, crops may depend on other climatic conditions to thrive. The growing season, for instance, determines what crops can grow in the area during certain months. As the regional climate shifts, growing seasons for certain crops are extended. By the end of the century, the number of growing days in Maryland is expected to increase from 239 days a year to between 259-278 days a year.[44] To sustain familiar crops, farmers may begin to place an additional strain on water resources. While the growing season shifts, other crops may simply find it too warm to grow at all. For farmers with resources at hand, this may be seen as an opportunity. However, many farmers will find the adjustment challenging.[45]

Food security will be jeopardized in other ways. Animals will find it difficult to adapt to the changing climate and to respond to extreme temperature by altering their metabolic rates and behavior. According to the National Climate Assessment, increases in extreme heat events may place animals under conditions where their efficiency in meat, milk, or egg production is impacted.[46] Risk is intensified in animals used for meat production, as these animals are managed for a high rate of weight gain.

Baltimore is also susceptible to changing water conditions that will impact aquaculture operations. In addition to water quality concerns — levels of oxygen or the balance of nutrients — the City is also threatened by climate-related changes in aquatic environments. Marine environments are likely to change due to experienced increases in temperatures or from acidification. These conditions may force aquatic life to permanently migrate farther north, and can also increase instances of pathogens and disease, frequency and intensity of algal blooms, and the devastating effects of invasive species. Decreases in pH levels are caused by the buildup of carbon dioxide in the atmosphere. These changes make it more difficult for shellfish and similar creatures to develop their shells. Threat to aquaculture production is a global concern, and will therefore also have an effect on seafood goods which may be imported.

Figure 3–23 The aftermath of a 2011 Earthquake Event felt in Baltimore; *Source: WBALTV*

Land

Earthquakes

An earthquake, also called a seismic event, is a trembling of the ground caused by the sudden movement of large sections — called tectonic plates — of the Earth's outermost crust. The edges of tectonic plates are marked by faults. Most earthquakes occur along fault lines when two or more plates slide past each other or collide against one another. As a result, the shifting masses send out shock waves that may be powerful enough to:

- Alter the surface of the Earth, thrusting up cliffs and opening great cracks in the ground and
- Cause great damage ... collapse of buildings and other man-made structures, broken power and gas lines (and the consequent fire), landslides, snow avalanches, tsunamis (giant sea waves) and volcanic eruptions.

Earthquakes are measured both in terms of their magnitude and their intensity. The effect of an earthquake on the Earth's surface is called the intensity. The intensity scale consists of a series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and, finally, total destruction. Although numerous intensity scales have been developed over the last several hundred years to evaluate the effects of earthquakes, the U.S. currently utilizes the Modified Mercalli Intensity (MMI) Scale (Table 3–23). Developed in 1931 by a pair of American seismologists, the MMI scale distinguishes between 12 increasing levels of intensity — ranging from imperceptible shaking to catastrophic destruction — designated by Roman numerals. Because the MMI scale measures intensity based on the observed effects of an earthquake's impact on a particular area, it is often a better indication of severity to the nonscientist than is the measure of magnitude.

Earthquakes are low probability, high-consequence events. Although earthquakes may occur infrequently, they can have devastating impacts. Ground shaking can lead to the collapse of buildings and bridges; disrupt gas, life lines, electric, and phone service. Deaths, injuries, and extensive property damage are possible vulnerabilities from this hazard. Some secondary hazards caused by earthquakes may include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis, and dam failure. Moderate and even very large earthquakes are inevitable, although very infrequent, in areas of normally low seismic activity.

Table 3–23 The Modified Mercalli Intensity Scale of 1931 (abridged)

Intensity	Experience
I	Not felt except by very few people under especially favorable conditions.
II	Felt by a few people, especially those on upper floors of buildings. Suspended objects may swing.
III	Felt quite noticeably indoors. Many do not recognize it as an earthquake. Standing motorcars may rock slightly.
IV	Felt by many who are indoors; felt by a few outdoors. At night, some awakened. Dishes, windows and doors rattle.
V	Felt by nearly everyone; many awakened. Some dishes and windows broken; some cracked plaster; unstable objects overturned.
VI	Felt by everyone; many frightened and run outdoors. Some heavy furniture moved; some fallen plaster or damaged chimneys.
VII	Most people alarmed and run outside. Damage negligible in well-constructed buildings; considerable damage in poorly constructed buildings.
VIII	Damage slight in special designed structures; considerable in ordinary buildings; great in poorly built structures. Heavy furniture overturned. Chimneys, monuments, etc. may topple.
IX	Damage considerable in specially designed structures. Buildings shift from foundations and collapse. Ground cracked. Underground pipes broken.
X	Some well-built wooden structures destroyed. Most masonry structures destroyed. Ground badly cracked. Landslides on steep slopes.
XI	Few, if any, masonry structures remain standing. Railroad rails bent; bridges destroyed. Broad fissure in ground.
XII	Virtually total destruction. Waves seen on ground; objects thrown into the air.

Earthquake Fact Sheet, MGS, www.mgs.md.gov/esic/brochures/earthquake.html,

Table 3–24 Approximate relationships among earthquake magnitude, intensity, worldwide occurrence, and area affected

General Description	Richter Magnitude	MMI	Expected Annual Incidence	Distance Felt (miles)
Microearthquake	below 2.0	--	600,000	--
Perceptible	2.0-2.9	I--II	300,000	--
Felt generally	3.0-3.9	II-III	49,000	15
Minor	4.0-4.9	IV-V	6,000	30
Moderate	5.0-5.9	VI-VII	1,000	70
Large (Strong)	6.0-6.9	VII-VIII	120	125
Major (Severe)	7.0-7.9	IX-X	18	250
Great	8.0-8.9	XI-XII	1.1	450

MGS, Earthquake Fact Sheet, www.mgs.md.gov/esic/brochures/earthquake.html

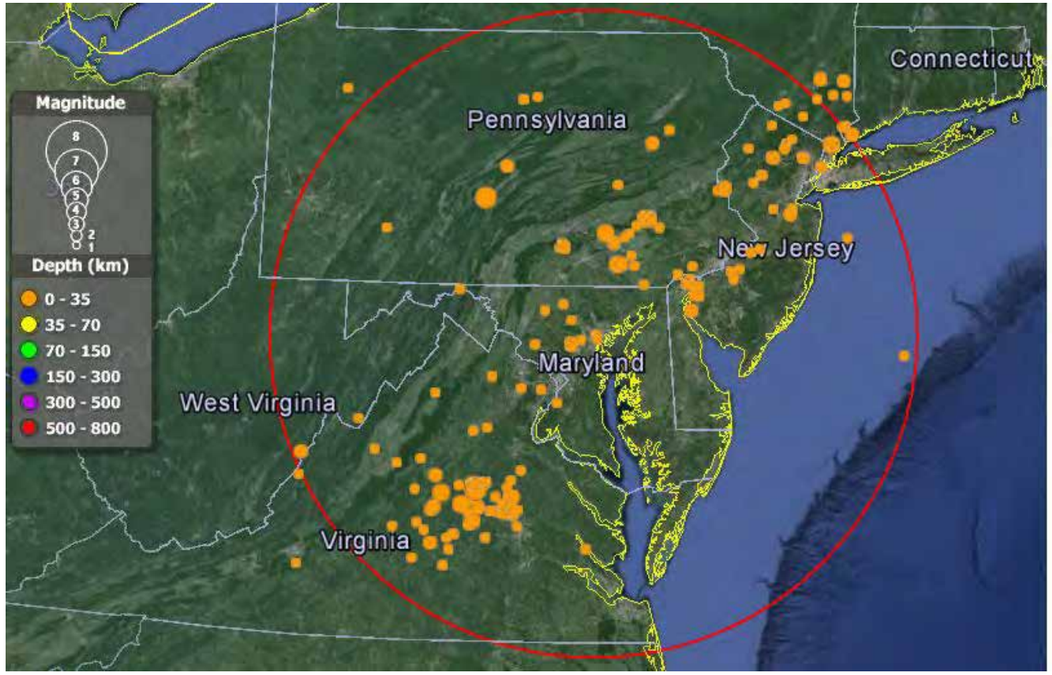


Figure 3–24 Earthquake Events Originating Around Baltimore City

Source: http://www.ncedc.org/acknowledge.html

Table 3–25 Earthquake Events Within 200 Miles of Baltimore City

Date	*Location*	*Magnitude*
8/23/2011	Louisa County, Virginia (37.94N, 7793W)	5.8
7/16/2010	Potomac Region (39.17, -77.25)	3.4
9/29/2009	Bel Air, Maryland (39.607, -76.342)	1.6
7/1/2009	SW New Jersey (39.64, -75.48)	2.8
12/27/2008	Lancaster, Pennsylvania	3.4
2/23/2005	SE Baltimore (39.26, -76.58)	2
12/9/2003	Virginia (37.599N, 77.932W)	4.5
8/26/2003	New Jersey (40.61N, 75.11W)	3.8
3/22/2002	Columbia, Maryland (38.19, -76.84)	1.0 to 2.0
12/18/2001	Columbia, Maryland (38.19, -76.84)	1.5 to 2.0
9/25/1998	Pennsylvania (41.49N, 80.38W)	4.5
12/22/1996	Columbia, Maryland (39.19, -76.87)	2.0, 2.3
12/16/1996	Ellicott City, Maryland (39.25, -76.77)	about 1.0
12/14/1996	Columbia, Maryland (39.19, -76.87)	<1.5
12/6/1996	Columbia, Maryland (39.19, -76.87)	<1.5
10/17/1996	Rising Sun, Maryland (39.7, -76.60)	2.2, 2.3
8/2/1996	Perryville, Maryland (39.57, -76.08)	22
10/28/1994	Glen Burnie, Maryland (39.1, -76.60)	2.7
1/16/1994	Pennsylvania	4
1/16/1994	Pennsylvania	4.6
11/27/1993	Columbia, Maryland (39.19, -76.87)	about 1.5
11/27/1993	Columbia, Maryland (39.19, -76.87)	<1.5
11/17/1993	Columbia, Maryland (39.19, -76.87)	1.7
10/28/1993	Ellicott City, Maryland (39.25, -76.77)	1.8
10/28/1993	Ellicott City, Maryland (39.25, -76.77)	2.1

[Table 3-24 Continued]

Date	*Location*	*Magnitude*
7/12/1993	Columbia, Maryland (39.19, -76.87)	2.1
7/9/1993	Columbia, Maryland (39.19, -76.87)	1.9
4/8/1993	Columbia, Maryland (39.19, -76.87)	1.0 to 1.5
4/4/1993	Columbia, Maryland (39.19, -76.87)	1.5
4/4/1993	Columbia, Maryland (39.19, -76.87)	1.5
3/26/1993	Ellicott City, Maryland (39.28, -76.82)	<1.5
3/22/1993	Columbia, Maryland (39.19, -76.86)	about 0.0
3/21/1993	Aberdeen, Maryland (39.47, -76.30)	1.5
3/19/1993	Columbia, Maryland (39.19, -76.87)	<1.0
3/19/1993	Columbia, Maryland (39.19, -76.87)	1
3/17/1993	Columbia, Maryland (39.19, -76.87)	<= 1.0
3/16/1993	Columbia, Maryland (39.19, -76.87)	1.8
3/16/1993	Columbia, Maryland (39.19, -76.87)	1.8
3/15/1993	Columbia, Maryland (39.19, -76.87)	2.7
3/12/1993	Columbia, Maryland (39.19, -76.87)	2
3/10/1993	Columbia, Maryland (39.19, -76.87)	2.5
9/28/1991	Granite, Maryland (39.35, -76.83	2.4
4/4/1990	Granite, Maryland (39.35, -76.78)	1.7
1/13/1990	Randallstown, Maryland (39.36, -76.78)	2.6
5/23/1986	Accoceek (38.69, -77.04)	2.5
4/23/1984	Lancaster County, Pennsylvania	4.4
4/26/1978	Hancock (39.7, -78.24)	3.1
9/7/1962	Hancock (39.7, -78.20)	3.3

The Table (Table 3–25) and Map (Figure 3–24) above display earthquake events within 200 miles of Baltimore City between 1950 and 2012. While no earthquake epicenters have been located within the City of Baltimore, strong earthquakes are capable of being felt for hundreds of miles. In 1897, the Giles County Virginia Earthquake measured 2.0 MMI in Baltimore. The strongest earthquake felt in the Baltimore region, however, was another Virginia earthquake that measured an intensity of 5.8, originating in Louisa County on August 23, 2011. This event caused considerable damage in Baltimore; a number of buildings were damaged, including the historic and celebrated Baltimore Basilica, which reported between $3-5 million in damages.

Compared to other parts of the United States, the Baltimore region has relatively low probability of experiencing strong earthquakes. Figure 3–25 shows the expected maximum horizontal ground acceleration (PGA) — or ground shaking — as a percent of gravity (%g). The Baltimore region has an expected peak acceleration of 8%g. At this level, as noted in Table X, any potential damage is expected to be very light.[47]

Landslides and land slumping may contribute to, or heighten, the probability of earthquake events in Baltimore. Landslides often occur along steep slopes, karst terrain (see below), or otherwise unstable land. Slopes greater than 15 percent often become unstable due to one, or a combination of, conditions including loose soil or rock, lack of vegetation, insufficient moisture, or instability during or after an earthquake. The Maryland Geological Survey (MGS) does not consider Baltimore to have a significant risk of landslide due to the lack of mountainous areas. While there are indeed some steep slopes, particularly near streams, these slopes are usually vegetated and stable, and are therefore unlikely to instigate minor earthquakes.

The Maryland Geological Survey does caution, however, that land slumping could become a significant hazard in the event of a major earthquake. Downtown Baltimore has been developed upon a considerable amount of artificial fill that extended into harbor waters. Deposited into the water as a means to dispose of debris after the Great Fire of 1904, the fill provided reclaimed land for the growing city. Were a severe earthquake to occur in or near Baltimore, scientists at MGS predict that many structures located atop the filled land would likely suffer significant damage.

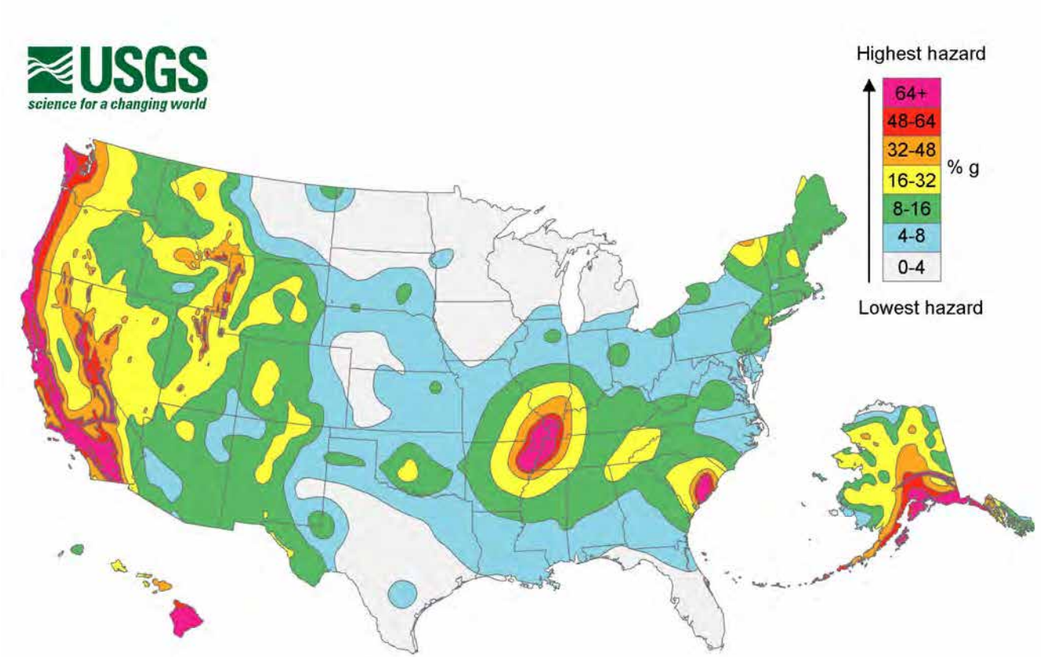


Figure 3–25 Peak Ground Acceleration

Source: USGS; http://earthquake.usgs.gov/hazards/products/

Subsidence

Land subsidence is the gradual settling or sinking of the Earth's surface. Subsidence may be gradual or sudden and can range in extent—from broad, regional reductions in elevation to localized areas of collapses. It is often caused, principally, by aquifer system compaction, drainage of organic soils, underground mining, hydro-compaction, natural compaction, sinkholes, and thawing permafrost. Subsidence is a global problem; in the United States, more than 17,000 square miles in 45 states — an area roughly the size of New Hampshire and Vermont combined — have been directly affected by subsidence.

Regional subsidence is believed to be the result of post-glacial rebound following the last glacial maximum. The mass of the ice sheet had displaced land, pushing the surrounding land upward at the ice sheet's coverage (Chesapeake Bay region in Maryland). Ever since the ice sheets retreated, the elevated area has been subsiding. At the regional level, Maryland has been subsiding at a rate of approximately 1.5 mm/yr.[48] Recent climate assessments have reported Baltimore's rate of land subsidence to have been roughly half a foot in the last century.[49] When coupled with rising waters, local land subsidence can exacerbate relative sea level rise.

Urban Karst/Sinkholes

The term "karst" refers to land that is characterized by various subterranean features—including sinkholes, caves/caverns, underground streams, and other features that are formed by the dissolution of calcium and magnesium oxides in certain rocks. Karsts may produce surface and subsurface conditions that give rise to a number of problems. According to a report published by the Western Maryland Resource Conservation and Development Council, Karst regions are prone to unpredictable or easily contaminated groundwater supplies.[50] Additionally, karst lands are susceptible to subsidence and other changes in land, such as sinkholes which present a physical hazard. Karst formations develop in specific ways that are influenced by unique local conditions. These geological conditions are not naturally present in Baltimore, and so the City is not significantly impacted by karst formations. In fact, to date, there have been no Federal Declared Disasters or NCDC recorded events for karst-related hazards in all of Maryland.[51]

In addition to natural processes, however, sinkholes can be induced through human actions. Human-induced sinkholes can be triggered by simple alteration in the local hydrology. Inadequate drainage along highways and increased runoff from pavement can also be sources of sinkhole development. In Baltimore, infrastructure-related sinkholes have been the primary concern.

Maryland is affected by a broad, regional subsidence phenomenon and more localized land collapsing due to sinkhole formation. Sinkholes have the potential to cause damage to infrastructure and buildings and may result in injuries or even fatalities. When coupled with heavy rainfall, risks associated with sinkholes may increase. In August of 2012, following heavy rains, a sinkhole opened on Baltimore's East Monument Street above a 120-year-old drainage culvert. When another storm released an estimated one to three inches of rain on top of the repair effort, emergency workers were forced to once again evacuate the site. The impact was extensive; not only was the roadway closed due to repair and reconstruction, but the drainage pipe beneath it, "the main artery draining storm water to the Inner Harbor for hundreds of acres," was also out of commission — unable to accommodate those heavy rains, contributing to local flooding and leading to additional sinkhole damage.[52] It took five months for crews to complete restoration — a project that cost the City $7 million (not including the economic impact on four blocks of affected area businesses, which was severe).[53] Furthermore, additional funds would still be needed to fully repair the three water utility lines below the roadway.

Figure 3–26 A Sinkhole in Baltimore's Canton Neighborhood, O'Donnell Street, Occurred in the last week of June, 2013

Source: WBALTV

Table 3–26 Major Baltimore Sinkholes in the Past Decade

Race and West Street	2008
2238 East Monument Street	2009
2100 S. Clinton Street	2009
600 Cathedral Street	2011
I-83 & 29TH Street	2012
2300 block of East Monument Street	2012
W 37th and Keswick	2013
721 Gorsuch Avenue	2013

Source: Baltimore City Department of Public Works

Sinkholes appear to be happening more frequently. An article from December 2012 noted that sinkholes had been occurring in large numbers across the country, suggesting that frequent and large sinkholes may be quickly becoming the "new normal." The article noted that, in Baltimore specifically, more than four sinkholes had recently developed in three weeks that December. In fact, the article states that "as [Baltimore] crews worked on one sinkhole, another opened up about 125 ft. west of the original sinkhole widening rapidly within 15 minutes" noting also that two Fells Point homes were sinking during the same time period.[54] While it would appear that sinkholes are becoming more of a threat in Baltimore, it remains difficult to identify key sensitivities.

Chapter 4

Vulnerability and Risk Assessments

A risk assessment is a multi-faceted, 'stepped' process. To conduct a risk assessment, the first step required is a thorough hazard identification analysis, as provided in Chapter 3 Hazard Assessment. This hazard identification process reviewed cases of historical hazards in Baltimore — including current threats as well as any predicted threats due to climate change — and considered the severity of each hazard. Understanding the full extent to which Baltimore may be affected in the future by the hazards identified and profiled in this document provides the foundation for a comprehensive vulnerability assessment.

The vulnerability assessment, the second step of the risk assessment, is the process of evaluating the potential losses associated with a given hazard and estimating the degree to which property damage, economic loss, physical injury, or death are likely to occur. In this chapter, the risk assessment is expanded beyond identifying relevant hazards to fully understand how and why Baltimore is at risk, and where a risk may be greatest in Baltimore City.

Vulnerability, specifically, refers to the *susceptibility* of people, properties, and resources to the impacts associated with such hazard events. For example, a range of community assets — including residential or public structures and infrastructure — may be deemed vulnerable to various hazard risks. The level of vulnerability depends on a number of factors, including location, construction, property contents, and the economic value of the function(s) being provided by an individual, facility, or system. Vulnerability may be intensified due to a lack of resources or information. Additionally, certain geographic areas or social dynamics may contribute to the circumstances that can make one population more sensitive to hazards than others. When vulnerability is greater for particular social groups or individuals, it becomes a matter of environmental justice. The vulnerability assessment investigates the exposure (lack of defense), sensitivity (degree to which a system is affected), and Adaptive Capacity(ability to recover[1]) of an individual or asset in regards to a particular hazard.

Observing conditions in Baltimore City as a whole, the vulnerability assessment identifies what key community assets and critical facilities exist across all of Baltimore in order to understand where special consideration may be required (see Assessing General Hazard Vulnerabilities for the City of Baltimore). Later in the chapter, vulnerability is assessed for each of the specific hazards identified in Chapter 3 and, again, identifies which community assets and critical facilities are vulnerable to the specific hazard. These focused inventories will, when possible, provide descriptions to note why certain structures, critical facilities, or vulnerable populations are most susceptible.

While "impact" had been considered in the previous stages of the risk analysis (the hazard identification process considered what, in the past, had been impacted during a hazard event in terms of extent and severity; while the vulnerability analysis reviewed assets and systems that are most likely to be impacted during a hazard event based on their exposure, sensitivity, and adaptive capacity), the formal impact assessment offers a better understanding of the types and costs of injury or damage that a hazard event may cause in Baltimore. As a result, the impact assessment builds upon the earlier risk assessment stages through an evaluation of the asset inventory — highlighting particular assets that are likely to be impacted and summarizing estimated potential losses sustained as the result of a particular hazard.

By doing so, the vulnerability and impact assessment findings discussed below, when combined with the information revealed in the previous hazard identification process, will lay the foundation for effective adaptation and mitigation strategies.

Chapter 4 provides the following information:

1. Self-Assessments of the City of Baltimore vulnerabilities;
2. Description of HAZUS-MH assessment tool;
3. General inventory of assets and critical facilities;
4. Specific vulnerability assessments by hazard including:
5. Identification of the range of vulnerabilities to community assets;
6. Identification of the range of vulnerabilities to critical facilities;
7. Estimated economic impacts
8. Initial selections of key vulnerabilities; and
9. An explanation of adaptive capacity.

Throughout this process, the City utilized self-assessment tools as well as the Hazards U.S.–Multi-Hazard, or HAZUS-MH, software offered by the Federal Emergency Management Agency (FEMA). Self-assessments were conducted with Agency Directors, the DP3 Advisory Committee, and members of the public. To further inform the assessment, FEMA's HAZUS-MH software was utilized for estimating potential losses to natural disasters which is the national standardized methodology used across the country.

Vulnerability Assessment Tools Utilized

This plan recognizes that a number of tools for understanding natural hazard and climate impacts already exist. Perhaps most notable among these existing resources is NOAA's Coastal Services Center (CSC) Roadmap for Adapting to Coastal Risk, which includes a Risk and Vulnerability Assessment Tool (RVAT) and a Community Vulnerability Assessment Tool (CVAT). These existing tools and resources helped to establish a thorough framework for guiding the risk and vulnerability process of this plan. Learning from such tools, DP3 created an approach that was most appropriate for issues specific to Baltimore.

Self-Assessment Tools and Methodology

To supplement the technical and quantitative methods used to analyze potential natural hazards in Baltimore, the DP3 process consulted a number of community stakeholders and constituents, as well as the expert input from members of the Advisory Committee, for a self-assessment of risk and vulnerability. This process guided early development of the DP3 plan by identifying priority actions for addressing the key issues which confront the City of Baltimore.

Self-Assessment by Agency Directors

Assessing risk required input from the City of Baltimore DP3 Advisory Committee; this self-assessment utilized two different methods. First, the process employed a Disaster Preparedness and Planning Project Vulnerability Assessment Tool. This tool, which asked members to rank the probability and severity of various hazards (both natural hazards and man-made incidents were considered), revealed the percentage of relative threat (risk) for each hazard.

The Vulnerability Assessment Tool determined that extreme heat and severe storms were considered high concerns, in regards to both their relative threat and potential severity. Events which would either have small implications (e.g. drought or erosion of the coastline), as well as those hazards which have had little effect in the past or are unlikely to impact the City in the future, were of less concern. (A detailed summary of the findings of this assessment may be found in Appendix X.

In a second self-assessment, the Advisory Committee was asked to interpret potential impacts from three different scenarios by providing their qualitative input regarding the potential impact to economic, environmental, personal, and systems-related aspects of urban living. In each category, a number of factors were considered.

This assessment focused on specific vulnerabilities. In general, the responses indicate that the committee members were most concerned about the impact of hazards on Baltimore's operational systems, primarily on energy systems (demand and capacity), and any associated increases in costs required for maintaining continuous service. Additionally, throughout all scenarios, health, healthcare, and individual wellness and productivity were commonly cited as potentially being impacted.

The questions listed below were asked of the Advisory Committee members when interpreting the scenarios impacts.

PERSONAL

- How would this scenario impact your personal life?
- How would it impact your immediate family?
- How would it impact the people you work with?
- What impact would it have to your home?

ECONOMIC

- How would this scenario impact business in your neighborhood?
- How would it impact the city at large?
- Environmental:
- How would this scenario impact your local environment?

SYSTEMS

- How would this scenario impact the systems in which you work?
- How would it impact the systems you rely on daily?

Main economic matters that were discussed included business viability, business owner hardship, workforce capacity, and other issues related to meeting commercial and service demands. Even outside of questions specifically about economic implications, financial impact was a major concern of all scenarios. Systems interpretations of each scenario were focused on infrastructure, particularly related to transportation and utilities, communication, and water and wastewater systems. Additional concern was expressed for the resiliency of city services, including trash collection.

Overall, Committee members were concerned with resident health and for the capacity of Baltimore's infrastructure and economic systems to withstand hazard impacts. A detailed summary of this self-assessment, included each committee member's survey, may be found in Appendix ___.

Self-Assessment by Members of the Community

Members of the community were also asked to provide their input through various outlets and tools. First, community members received brief surveys during attendance of the two Town Hall events. At the second Town Hall, residents and attendees were also asked to participate in two activities through which they could recommend directed actions.

During the April 30th Town Hall event, surveys indicated that most residents perceived an increase in the frequency of extreme weather events, particularly storms accompanied by high wind and heavy rain. Most respondents felt that individuals in their immediate households were moderately vulnerable to extreme weather events. Approximately half of the respondents expressed concern for both public sewer systems and human health. While the Advisory Committee self-assessments indicated that few representatives saw erosion or coastline damage to be a major issue, about half of the community participants selected coastlines as a resource that may be harmed by climate change.

Although most respondents indicated the presence of a hospital and strong community groups in their areas, there was a general lack of additional critical facilities or assets within the communities of the survey participants. While this may be true, it could, however, indicate a lack of awareness where those facilities and assets do indeed exist. These same surveys were distributed at a second Town Hall on July 30th.

During the July 30th Town Hall, attendees were asked to participate in two activates. As they arrived, attendees were given $500 in "DP3 Dollars" to allocate, with their limited budget, where Baltimore should spend money to create a more resilient City. Their options included stormwater infrastructure, resilient energy systems, transportation infrastructure, human health programs, trees and greening, and building codes. The funds were distributed relatively evenly; in total, 22 percent of the money had been "invested" in stormwater infrastructure, with 21 percent going towards resilient energy systems. The remaining money was allocated, in order of importance, to transportation infrastructure (19 percent), human health programs (15 percent), trees and greening (12 percent), and building codes (10 percent).

As attendees arrived, they were also provided with six blue sticker dots and were asked to place stickers

Photos from the July 30th Town Hall

next to strategies they felt would be most important. A total of nine strategies received ten or more stickers; four from infrastructure, two from natural systems, two from public services, and one from buildings. In general, the attendees were concerned with strengthening the resiliency of systems upon which residents depend on a daily basis. Water quality was a major concern, and strategies which protected distribution systems for drinking supplies (IN-14, 16 votes) and improved stormwater management techniques — including reductions in impervious surfaces (IN-17, 12 votes)and the enhanced environmental health of Baltimore's watersheds (NS-3, 11 votes) — were supported. Environmental health efforts were also valued, illustrated by the number of attendees supporting a strategy that would enhance the resilience of Baltimore's urban forest (NS-2, 12 votes).

The preferred strategies also tended to ensure adequate integration of hazard mitigation planning with City and community plans (PS-4, 11 votes), as well as with existing private and State systems, operations, and maintenance efforts (IN-21, 10 votes). Similarly, attendees were interested in empowering community members to be involved and assist with the DP3 process (PS-3, 10 votes). Finally, attendees supported the increased resiliency of electricity systems (IN-1, 10 votes) and a revision of building codes to reflect anticipated climate changes (BL-3, 10 votes). (Detailed descriptions of these strategies can be found in the following Chapter, Strategies and Actions, or in the Implementation Maintenance and Evaluation segment of Chapter 6)

HAZUS-MH

The City of Baltimore has utilized the Hazards U.S.–Multi-Hazard, or "HAZUS-MH," software offered by FEMA. HAZUS-MH is a nationally standardized methodology that provides a framework for estimating potential losses from natural hazard events—specifically, earthquakes, floods, and hurricanes. HAZUS-MH uses Geographic Information Systems (GIS) technology to map and estimate the potential physical, economic, and social impacts of these natural disasters. Providing an essential function of pre-disaster planning, the mapping processes can illustrate the coverage of identified high-risk areas, allowing users to visualize the spatial relationships between these specific hazards and Baltimore's many populations, assets, and resources.

HAZUS-MH is used for both mitigation and recovery efforts, as well as for preparedness and emergency response activities. Government agencies, GIS specialists, and emergency planners use HAZUS-MH, reviewing estimated losses to determine the most beneficial mitigation approaches for minimizing impacts. As a part of DP3's risk assessment, products of HAZUS-MH analyses help to identify critical vulnerabilities and significant impacts, and to inform long-term strategies and actions for preventing damage, effectively aiding in recovery and reconstruction efforts. Additionally, the maps generated by HAZUS-MH software are being used to supplement the information discussed in this report, as well as to grow general hazard awareness across the City.

Hurrivac Call-Out

Assessing General Hazard Vulnerabilities for the City of Baltimore

General Inventory of Community Asset in Baltimore City

Baltimore City has a rich history and boasts many diverse, vibrant communities. Community assets are all of the people, places, and activities which shape everyday life. A Community Asset Inventory (CAI) considers both physical structures and social environment. The CAI considers highly vulnerable populations, historic and cultural resources, economic elements, natural resources and recreation areas, and other important services.

While the CAI reviewed a number of facilities that contribute to the City's emergency response to hazards (see the General Inventory of Critical Facilities in Baltimore City segment below), there are also many community assets that — while not directly affecting the City's capacity for emergency response — will have a devastating impact should they not be aware of the vulnerability and take appropriate steps to mitigate and prepare. Next steps of the continuing DP3 effort will include outreach to the responsible parties identified in the CAI by communicating risks of hazards; offering assistance in vulnerability assessments; and to generally assist parties responsible for these assets in the own risk assessments. Outcome of this effort will be a partnership to identify common-interest mitigation measures.

Societal Impact Analysis

As stated, the CAI reviews an asset in terms of its hazard risk and vulnerability. The assessment below considers the various conditions that may make one person, place, or activity more vulnerable than others. In all instances of hazard events, vulnerability of the human population is based on the availability, reception and understanding of early warnings of hazard events (i.e., Hurricane Watches and Warnings issued by the NWS; Tornado Warning issued by the NWS) as well as access to substantial shelter and a means and desire to evacuate if so ordered. In some cases, despite having access to technology (computer, radio, television, outdoor sirens, etc.) that allows for the reception of a warning, language differences are sometimes a barrier to individuals understanding them. Certain populations — including children, elderly residents (Figure 4–1, right), and non-English speaking residents— may face greater challenges when overcoming the impacts of a hazard.

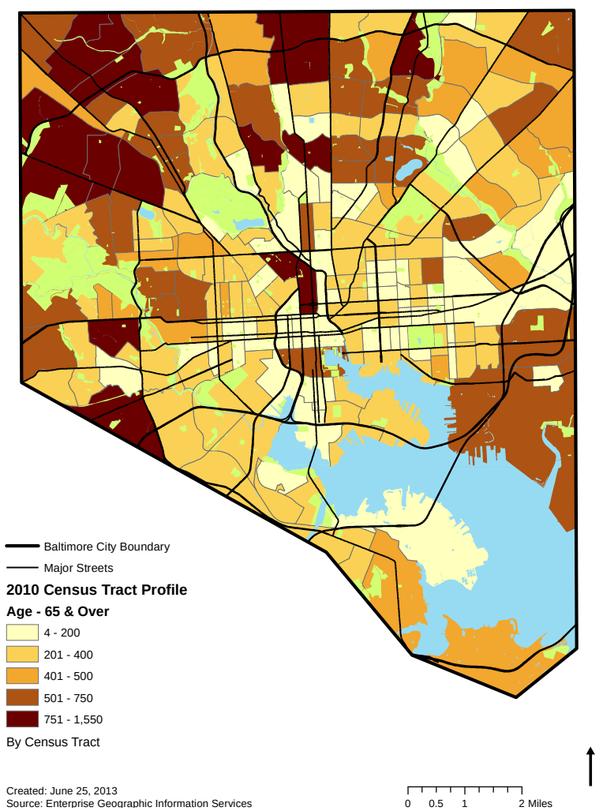


Figure 4–1 Concentrations of Baltimore City Elderly Residents

Health Impact Assessment (HIA)

The Baltimore Office of Sustainability (BoS) worked with the Baltimore City Health Department (BCHD) to integrate a preliminary Health Impact Assessment (HIA) into the Disaster Preparedness and Planning Project (DP3). The HIA focused on one strategy and two specific actions of the plan:

Strategy NS-2: Increase and enhance the resilience and health of Baltimore's urban forest

Action 3: Establish a comprehensive maintenance program that includes pruning for sound structure and the removal of hazardous limbs and trees. First focus on vulnerable infrastructure nearby such as essential facilities and roads

Action 5: Increase the urban tree canopy and target areas with urban heat island impacts.

The BCHD HIA team conducted preliminary research to gather evidence around the potential health outcomes related to NS-2. In order to better understand the impact on health outcomes of the proposed actions, community stakeholders were gathered to provide feedback and guidance. This meeting was held on July 31st, 2013. The stakeholder group was recruited through the Citizen's Planning and Housing Association to represent vulnerable stakeholders including residents, non-profits, City agencies, and community organizations. The stakeholders, in collaboration with the City agency representatives, prioritized their health concerns and indicated the magnitude of the potential health outcomes, keeping equity in mind.

The HIA team refined the literature and data search based on stakeholder input, thoroughly exploring areas prioritized by the community in addition to other significant areas identified through the preliminary research. Additionally, the team gathered data on local air temperature, crime, and Baltimore's tree canopy. On September 5th, 2013 the stakeholders reconvened to discuss new information and data. The stakeholder group reviewed the data and developed draft recommendations focused on equity and maximizing positive health outcomes.

The HIA team is currently in the process of developing formal recommendations concerning the types of trees, the locations of trees, the number of trees, and incentives for stakeholder engagement around tree maintenance. Additional information about this process can be found in Appendix XX.

Economic Impact Analysis

This risk and vulnerability analysis has also reviewed information regarding some of Baltimore's major employers. These facilities and businesses play a significant role in Baltimore's economy. Furthermore, due to the number of residents who may be employed by, or benefit from, these businesses, consideration must be given to their integrity to reduce and prevent the severity and scope of any possible impact as a result of a natural hazard. The map below (Figure 4–2) shows the location of major employers in Baltimore.

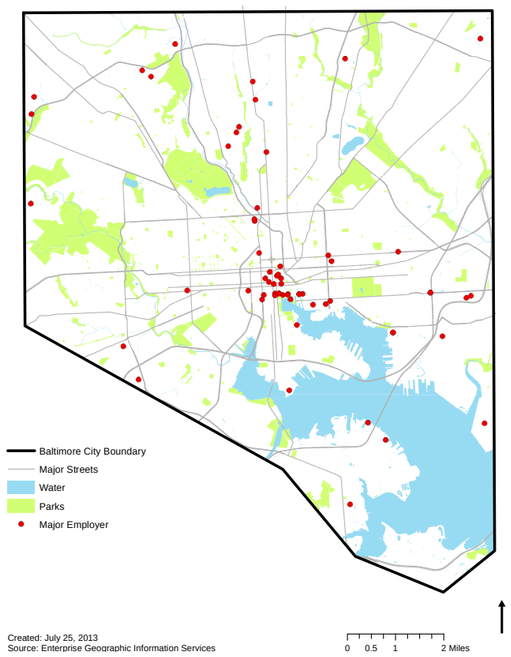


Figure 4–2 Major Employers in Baltimore City

Environmental Impact Analysis

Baltimore City has a number of natural features, open spaces, and parks and recreational facilities which should also be considered in the hazard mitigation and climate adaptation process. Natural features provide valuable ecosystem services, and may be vulnerable to the impacts of hazards. At the same time, parks and recreational areas offer unique value to the City and its communities, and may be susceptible to hazard events. On the other hand, natural systems often play a role in mitigating impacts from climate change and hazard events, and can be seen as a resource.

Historical and Cultural Impact Analysis

Historic and cultural resources are also considered as they make a significant contribution to local history and culture, and often have strong emotional ties with the community. Baltimore has a rich historic fabric, and the City prides itself on being a national leader in historic preservation. In fact, Baltimore has 34 local and 67 national historic preservation districts, which include 196 landmarks. Designated Historic structures represent approximately one-third of Baltimore's built environment. Baltimore has one of the highest percentages of designated historic structures of any major city in the United States.

Historic structures may be at an even greater risk as these buildings were constructed prior to the adoption of appropriate building standards (e.g. floodplain development code, electrical code). FEMA has produced a guideline for Integrating Historic Property and Cultural Resource Considerations Into Hazard Mitigation Planning. It is important to recognize that these assets may require special considerations, or specific technical and financial assistance.

Finally, other assets and facilities deserve attention as they can have immediate or lasting impact on people and everyday services. In the event of a no-warning hazard, densely populated facilities, for instance, would be of more concern due to the number of people that might potentially be within. This list includes hotels, malls, theaters and auditoriums, and churches, among other things. Some of Baltimore's larger scale facilities include the convention center, stadiums and arenas, and major tourist destinations like the National Aquarium in Baltimore and the Science Center. High-density residential and commercial developments could likewise result in high injury or fatality rates if damaged. Other assets, still, provide vital services which ensure the continuity of everyday activities. These facilities include grocery stores, banks, government buildings, gas stations, and agricultural areas, to name a few.

Some assets may be more vulnerable than others depending on their age, location, or other characteristics. Additionally, facilities are impacted differently depending on the type of hazard experienced. A more detailed impact on Baltimore assets accompanies the assessment of each hazard type below.

General Inventory of Critical Facilities in Baltimore City

According to FEMA, a **Critical Facility is a** structure or other improvement that — because of its function, size, service area, or uniqueness — has the potential to contribute to serious bodily harm, extensive property damage, or to the disruption of vital socio-economic activities if that facility is either destroyed or damaged, or if functionality is impaired. Critical facilities include essential operations, such as health facilities, including hospitals, critical care facilities, outpatient clinics — and any other facility that would be able to provide immediate emergency relief and care following a hazard event. Emergency response stations and evacuation centers are considered to be critical facilities, as well as fire stations, police stations, government buildings, buildings that store critical records, and other similar facilities that might manage essential activities. Each of these facilities plays a vital role in disaster response and recovery and must therefore remain fully operational and accessible before, during, and after a hazard event.

Table 4–1 Critical Facilities Located in Baltimore City

Critical Facility	Number
Hospitals	15
Police Stations	10
Fire Stations	41
Schools (Public and Private)	235
Colleges	15
Government Facilities	374
Banks	54
Grocery Stores	48
Hardware Stores	37
Gas Stations	238
Water Pumps	15
Electrical Cooperatives	-
Wastewater Treatment Facilities	3
Sewage Treatment Facilities	12
Drinking Water Treatment Facilities	11
Critical Roadways	61
311 and 911 Operation Centers	-
Hazardous Waste Facilities	-
Total	**1169**

Source: Baltimore City Enterprise Geographic Information Services and HAZUS

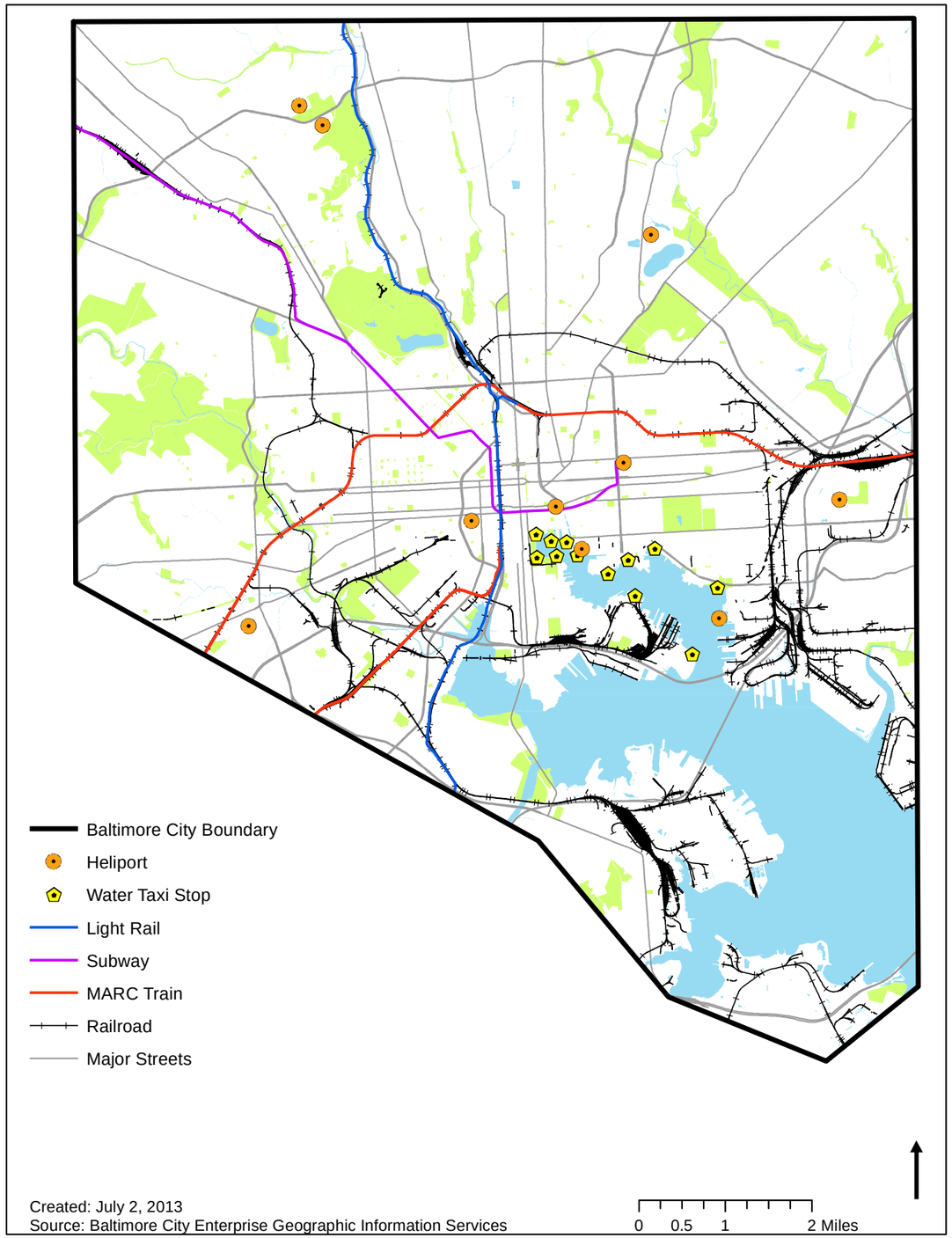


Figure 4–3 Baltimore City Transportation Systems

By evaluating key facilities, roadways, transportation corridors, and resources within the community, the vulnerability analysis of critical facilities determines the degree to which each facility is exposed to various hazards. As reviewed in the Table 4–1 Critical Facilities Located in Baltimore City, there are approximately 1,169 critical facilities within Baltimore City. The level of vulnerability and the total potential economic loss associated with each of facility will vary by hazard event and depends on a number of additional factors, including location, construction, property contents, and the economic value of the function(s) being provided by the facility. Critical facilities need to understand and respond to hazard vulnerabilities in order lessen or avoid interruption to essential services.

Transportation systems allow for movement — for emergency response as well as evacuation — and may be significantly impacted by hazard events. Figure 4–3 Baltimore City Transportation Systems, illustrates major streets and transportation systems within Baltimore.

In a hazard event, Baltimore must maintain its lifeline utility and infrastructure systems. These systems provide access and assets to respond. Communication systems need redundancy, particularly with emergency response entities, and critical City services should be evaluated for further mitigation/preparedness measures, particularly water delivery, wastewater treatment and power generation. Additionally, efforts should be made to ensure that critical evacuation routes are evaluated for various impacts. These services continue to be provided to Baltimore's residents and businesses.

Finally, high potential loss and hazardous material facilities include those facilities that would pose a danger should they be destroyed or damaged. Such facilities include hazardous waste facilities, dam structures, and any facilities housing industrial/hazardous materials. A map of vulnerable dam facilities is featured in the Flooding Risk and Vulnerability Assessment below; there are no public maps, however, of hazardous material facilities as this information is considered sensitive information. Our risk analysis will be shared with those facilities and other appropriate parties to ensure proper measures are being taken.

Some critical facilities may be more vulnerable than others depending on their age, location, or other characteristics. Additionally, facilities are impacted differently depending on the type of hazard experienced. A detailed impact assessment of critical facilities is included in the review of each hazard type below.

DETAILED VULNERABILITY ASSESSMENT BY HAZARD

Flooding

Background

At the heart of City, water of the Inner Harbor — as well as from the many tributaries that flow into it — is a central feature of Baltimore's historic landscape. Considering how closely Baltimore has developed alongside the water, it is understandable that the City has endured a history of significant flooding events. As Table 4–2 NCDC Total and Annualized Flood Events (1993-2010) in Baltimore City conveys, annualized flood occurrences in Baltimore City total approximately 2.67 annualized flood events each year, and 1.22 annualized flash flood events each year. Recognizing this historical information and anticipating future changes, flooding is considered a major hazard for the City of Baltimore.

In Baltimore, 5.19 square miles of property, or 6.4 percent of the City's total area, currently rests within the flood zone; while 3 percent of Baltimore's overall land — primarily in the Inner Harbor or the Fells Point Historic District — is within the coastal floodplain.[2] By the end of the century, approximately 180 square miles of currently dry land along Maryland's coastline is expected to be inundated. Coupled with more frequent and extreme precipitation events (See Precipitation Variability Hazard Profile in Chapter 3 Hazard Assessment) these conditions could become a common hazard.

Moreover, a number of anticipated climate change impacts may intensify extent and damage from flood events. Future sea level rise (for a discussion of sea level rise, refer to the Coastal Hazards Risk and Vulnerability Assessment below) or land subsidence is an addition to storm surge increasing flood depths, thereby intensifying losses even further.

In the conduct of the vulnerability analysis, there are two types of flood events that need to be distinguished. One is a tidal influenced flood (i.e. storm surge) or/and-in-addition-to a non-tidal flood (i.e. precipitation event). For example, Isabel was a strictly a tidal flood. The flooding was the result from a storm surge that pushed the waters seven feet above the predicted tide. It is possible to have the same storm surge coupled with a precipitation event. In addition to drawing that distinction between tidal and non-tidal, the vulnerability analysis goes further by reporting out impacts on different probability flood events – that is the 100-year and the 500-year events.

Below are results and discussion on the vulnerability analysis. Some of the vulnerability analysis is based on results from HAZUS (refer back to the discussion on HAZUS-MH) that was done by both the State and the City. The vulnerability analysis continues with the Community Asset Inventory.

Vulnerability Assessment

The City utilized HAZUS modeling software, FEMA Flood Insurance Rate Maps, and NOAA's Critical Facilities Exposure Tool to determine citywide vulnerability to flooding. Results from these tools were analyzed by flood experts from the State of Maryland and Baltimore City to determine vulnerabilities in the floodplains and floodways.

Table 4–2 NCDC Total and Annualized Flood Events (1993-2010) in Baltimore City

Flood Total Events	Flood Annualized Events	Flash Flood Total Events	Flash Flood Annualized Events
48	2.67	22	1.22

Source: Table 3-27, Maryland Emergency Management Agency, 2011: 105-106

Exposure

An evaluation of exposure identifies who and what may be vulnerable to flooding hazards. This analysis takes into consideration where flooding occurs through a process that delineates floodplains and floodways and identifies what assets or facilities are located within those areas. Maps of flooding exposure, as well as information regarding to what level various City assets are exposed to flooding, are depicted in the Inventories of community assets and critical facilities below.

Additionally, the Baltimore City Department of Planning, in partnership with FEMA, is developing Digital Flood Insurance Maps (DFIRMs) which, when complete, will provide a more accurate picture of exposure in the updated floodplain and floodway.

In addition to the financial damages caused by previous 100-year and greater floods, localized flooding has disrupted the lives of Baltimore residents. The map below (Figure 4–5 Baltimore City Floodplains and Floodway) illustrates the areas that are susceptible to flooding from 100- and 500-year flooding events. The insets (Figure 4–6, Figure 4–7, and Figure 4–8) further clarify how the structural fabric of two particular areas — Fells Point and Westport — may be impacted from such events.

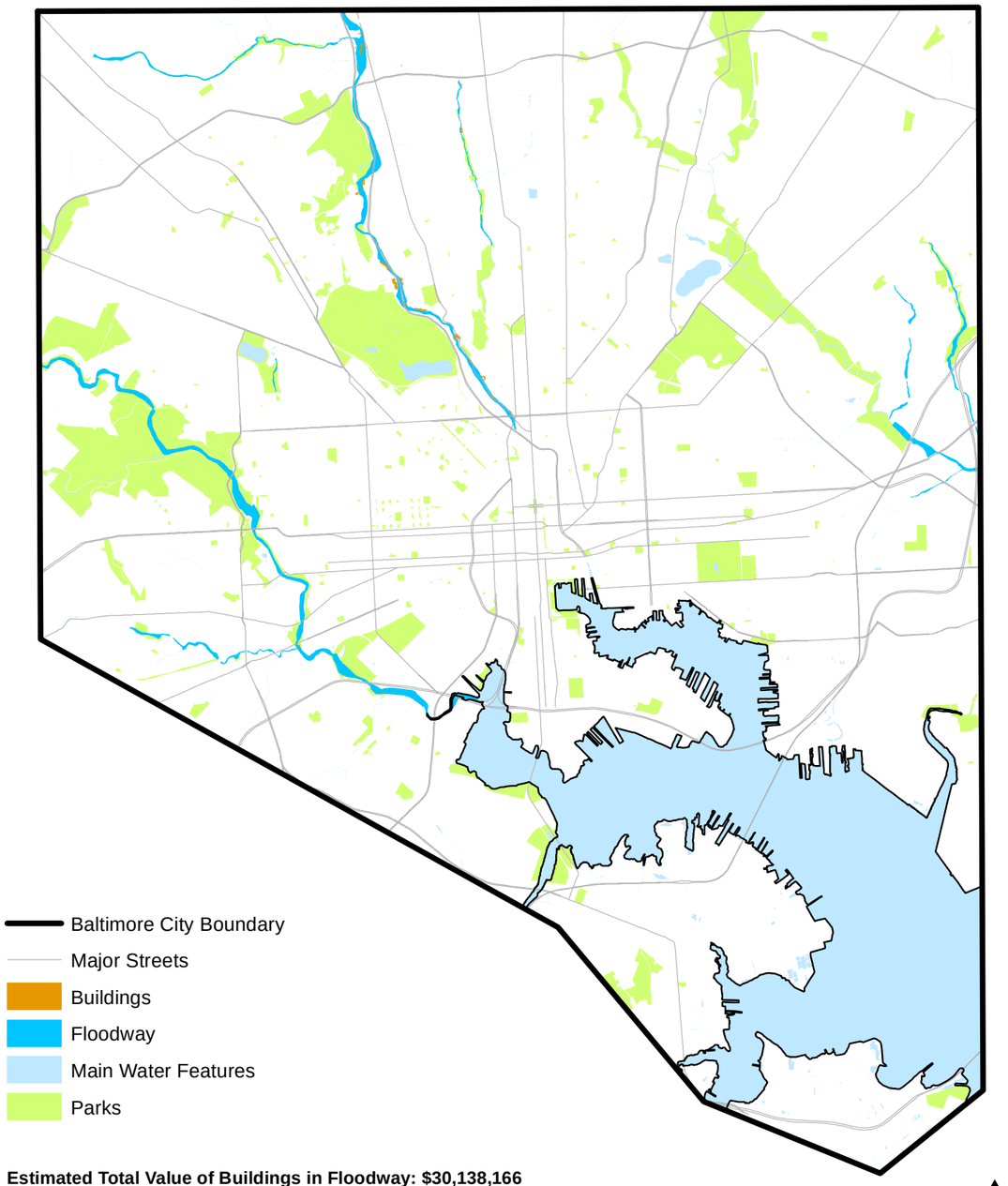
Figure 4–4 Flooding of Baltimore's Herring Run, June 2013
Source: Bob Mayes

Sensitivity

Considering the number of assets that are exposed to flooding hazards, sensitivity identifies the degree to which these assets are vulnerable, and how some may be more so than others. When considering flooding, for instance, a structure may be more vulnerable if the building is not compliant with Base Flood Elevation (BFE) guidelines. Additional characteristics may influence sensitivity further.

Adaptive Capacity

An asset's ability to respond to a hazard defines its adaptive capacity. In areas like Fells Point, many structures have repeatedly endured extreme flooding events. Indeed, many buildings are able to adapt, but this potential is dependent upon additional factors, including occupant understanding and behavior, or the City's recognition of future changes in hazard frequency and intensity.



Estimated Total Value of Buildings in Floodway: $30,138,166

Created: June 25, 2013
Source: Baltimore City Enterprise Geographic Information Services

0 0.5 1 2 Miles

Figure 4–5 Baltimore City Floodplains and Floodway

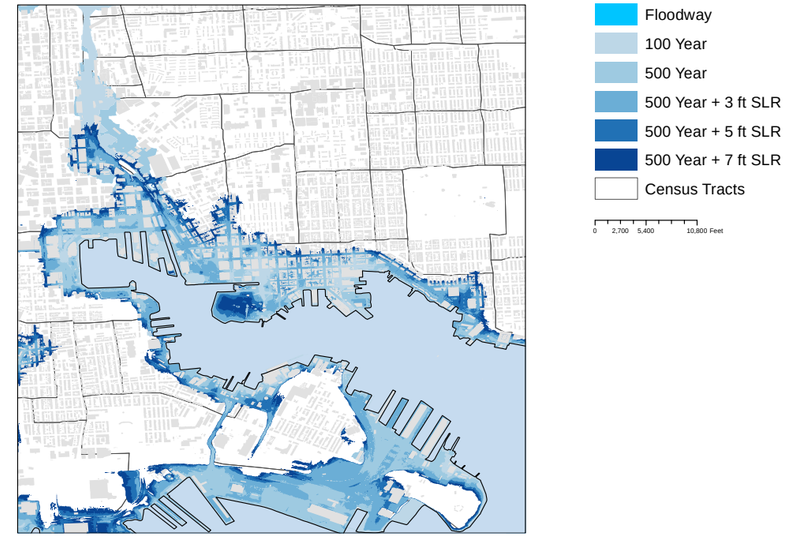


Figure 4–6 INSET | Fells Point Flood Exposure Areas

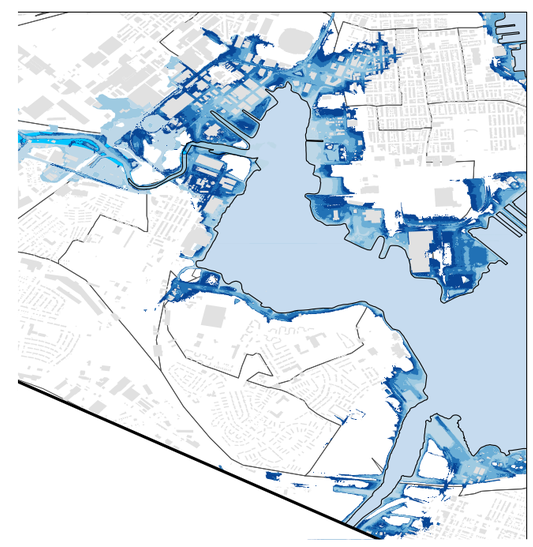


Figure 4–7 INSET | Westport Flood Exposure Areas

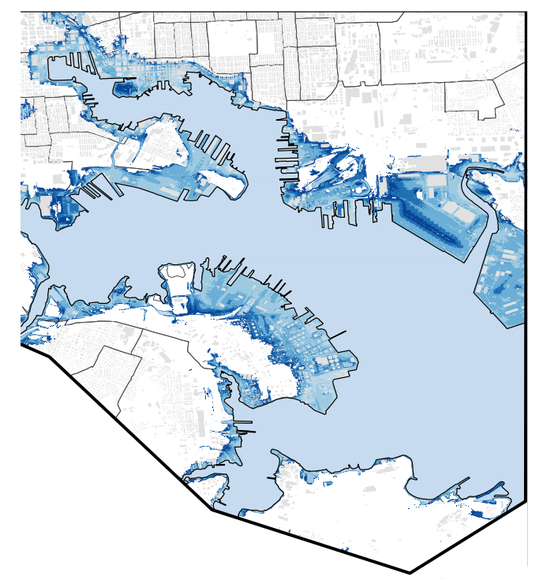


Figure 4–8 INSET | Industrial Flood Exposure Areas

Table 4–4 Sum of Parcels Located within the 100-year and 500-year Floodplains

100 Year	Sum of parcels	2941
	Sq Footage	45835550 ft
	Year Constructed*	1754- 2012
	Estimated Value	$2,659,994,010
500 Year	Sum of parcels	3027
	Sq Footage	43062241 ft
	Year Constructed**	1754 - 2012
	Estimated Value	$1,861,554,433

**1108 buildings missing information for year constructed for 100 year;*
***999 buildings missing information for year constructed for 500 year.*

Inventory of Community Assets Susceptible to Flooding

Populations and property are extremely vulnerable to flooding. Homes and business may suffer damage and be susceptible to collapse due to heavy flooding. In addition, floods may threaten water supplies and water quality, as well as initiate power outages. Floodwaters can carry chemicals (there are about a half a dozen hazardous material sites and one oil refinery within Baltimore's flood zones), sewage (four waste water facilities within flood zones), and toxins from roads, factories, and farms; therefore any property affected by a flood may be contaminated with hazardous materials.[3] Debris from vegetation and man-made structures may also become hazardous during the occurrence of a flood. During flood events, objects (floating material, e.g. wood, cars, etc.) in rivers and streams carry the force of the water behind them increasing the potential for damage to other structures like buildings and bridges. In permitting development the City needs to take into account the need and capacity of emergency personnel to respond to a facility facing a hazard – particularly flood hazards zones.

Table 4–3 City-Owned Facilities within the 100+500 Year floodplains

FACILITY NAME	Neighborhood
Dpw Museum	Inner Harbor
Brokerage Annex	Downtown
Wahl Bldg - (Clinic)	Downtown
Culinary Arts Bldg	Downtown
Abel Wolman Bldg	Downtown
Signet Building	Downtown
Kids Diner	Downtown
Parking Control Agency	Penn-Fallsway
Surveys & Records Office	Penn-Fallsway
Impound Lot Cashier's Booth	Penn-Fallsway
War Memorial Bldg	Downtown
Water Street	Downtown
Adminis-Dpw, Director's Staff	Downtown
U.S. Custom House	Downtown
Headquarters	Downtown
Police Headquarters, Annex	Downtown
Mounted Police	Penn-Fallsway
Fort Holabird Comfort Station	Holabird Industrial Park
Fort Holabird Park Service Bldg	Holabird Industrial Park
Thames Park	Fells Point
9 N Front St	Jonestown
1840 House	Jonestown
Administative Bldg	Jonestown
Archeology Center	Jonestown
Carroll Mansion	Jonestown
Exhibition Center	Jonestown
Peale Museum	Downtown
Shingle Bldg (Overton's Old House)	Harford-Echodale/ Perring Parkway
Camp Small	Coldspring
Inner Harbor Park	Inner Harbor
Leon Day Park Baseball/ Football Fields	Gwynns Falls/Leakin Park
Port Discovery Fountain	Downtown

Table 4–5 State and Critical Facilities within FEMA 100-year flood zone

	Total Number of Critical Facilities	Critical Facilities Building and Content Values	Total Number of State Facilities	State Facilities Building and Contents Values
Baltimore City	1,049	$ 149,117,733.00	106	$ 1,127,435,779.00

Source: Table 3-30, Maryland Emergency Management Agency, 2011: 110.

A flooding vulnerability assessment estimates the number of structures that are located within the regulated 100-year floodplain and are thus susceptible to 100-year flooding. There are an estimated 2,941 facilities, valued at approximately $2,659,994,010, within the City's 100-year floodplain. (Economic loss estimates do not include calculations for contents and inventory.) Additionally, as many as 2,000 people would be displaced by a 100-year tidal flood. As many as 3,027 properties, with an estimated value of $1,861,554,433, are located within the 500-year floodplain. Table 4–4 provides details regarding the properties within the floodplain and floodways; floodplain counts are inclusive of floodway properties).

The completed vulnerability analysis found that the Inner Harbor and Downtown neighborhoods are the most vulnerable to inland flooding based on the number of city-owned structures potentially impacted (Table 4–3 City-Owned Facilities within the 100+500 Year floodplains, right). The Downtown neighborhood has 14 city-owned structures within the 100- and 500-year floodplains, and the Inner Harbor has two city-owned facilities. Other neighborhoods with exposed City-owned facilities include Penn-Fallsway, Holabird Industrial Park, Fells Point, Harford-Echodale/Perring Parkway, Coldspring, and the Gwynns Falls/Leakin Park neighborhoods.

Inventory of Critical Facilities Susceptible to Flooding

For some services and facilities, even a slight chance of flooding is too great a threat. These facilities should be given special consideration when forming regulatory alternatives and floodplain management plans. Ideally, critical facilities should not be located within a floodplain if at all possible. However, due to a range of factors, many of Baltimore's critical facilities currently sit within this zone (Figure 4–12 on page 121, below). If a critical facility must be located in a floodplain it should be given a higher level of protection so that it can continue to function and provide services during and after a flood. According to NOAA's Critical Facilities Flood Exposure Tool, the Westport Baltimore Gas and Electric facility and the Gould Street Generating Station are vulnerable to flooding.

Table 4–6 Critical Facilities Located in Baltimore City HAZUS Coastal Flood Extents

Critical Facility	100 Year	500 year
Subway	0	0.42 miles
Railroad	15.24 miles	51.59 miles
Bridges*	3	4
Tunnels	1	1
Major Roads	15.08 miles	22.93 miles
Police Stations	0	0
Fire Stations~~	0	1
Emergency Operation Centers	0	0
Public Schools^^	0	1
Private Schools	0	0
Colleges^^	0	1
Hospitals	0	0
Nursing Homes	0	0
Cultural Facilities	3	6
Power Plants*	0	3
Waste Water Treatment Plants	0	2

Source: HAZUS; GIS Data Collections
**Numbers based on HAZUS inventory/ Coastal Flood Extent, not Baltimore City Data.*

Additionally, there are a number of State facilities within the 100-year floodplain in Baltimore City. These structures, and their contents, have an estimated value of $1.2 billion (Table 4–5 State and Critical Facilities within FEMA 100-year flood zone). HAZUS and City facility databases were used to calculate the value of facilities within the flood zone and the number of people who would potentially be impacted by inland flooding.

HAZUS-MH data was used to identify potential impact of a significant 100-year or 500-year storm (Table 4–6 Critical Facilities Located in Baltimore City HAZUS Coastal Flood Extents, below). A number of key facilities are located within the floodplains, and vulnerable to flooding hazards. For instance, after a 100 year storm, a total of 225 buildings may be moderately damaged, with 22 being completely destroyed. The chart also takes into consideration the additional impact of a projected sea level rise (Sea Level Rise is discussed in more detail in the Coastal Hazards Risk and Vulnerability segment below). If Baltimore were to experience a 500-year event, in addition to a possible 5 foot sea level rise, damage could cost as much as $10 billion.

Flooding from dam failure may also impact critical facilities. Transportation facilities and water/wastewater treatment infrastructure are typically vulnerable to damages from dam failure as these facilities are often located within or near floodplains that are downstream of dams. Additionally, dam failure may damage power lines and telecommunication facilities and, thus, have serious consequences in terms of power generation and communication capacity. Most importantly, however, is consideration of Critical and State facilities that are at risk from dam failure (shown in Table 4–7 Critical and State Facilities at Risk Due to Failure of High Hazard Dams, and Figure 4–9 Maryland's Dams, Hazard Classifications below.) With 935 critical and 128 state facilities at risk, combined total exposure is almost $1.8 billion.

Table 4–7 Critical and State Facilities at Risk Due to Failure of High Hazard Dams

Facility Type	Number of Facilities	Total Building Value Exposure	Total Contents Value Exposure	Total Exposure
Critical	935	$ 195,554,500	$ 65,184,833	$ 260,740,268
State	128	$ 1,443,862,337	$ 94,000,353	$ 1,537,862,690

Source: Tables 3-103 and 3-104, Maryland Emergency Management Agency, 2011: 254-275.

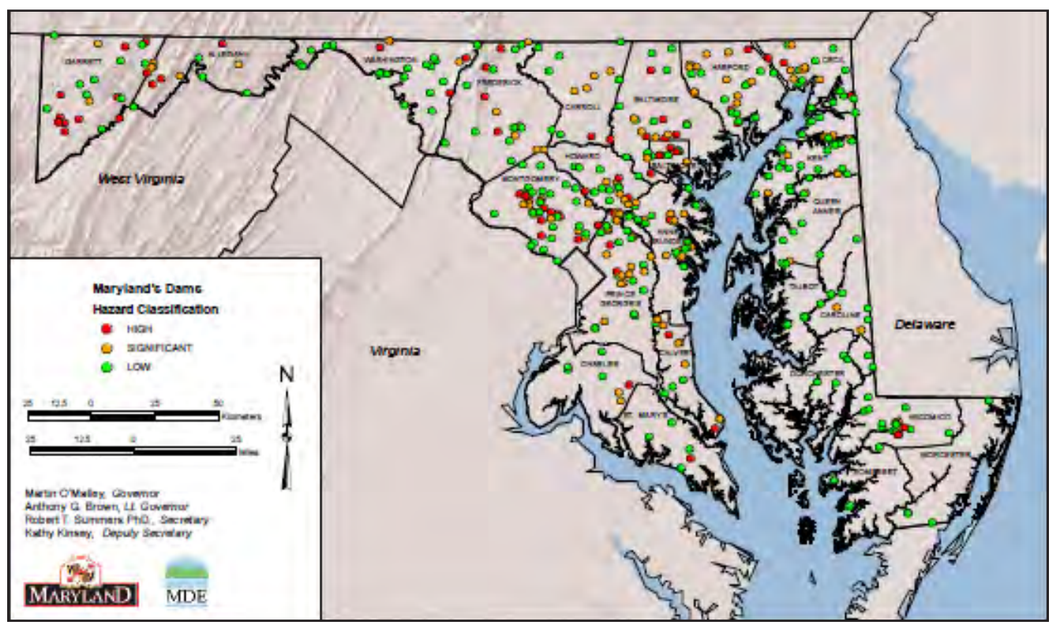


Figure 4–9 Maryland's Dams, Hazard Classifications

Source: www.mde.state.md.us

Estimated Losses

As a port City, Baltimore is very much dependent on its harbor and waterways. In 2006, the Port of Baltimore generated over 50,200 jobs, $3.6 billion in personal income, $1.9 billion in business revenues, and $388 million in state/county/municipal tax.[4] Without adequate planning and preparation, that vitality may be at risk.

In order to conduct an accurate estimate of the economic losses produced by flooding, it is necessary to know the first floor elevation for vulnerable structures, as well as the replacement costs which are calculated using information on construction materials and square footage. Such specific information, however, is not always readily available for the properties identified in the tables above. Consequently, it is difficult to develop an accurate estimation of losses. Nevertheless, it is possible to develop specific mitigation measure to address the magnitude of potential losses within the coastal flood zones. The City will share the DP3 risk assessment with various port related organizations. By combining the City's risk assessment, with their own assumptions and site knowledge about structure size, equipment, function, these entities can respond appropriately.

The table below (Table 4–8 Baltimore City Flood Impact - HAZUS) details the potential losses to the structures within the 100- and 500-year floodplains, and identifies the percentage of building damage, dollar cost of building damage, cost of contents (residential interior losses) and cost of inventory (commercial and industrial material and operations losses), and total economic damage (in thousands of dollars). This analysis assumes that no flood-proofing methods are currently being employed, and that there is a two-foot flood depth for all structures within the floodplain or a four-foot flood depth for those in the floodway. Certain essential elements of flood loss estimates — including displacement costs or functional downtime costs — are not included in these evaluations. While this table provides only a broad illustration of potential losses, it demonstrates the seriousness of a wide-spread 100- or 500-year flood event.

Estimated economic loss may be associated with very different costs. For instance, in addition to structural or content damage, floods may force property owners to relocate, or an individual may lose 'service' income from being displaced from their place of business as a result of a flood. When all of these factors are taken into consideration, total losses may be much greater. In Table 4–9 Flood Loss Estimates (in Thousands of Dollars) for 100-year and 500-year Floods in Baltimore City, below, the Maryland Emergency Management Agency sorted these various costs by type of loss. For a 500-year flood, total economic loss would exceed $1 billion.

Table 4–8 Baltimore City Flood Impact - HAZUS

	% of Building Damage	Building Damage $	Contents Damage $	Inventory $	Total $
100-Yr Floodplain	79%	1,025, 399	973, 608	2,729	2,004, 798
500-Yr Floodplain	76%	1,790,423	1,705,072	6,379	3,507,857

Table 4–9 Flood Loss Estimates (in Thousands of Dollars) for 100-year and 500-year Floods in Baltimore City

Flood Type	Building	Contents	Inventory	Relocation	Income	Rental	Wage	Direct Loss	Grand Total
100-Year	200,365	387,009	19,877	663	2,436	567	8,320	7,737	626,974
500-Year	395,211	718,477	36,480	1,152	4,317	1,269	17,869	14,257	1,189,032

Source: Tables 3-32 and 3-33, Maryland Emergency Management Agency, 2011: 112-113.

Coastal Hazards

Background

More than just flooding, coastal hazards may have a variety of additional consequences. The impact of a significant coastal event is greatest for those areas along and immediately near the coast, but can spread across the region. An evaluation of coastal hazards reported between 1993 and 2010 reveals that Baltimore City experienced more than 1 coastal event every two years (Table 4–10 NCDC Total and Annualized Coastal Hazards in Baltimore City (1993-2010), below). As discussed in the Coastal Hazards Profile of Chapter 3 Hazard Assessment, these events are likely to be more frequent and intense in the future.

Table 4–10 NCDC Total and Annualized Coastal Hazards in Baltimore City (1993-2010)

Total Events	Annualized Events
10	0.56

Source: Table 3-36, Maryland Emergency Management Agency, 2011: 127.

Vulnerability Assessment

Baltimore City, with its Harbor and close proximity to the East Coast, can be highly vulnerable to coastal hazards. Specifically, electrical and communications utilities, as well as transportation infrastructure, are vulnerable to significant coastal events. Damage to electrical lines or communication towers has the potential to cause power and communication outages. In addition to lost revenues, downed power lines present a threat to personal safety. Further, downed wires and lightning strikes have been known to spark fires (for a description of risks associated with lightning, see the Precipitation Variability Risk and Vulnerability Assessment below).

Exposure

An evaluation of exposure identifies who and what may be vulnerable to coastal hazards. This analysis takes into consideration where significant coastal storms or other coastal hazards tend to occur, and what assets or facilities may be located within those most vulnerable areas. The community assets and critical facilities inventories below identify specific properties that are exposed to coastal hazards and depict maps of exposed areas.

The City employed HAZUS modeling software, combined with expert input, to evaluate citywide vulnerability to coastal flooding. Sea, Lake, and Overland Surge from Hurricanes (SLOSH) Maps were also utilized to determine exposure. Three categories of storms were evaluated — tropical storms, in addition to Category 1 and Category 3 hurricanes — with varying levels of storm surge heights. Neighborhoods that are not at risk to storm surge were omitted from the coastal flooding analysis.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to coastal hazards. Additionally, understanding sensitivity considers how some properties may be more vulnerable to coastal hazards than others. For instance, the sensitivity of a structure to significant coastal hazard events is based, in large part, on a particular building's construction and its location in relation to potential storm surge inundation zones. In general, mobile homes and wood-framed structures are more vulnerable to damage from wind during significant coastal events than steel framed structures. Such construction types, however, are not typical of Baltimore. Other factors — including the location, condition, and maintenance of trees — also play a significant role in determining vulnerability to damage from coastal hazards. Furthermore, as noted above, various systems are highly sensitive to the impacts of coastal hazards, including electrical and utility infrastructure.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to coastal hazards, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with coastal hazards, infrastructural and structural preparedness, and regulations for development within exposed areas.

Inventory of Community Assets Susceptible to Coastal Hazards

The vulnerability of Baltimore residents to coastal hazards is primarily based on the availability, reception, and individual understanding of early warnings. Once warned of an impending significant coastal hazard event, seeking shelter in a substantial indoor structure —one that is also wind-resistant and outside of storm surge zones — is recommended as the best protection against bodily harm.

The map to the right (Figure 4–10 Maryland Western Shore Hurricane Evacuation Study Storm, Surge Map) shows that Category 1, 2, 3, and 4 hurricanes have the potential to inundate a significant portion the City. Baltimore's harbor and waterways are the life-blood of the City, and have been a focus of industrial, commercial, and residential development in recent years.

The City utilized similar techniques when evaluating vulnerability to coastal flooding when combined with anticipated Sea Level Rise (SLR). Five SLR scenarios were evaluated. Due to the uncertainty of climate conditions, and thus of relative seal level rise projections, it can be difficult to assign quantitative probabilities to projections of sea level increases. The most current sea level data from the Maryland State Climate Change Commission, and from the Intergovernmental Panel on Climate Change, indicate that sea levels in the Baltimore region could experience an additional rise of 1.5 to 3 feet in the next 50 years. This rise could have significant impact, particularly on City and State roadway systems. The table below (Table 4–11 Critical Facilities Located in Baltimore City HAZUS Coastal Flood Extents) indicates key City-owned assets and facilities within Baltimore's 100- and 500-year floodplains, including estimates for an additional 3, 5, or 7 foot in sea level rise.

In all of Maryland, a recent study reports, approximately 800 miles of roadway are vulnerable to impact if sea levels rise more than 2 feet.[5] This same rise would affect 93 bridges, culverts, and highway structures in Maryland. If sea levels rise as much as 5 feet, which is what high end predictions suggest, an estimated 3,700 miles of road could be underwater.[6] In Baltimore, as the table above suggests, 32.35 miles of local roadway would be underwater in a 500 year event with the projected additional 5 foot sea level rise. For this reason, it is essential that transportation functionality that accommodates projected sea level rise is considered as part of future strategies.

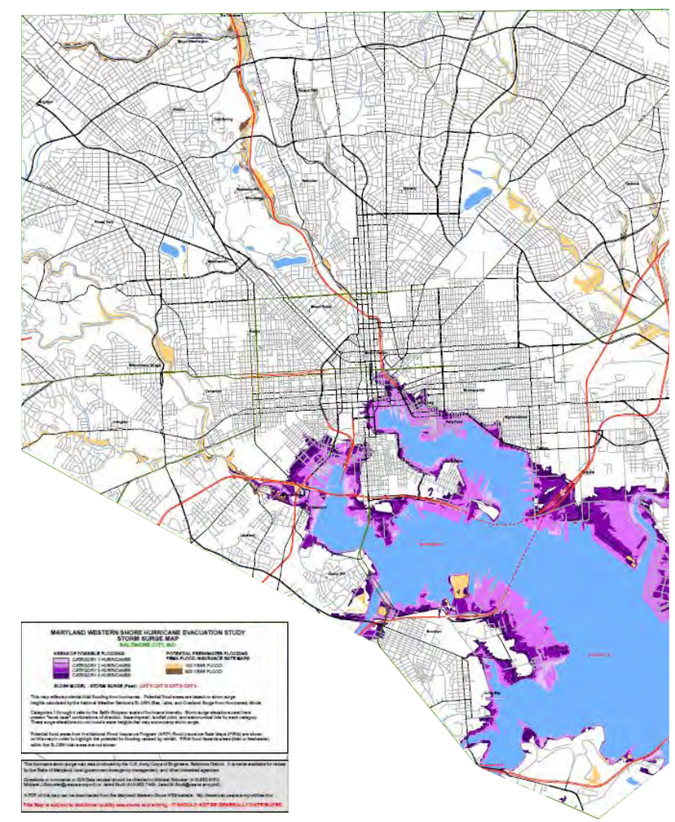


Figure 4–10 Maryland Western Shore Hurricane Evacuation Study Storm, Surge Map

Table 4–11 Critical Facilities Located in Baltimore City HAZUS Coastal Flood Extents

Critical Facility	100 Year	500 year	500 year + 3 ft SLR	500 year + 5 ft SLR	500 year + 7 ft SLR
Subway	0	0.42 miles	0.79 miles	0.79 miles	0.79 miles
Railroad	15.24 miles	51.59 miles	76.64 miles	93.59 miles	107.89 miles
Bridges*	3	4	4	4	8
Tunnels	1	1	1	1	1
Major Roads	15.08 miles	22.93 miles	26.85 miles	32.35 miles	37.14 miles
Police Stations	0	0	1	1	2
Fire Stations	0	1	1	1	1
Emergency Operation Centers	0	0	0	0	0
Public Schools	0	1	1	1	2
Private Schools	0	0	0	0	0
Colleges	0	1	1	1	1
Hospitals	0	0	0	0	0
Nursing Homes	0	0	0	0	0
Cultural Facilities	3	6	16	18	30
Power Plants*	0	3	4	4	7
Waste Water Treatment Plants	0	2	2	2	2

**Numbers based on HAZUS inventory/Coastal Flood Extent, not Baltimore City Data.*
Source: HAZUS; GIS Data Collections

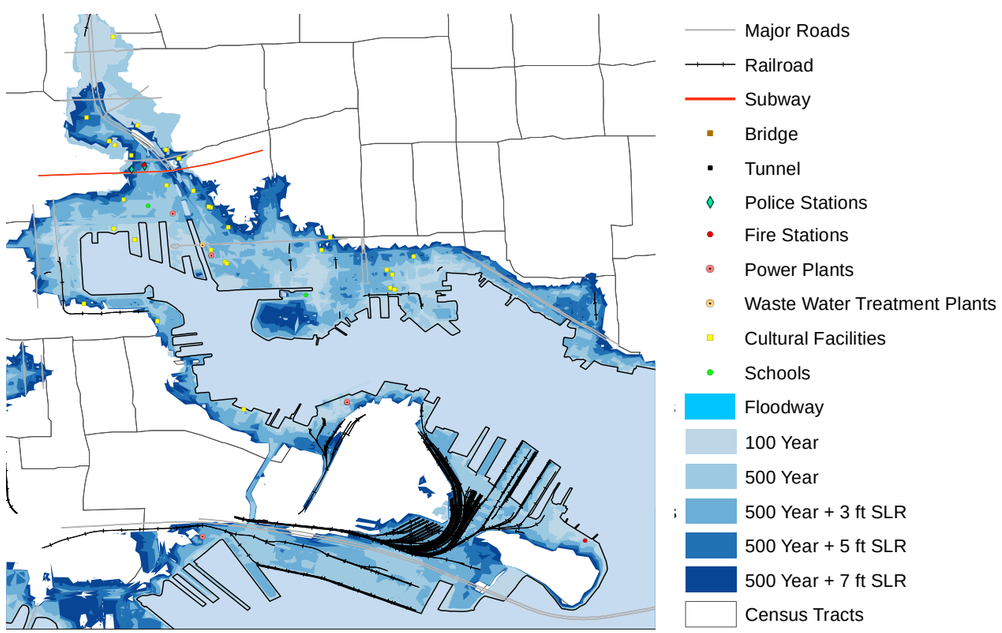
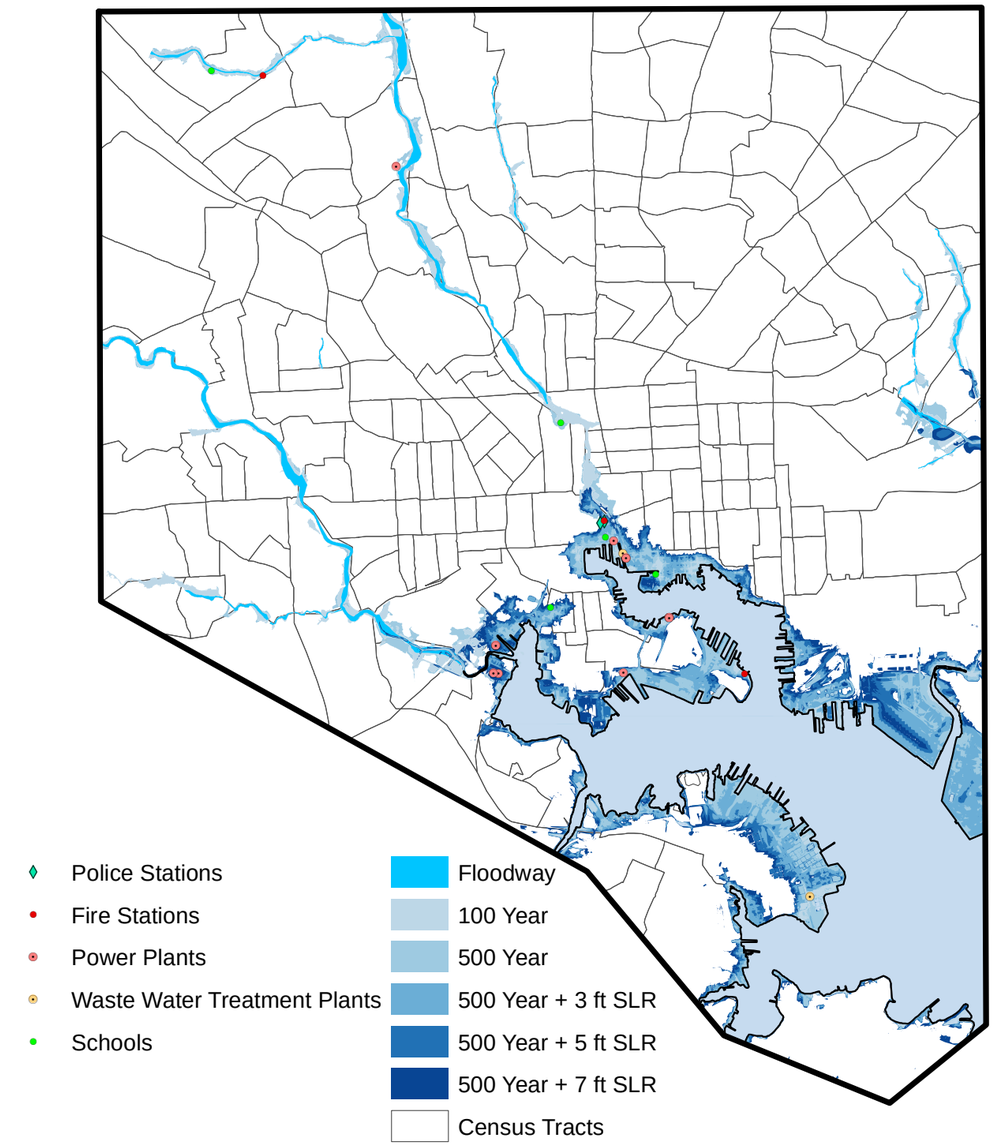


Figure 4–11 Focus Area | Critical Facilities in the Fells Point Flood Hazard Area



Created: June 25, 2013
Source: HAZUS FL
Baltimore City Enterprise Geographic Information Services

0 0.5 1 2 Miles

Figure 4–12 Critical Facilities in the Flood Hazard Area, Showing 3 ft, 5 ft, and 7 ft Sea Level Rise Scenarios

Inventory of Critical Facilities Susceptible to Coastal Hazards

As shown in Table 4–12 State and Critical Facilities within High Coastal Hazard Ranking Areas in Baltimore City, below, there are a total of 765 State facilities, valued over $7.5 billion, and 7,904 Critical facilities, valued over $3.1 billion, in Baltimore City that are considered to be at high risk from coastal hazards in general.

Critical facilities impacted by hurricane (of categories 1, 2, 3, and 4) inundation areas are the same as those that are located within flood zones (see the flooding risk and vulnerability segment above). The map above (Figure 4–12 Critical Facilities in the Flood Hazard Area, Showing 3 ft, 5 ft, and 7 ft Sea Level Rise Scenarios), notes the additional risks associated with potential sea level rise. It is difficult, however, to identify additional exposure and sensitivity to coastal hazards. For instance, all buildings in Baltimore will be exposed to high winds associated with coastal storms.

Table 4–13 HAZUS-Flood: Sum of Facilities (type) located in floodplain, below, shows the estimated number of facilities (sorted by type) and their value, susceptible to inland flooding. To ensure that these facilities continue to offer their services before, during, and after a hazard event, each will require special attention and a high level of protection.

Table 4–12 State and Critical Facilities within High Coastal Hazard Ranking Areas in Baltimore City

Total Number of Critical Facilities	Critical Facilities Building and Content Values	Total Number of State Facilities	State Facilities Building and Contents Values
7,904	$ 3,179,149,973.00	765	$ 7,596,281,448.00

Source: Table 3-42, Maryland Emergency Management Agency, 2011: 135.

Table 4–13 **HAZUS**-Flood: Sum of Facilities (type) located in floodplain

	100 year	500 year	500 year + 3 ft SLR	500 year + 5 ft SLR	500 year + 7 ft SLR
Facilities (type)	Number of Buildings	Number of Buildings	Number of Buildings	Number of Buildings	Number of Buildings
Hospitals	8	16	23	22	24
Schools	0	4	5	5	7
Fire Stations	0	2	2	3	3
Police Stations	0	1	3	3	6
Emergency Operation Centers	0	0	0	0	0
Power Plants	0	7	7	8	13
Waste Water Treatment Plants	0	4	4	4	4
Total Damage					
Buildings Moderately Damaged	225	475	981	1,334	1,693
Percentage of Buildings Damaged to Total Number of Buildings	79%	76%	81%	88%	88%
Buildings Completely Destroyed	22	48	60	94	174
People seeking shelter	1,093	2,409	4,090	4,928	5,694
Building Loss Total (Millions)	$2,001.74	$3,501.78	$7,033.92	$10,058.35	$13,373.50

Estimated Losses

As evidence in property loss figures (Table 4–14 Coastal Hazard Property Damage, right) obtained from NCDC, coastal hazard events have the potential to be very destructive. Total damages (adjusted for inflation) on an annualized basis exceeds $2 million in Baltimore City. These estimates, however, are believed to be an under-representation of the actual losses experienced due to coastal hazards considering losses from events that go unreported or that are difficult to quantify are not likely to appear in the NCDC database.

Table 4–14 Coastal Hazard Property Damage

County/City	Property Damage (Total)	Property Damage (Annualized)
Baltimore City	$ 40,107,828	$ 2,228,213

Source: Table 3-38, Maryland Emergency Management Agency, 2011: 130.

HAZUS-MH MR5 was also run for hurricane wind in order to determine potential losses due to winds associated with tropical storm and hurricanes. Annualized losses estimates based on this analysis of hurricane wind were estimated at $2.6 million in Baltimore City (shown in Table 4–15 HAZUS-MH MR5 Hurricane Wind Annualized Loss Estimates, right).

Table 4–15 HAZUS-MH MR5 Hurricane Wind Annualized Loss Estimates

County/City	Annualized Losses
Baltimore City	$ 2,619,000

Source: Table 3-39, Maryland Emergency Management Agency, 2011: 131.

An analysis of occupancy type (Table 4–16 HAZUS-MH MR5 Hurricane Wind Annualized Loss Estimates by Occupancy, below) further evaluates this estimate. In Baltimore, most damage from hurricane winds is likely to be sustained by residential structures, which account for just over $2 million in the estimated losses.

Table 4–16 HAZUS-MH MR5 Hurricane Wind Annualized Loss Estimates by Occupancy

Agricultural	Commercial	Educational	Government	Industrial	Religion/ Non-Profit	Residential
$ 2,000	$ 351,000	$ 21	$ 18,000	$ 71,000	$ 35,000	$ 2,121,000

Source: Table 3-40, Maryland Emergency Management Agency, 2011: 132.

Precipitation Variability

Background

With precipitation from atmospheric rivers, as well as other storm events, precipitation variability poses a risk - particularly from hazards during and after storm events. Hazards associated with precipitation variability manifest as a thunderstorm (with lightning and hail), winter storm, or drought (for a description of flooding hazards, see the Flooding Risk and Vulnerability Assessment above; for risks associated with strong winds, see the Wind Risk and Vulnerability Assessment below).

Table 4–17 NCDC Total and Annualized Thunderstorm (Lightning & Hail) Events (1956-2010)

County/City	Total Events*	Annualized Events
Baltimore City	19	0.35

Source: Table 3-64, Maryland Emergency Management Agency, 2011: 178.
**Grand total values are not a direct sum of each of the county/city totals. The grand total events do not include zonal events.*

Significant thunderstorms are very difficult to predict, but based on past NCDC records of thunderstorm occurrence, a reasonable determination of the probability of future significant hail or lightning events can be made. Table 4–17 NCDC Total and Annualized Thunderstorm (Lightning & Hail) Events (1956-2010), above, indicates that Baltimore City experiences a significant thunderstorm event — one that causes injury, fatalities, and/or damage — will occur a little over once every three years.

Table 4–18 NCDC Total and Annualized Winter Storm Events (1993-2010)

Total Winter Storm Events	Annualized Winter Storm Events	Total Ice Events	Annualized Ice Events
93	5.17	4	0.22

Source: Table 3-75, Maryland Emergency Management Agency, 2011: 202-203.

In addition to thunderstorms, winter storms create dangerous conditions in Baltimore. Using data collected between 1993 and 2010, it is determined that Baltimore City already experiences an average of 5.17 winter storm events each year, and a little more than one ice event every 5 years (Table 4–18 NCDC Total and Annualized Winter Storm Events (1993-2010)). Although climate change is expected to bring an increase in winter precipitation, it is expected to be increasingly wetter than what we currently receive and precipitation will fall in liquid-form rather than frozen. Studies project a 25 percent decrease in snow volume by the year 2025 and a 50 percent decrease by the end of the century.

Finally, in addition to risks associated with extreme precipitation events, drought incidences may also present a risk in Baltimore. Due to the relatively short period of recorded NCDC drought data, it is difficult to accurately forecast future frequency of drought. However, upon examining available data, it is reasonable to assume that Baltimore City, through its management of the reservoirs, is susceptible to impacts of extended drought events. Already, significant drought events occur a little more than once every two years (Table 4–19 Annualized Drought Events, 1995-2010, below). Additionally, future droughts are expected as a result of more frequent extreme heat events due to the warming of Baltimore's climate (see the Extreme Heat Risk and Vulnerability Assessment later in this chapter). There may also be concern for accelerated sedimentation of the reservoirs from the combination of draught events (that stresses vegetation) and more frequent and intense precipitation events. In addition to the sedimentation these short duration storms do not allow for the saturation of soil and the recharge of groundwater that feed streams that in turn feed the reservoirs. Long-term climate forecast models suggest that a warming planet will lead to changes in precipitation distribution as well as more frequent and severe drought.

Vulnerability to Precipitation Variability

Precipitation Variability can present a number of hazards to which Baltimore may be vulnerable. Depending on the nature of the event, vulnerability may be quite different. Storm events, accompanied by hail and lightning, as well as winter storms and droughts could potentially impact Baltimore and its residents.

Table 4–19 Annualized Drought Events, 1995-2010

County/City	Total Events	Annualized Events
Baltimore City	9	0.56

Source: Table 3-91, Maryland Emergency Management Agency, 2011: 239

Exposure

An evaluation of exposure identifies who and what may be vulnerable to precipitation variability hazards. This analysis takes into consideration where precipitation variability may occur, in addition to what assets and facilities may be located within those vulnerable areas. The community assets and critical facilities inventories below will note specific properties that are exposed to precipitation variability.

However, unlike some other hazard analyses, the exposure of Baltimore to precipitation variability is not limited to specific regions or areas. Rather, exposure is extensive and the impacts are likely to affect everyone. Sensitivity, more than exposure, presents a better understanding of Baltimore's vulnerability to precipitation variability.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to precipitation variability hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to than others.

Hazards associated with thunderstorms often include lightning and hail. Building construction, location, and nearby trees or other tall structures will have a large impact on how vulnerable an individual facility is to hail or lightning strikes. A rough estimate of a structure's likelihood of being struck by lightning can be calculated using the structure's ground surface area, height, and striking distance between the downward-moving tip of the stepped leader (negatively charged channel jumping from cloud to earth) and the object.[7] In general, buildings are more likely to be struck by lightning if the structure is located on a hilltop; is tall or is surrounded by tall structures; or has large, exposed windows. Electrical and communications utilities are also vulnerable to direct lightning strikes. Communications and power supplies may be compromised during thunderstorms, and some critical facilities might not be equipped with a backup power source.

Structural vulnerability to hail is determined by a facility's construction and exposure. Metal siding and roofing is better suited to withstand the damages of a hailstorm than many other construction materials (though it may still sustain damage by denting). Exposed windows and vehicles are also susceptible.

Winter storms pose many of the same dangers as thunderstorms, but also have additional specific concerns. As in a thunderstorm, transportation and communication structures are also at risk from winter storms. The type and age of construction influences a facility's vulnerability to winter storms. Building construction type – particularly, roof span and construction method are examples of factors that determine the ability of a building to perform under severe stress from the weight of a heavy snowfall. The potential for such damage was demonstrated by a notorious incident at the B&O Railroad Museum, a historic structure and repository of irreplaceable railroad industry artifacts and antique equipment, where heavy snow collapsed the Museum's roof.

Baltimore has several thousand rowhouses with flat roofs which may be susceptible to collapse in the event of heavy snowfall. Recent experience has proven this vulnerability, and a number of roofs have collapsed in heavy winter storms. Unfortunately, the City does not maintain data on building roof type; therefore, this analysis can estimate neither the total number, nor the likely economic losses, of susceptible structures.

Winter storms may bring more than just snow. Ice storms and freezing rain events can be particularly disruptive. Freezing rain and ice can weigh down power lines, cause branches to break, and cause trees to break or become uprooted. Downed trees and power lines may disrupt traffic, hinder emergency response vehicles, and necessitate costly clean-up and disposal of debris. Damage to power lines or communication towers has the potential to cause electrical and communication disruptions for residents, businesses and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Furthermore, downed wires have been known to spark fires. Vulnerability to winter storm damage will vary, in large part, due to specific factors; for example, proactive measures, including regular tree maintenance and utility system winterization, can minimize property vulnerability. It is impossible to predict with certainty where lightning or hail will strike, and all counties in Maryland are susceptible to these dangers.

Likewise, while extreme precipitation may pose a danger, a lack thereof can also become a hazard. Short-term droughts can impact agricultural productivity (though not a common activity in Baltimore City) while longer term droughts are also likely to impact water supply. Groundwater is a commonly used source of water supply and is obtained from both confined and unconfined aquifers. Many individual home owners in rural areas pump groundwater from their own wells. Public water suppliers like the Washington Suburban Sanitary Commission rely on surface waters for their water supply. About two-thirds of Maryland's citizens regularly consume water that originates from a surface water source. In general, counties that have invested in water supply and distribution infrastructure are generally less vulnerable to drought. However, communities where water supplies rely on the Potomac or Susquehanna Rivers and their tributaries are more vulnerable during a drought than those using the Chesapeake Bay for water supply. This is due to the lack of recharge from surrounding watersheds that flow into the rivers.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to precipitation variability, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with precipitation variability hazards, infrastructural and structural preparedness, and regulations for development that may be exposed or highly sensitive.

Inventory of Community Assets Susceptible to Precipitation Variability

The vulnerability of Baltimore residents to precipitation variability as it specifically relates to storm events is based on a number of factors, including availability, reception and understanding of early warnings. Once warned of an impending storm hazard, individuals who immediately seek shelter in a sturdy building or metal-roofed vehicle are much safer than those who remain outdoors. Early warnings of severe storms are also vital for aircraft flying through the area.

Due to the wide scope of potential impacts from precipitation variability events, it is difficult to identify specific vulnerabilities in Baltimore's community assets. By recognizing key characteristics which would increase a structure's vulnerability (as mentioned in the sensitivity segment above), residents and City agencies can increase overall resiliency by reinforcing structural integrity and developing comprehensive preparedness guidelines.

Table 4–20 State and Critical Facilities within High Winter Storm Ranking Areas in Baltimore City

Number of Critical Facilities	Critical Facilities Building and Content Values	Total Number of State Facilities	State Facilities Building and Contents Values
7,904	$3,179,149,973.00	765	$7,596,281,448.00

Source: Table 3-79, Maryland Emergency Management Agency, 2011: 208.

Inventory of Critical Facilities Susceptible to Precipitation Variability

Critical facilities are vulnerable to the effects of heavy storms, particularly to impacts on energy and infrastructure systems. However, facilities are generally equally vulnerable as precipitation variability events are not usually confined to certain regions. Hospitals and other essential medical facilities depend on a continuous power supply, without which the lives of thousands of patients may be in jeopardy. Ensuring that these facilities have back-up power systems is vital. Not all critical facilities have redundant power sources and may not even be wired to accept a generator.

With regards to extreme winter storms, future plan updates should consider closer examination of critical facilities risk by looking at construction type of critical facilities in jurisdictions considered to be at higher risk of winter storms.

Estimated Losses

In Baltimore, there are roughly 7,904 critical facilities — with an approximate value of $3.2 billion — that are vulnerable to severe winter storms (Table 4–20 State and Critical Facilities within High Winter Storm Ranking Areas in Baltimore City, above). Meanwhile, 765 state facilities, with an estimated $7.6 billion value, are at risk from such storms.

Wind

Background

Wind damage can come from a storm front moving through (e.g. derecho) or a tornado. Generally, every area in Maryland is vulnerable to severe winds, especially those in central Maryland and the Chesapeake Bay region. In Maryland, however, Baltimore City is not considered an area with high wind risk. Based on historical frequency of high wind event occurrences, revealed using NCDC data, a reasonable determination of probability of future high wind and tornado events can be made. Evaluating high wind events that were reported from 1956 to 2010 reveals that more than 2 high wind events occur each year (Table 4–21 NCDC Total and Annualized High Wind Events (1956-2010), below).

Table 4–21 NCDC Total and Annualized High Wind Events (1956-2010)

Total Events	Annualized Events
121	2.2

Source: Table 3-58, Maryland Emergency Management Agency, 2011: 166.

Although relatively infrequent, tornadoes have had significant impacts on Maryland in the past and are likely to impact Maryland in the future. According to NCDC historical records (Table 4–22 NCDC Total and Annualized Tornado Events (1950-2010), below), Baltimore experienced 4 tornado events between 1950 and 2010, or approximately .07 tornadoes each year. In other words, on average, Baltimore City is impacted by a tornado roughly once every 14 years.[8]

Table 4–22 NCDC Total and Annualized Tornado Events (1950-2010)

Total Events	Annualized Events
4	0.07

Source: Table 3-70, Maryland Emergency Management Agency, 2011: 189.

Vulnerability to High Wind Events

Tornadoes are considered to be low frequency, high-impact events. In the State of Maryland, all areas share a nearly uniform susceptibility to tornadoes. Electrical utilities and communications infrastructure are most vulnerable to tornadoes. Damage to power lines or communication towers has the potential to cause power and communication outages for residents, businesses, and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Furthermore, downed wires coupled with lightning strikes have been known to spark fires (for details regarding vulnerability to lightning, refer back to the Precipitation Variability Risk and Vulnerability Assessment).

Exposure

An evaluation of exposure identifies who and what may be vulnerable to high wind hazards. This analysis takes into consideration where high wind events may typically occur, in addition to what assets and facilities may be located within those vulnerable areas. The community assets and critical facilities inventories below will note specific properties that are exposed to impacts from high wind.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to high wind hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to high wind events than others. For instance, a structure's vulnerability to a tornado is based, in large part, on building construction methods and standards. In general, mobile homes and wood-framed structures are more vulnerable to damage in a tornado than steel framed structures (Baltimore, however, has a limited number of such structures). Other factors, including location as well as condition and maintenance of trees, also play a significant role in determining vulnerability.

The sensitivity of Baltimore residents to a tornado is based on a number of factors, particularly related to availability, reception, and understanding of early warnings. Once warned of an impending tornado hazard, seeking shelter indoors on the lowest floor of a substantial building, away from windows, is recommended as the best protection against bodily harm.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to future high wind events, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with high wind, an evaluation of the projected increased intensity and frequency of high wind events, infrastructural and structural resiliency and preparedness, and regulations for structures and development that may be exposed or highly sensitive.

Inventory of Community Assets Susceptible to High Wind

A majority of Baltimore City's structures were built in the late 19th or early 20th century, and are primarily constructed of heavy brick or stone. Wood frame structures that were built in the middle of the 20th century were also constructed from heavy materials. Additionally, these later structures had been built according to Baltimore's building inspection professional standards, and are thus expected able to handle a significant wind load. Baltimore's newer buildings, while not constructed with materials of the same density as the older building stock, have been subject to the International Building Code, which dictates that all construction have a wind resistance to winds of up to 160 mph.

However, two primary building classifications stand out as potentially vulnerable structures in the event of a tornado or high wind event. These structures include:

- Dilapidated structures: Well-maintained, older properties are expected to fare reasonably well in the event of a tornado or windstorm, however, there are numerous vacant and/or dilapidated structures in Baltimore City that sustain damage from wind events on a regular basis. The City expends resources by securing the area which often means 'finishing' the demolition and buttressing neighboring properties when the failure is an adjoining structure (e.g. rowhouse). These compromised structures are usually in already economically stressed areas thereby exacerbating an already difficult situation. Baltimore City Housing Authority, Baltimore Development Corporation, and the Department of Planning are assessing areas with a significant number of dilapidated structures to identify and prioritize actions that can address this hazard and other issues.

- Gable-roofed structures: Gable-roofed structures are primarily found in Baltimore City's low-density residential neighborhoods. While most of these areas are fairly well-maintained, and residents should have little reason to expect significant damage, the physical nature of gabled roofs makes them more susceptible to damage in the form of de-shingling or, in extreme events, de-roofing.

Additionally, vacant structures may be more vulnerable. Abandoned or vacant properties would likely not be insured and consequently, would not be rebuilt if significant damage were sustained. Should damage be so severe that the City resolves to demolish a vacant structure, the aesthetic impact on a community would leave behind empty lots among remaining houses, yielding a "gap-tooth" appearance. Gap-tooth housing — a characteristic usually found in (and contributing to) blighted neighborhoods — is an example of a secondary negative effect of hazard events.

Inventory of Critical Facilities Susceptible to High Wind

During a tornado or high wind event, critical facilities serve as shelter and help to ensure safe and effective emergency response. Fortunately, most police, fire, school, and major hospital facilities in the City are constructed of heavy materials. However, some critical facilities in Baltimore may still be vulnerable to strong winds. In particular, structures that were built prior to the use of building codes and consideration of construction design wind speeds for corresponding zones may be vulnerable to wind damage.

Furthermore, not all critical facilities have redundant power sources and might not even be wired to accept a generator. Future state mitigation plan updates should consider closer examination of critical facilities by looking at construction type of those facilities in jurisdictions recognized to be at higher risk of tornadoes.

Estimated Losses

In order to estimate the potential dollar losses for a high wind event, planners designed two scenarios which demonstrate possible effects of a tornado. Tornadoes, by their nature, are randomly occurring events; no particular region within a localized area such as Baltimore City is more or less at risk of a tornado occurrence. However, the damage that a tornado could potentially wreak on structures within a particular area varies significantly based on the quality and density of structures within it.

Extreme Heat

Background

Extended periods of extreme heat can tax the energy delivery system, leading to high cooling costs, and even blackouts or "brownouts." Additionally, at the same time as extreme heat may adversely affect the integrity of structures or infrastructure, other harmful costs of extreme heat are associated with human health and natural systems.

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report indicates that it is very likely that hot extremes and heat waves will become more frequent as the Earth warms. By the end of the century, the number of days above 90°F in Maryland is projected to more than double under lower greenhouse gas emissions scenarios, and roughly triple under higher emissions scenarios. Extended heat waves (temperatures above 90°F for at least three consecutive days) are expected to be much more frequent and longer lasting, particularly under higher emissions scenarios. Scientific predictions for increasing heat waves and temperature extremes are likely, with moderate confidence.[9]

Vulnerability to Extreme Heat

Extreme Heat events have been more frequent in recent years and are expected to increase by the end of the century. Energy and utility systems, transportation infrastructure, natural systems, and residents are all vulnerable to extreme shifts in temperature. Sensitivity to extreme heat depends on a number of location-related characteristics, including tree canopy coverage, impervious surface area, and resident demographic information (for resident vulnerability). Additionally, neighborhoods near to urban centers are more exposed to high heat conditions due to the Urban Heat Island effect.

Exposure

An evaluation of exposure identifies who and what may be vulnerable to extreme heat. This analysis takes into consideration where extreme heat may be most sever, in addition to what assets and facilities may be located within those vulnerable areas. The community assets and critical facilities inventories below will note specific properties that are exposed to extreme heat.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to extreme heat hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to extreme heat than others. For instance, a resident, structure, or asset may be more vulnerable if located in an area with minimal tree coverage. Additional characteristics, such as resident age or income, may influence sensitivity even further.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to extreme heat, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with heat-related hazards, programs to increase vegetative cover throughout the City, infrastructural and structural preparedness, and regulations for development that may be exposed or highly sensitive.

Inventory of Community Assets Susceptible to Extreme Heat

During Baltimore's hottest and most humid days, elderly residents living in neighborhoods with little tree cover are at a greater risk of suffering from heat-related impacts than are most other residents. Baltimore's neighborhoods with the lowest tree cover are shown in Figure 4–13 Baltimore City Tree Canopy by Neighborhood below. Resident income, in addition to resident age, may play a factor in an individual's ability to cope with extreme heat. For instance, when comparing the distribution of poverty throughout Baltimore's neighborhoods along with the location of low tree canopy areas, it becomes clear that areas with lower tree coverage are typically neighborhoods where residents have lower income. While it is more likely that lower income residents will not have air conditioning, those who do may experience rising electricity costs as a result of the higher energy use required to cool their homes. Additional Low Tree Canopy Neighborhoods Maps are found in Appendix X.

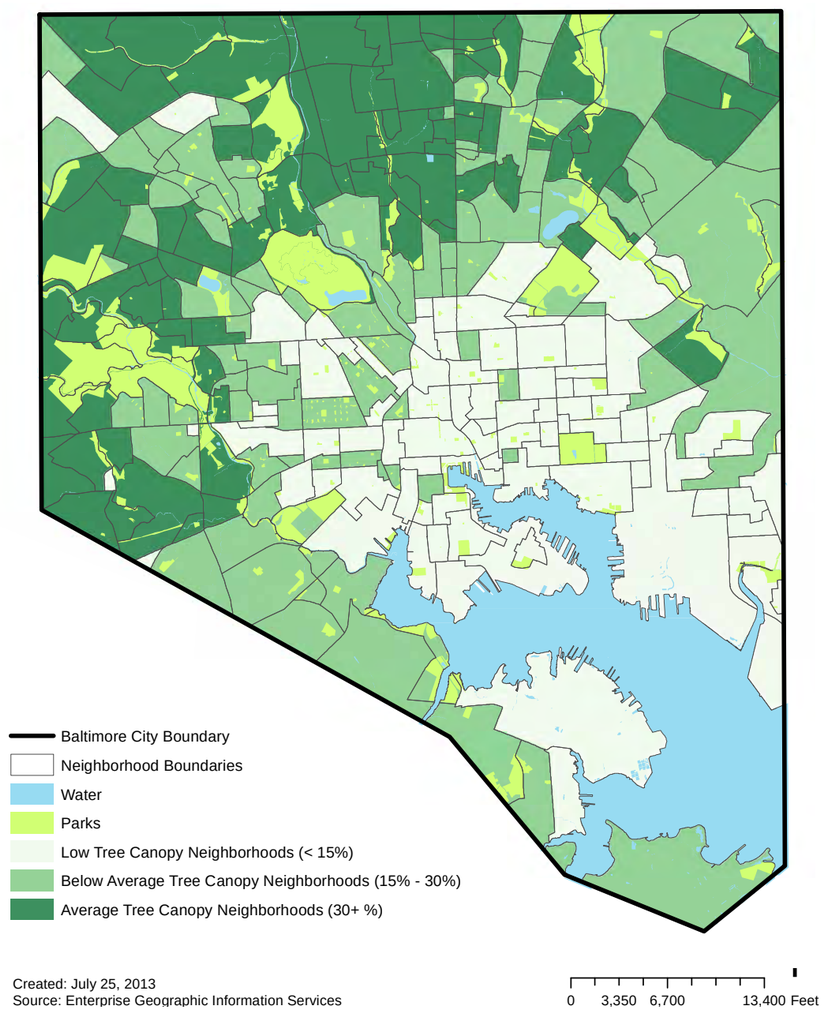


Figure 4–13 Baltimore City Tree Canopy by Neighborhood

On high heat days, residents may choose to remain indoors. However, not only will this raise risk of heat-related health impacts if homes are not equipped or utilizing A/C, but this behavior also limits economic activity. As people remain indoors, the active workforce is decreased and foot traffic in commercial areas is diminished. Likewise, business owners may also find their operating budgets have increased due to electricity usage, at the same time as revenues are dwindling.

Extreme heat will also impact natural systems. Trees have long been considered for their ability to absorb ozone pollution, and recent studies have been able to quantify that capacity.[10] In the past decade, however, Baltimore's tree canopy has been shrinking. Currently, only about 27 percent of Baltimore's landscape is covered by trees. Furthermore, between 16 – 20 percent of that canopy is considered to be unhealthy; and while we benefit from a tree's ability to absorb pollution, trees are significantly damaged by excessive pollution.[11]

Inventory of Critical Facilities Susceptible to Extreme Heat

Baltimore's exposure to extreme heat is extensive. Aside from local characteristics which may lessen the intensity of an extreme heat event (see the discussion of tree canopy above), extreme heat has to potential to impact all areas of the City equally. For this reason, it is not possible to map particular critical facilities that may be most exposed to extreme heat. However, certain urban systems or building types are highly sensitive to the impacts associated with high heat. Infrastructure systems are quite sensitive to extreme heat. Energy systems will be taxed, which will have additional impacts on other systems and structures. Understanding this, certain facilities — including hospitals, emergency shelters, and schools — are likely to endure increased financial burdens as normal operation conditions must be maintain operations under more demanding circumstances. Additionally, impacts on critical facilities may be exacerbated by damage to transportation systems.

Estimated Losses

For the same reason as it is difficult to estimate the exposure of specific facilities, it is challenging to estimate potential economic losses due to extreme heat. Energy and other infrastructure systems (transportation and utility) are likely to be impacted by extreme heat. Further evaluation of existing conditions will indicate the locations of existing vulnerabilities, and the potential cost to increase resiliency of these areas.

Baltimore City's Inner Harbor turned a milky green color in Summer 2013 after a heat wave. Extended periods of heat reduce oxygen, killing marine life. During this July event, it was estimated that more than 200 fish were killed.
Image Source: Blue Water Baltimore, Huffington Post

Land

Background

Earthquake events can, and occasionally do, occur in Maryland; though of much less intensity than those that occur elsewhere in the region or on the west coast. Although the area has experienced a handful of earthquakes from both inside and outside the State, land movement is more likely to be felt as a result of an earthquake that occurs in the surrounding region rather than originating within Baltimore City or Maryland. As yet, the small magnitude and minimal economic damage of previous earthquake events have not warranted the need for considerable structural retrofits or similar mitigation programs. At the regional scale, localized land subsidence, though less noticeable, can have considerable on urban systems.

The USGS recognizes four major impacts caused by land subsidence:

1. Changes in elevation and slope of streams, canals, and drains
2. Damage to bridges, roads, railroads, storm drains, sanitary sewers, canals and levees
3. Damage to private and public buildings
4. Failure of well casings from forces generated by compaction of fine-grained materials in aquifer systems

The direct consequence of regional subsidence does indeed pose a risk to Maryland (for a detailed discussion of land subsidence, please refer to the Land Hazards Profile in Chapter 3). However, due to the lack of historical data and detailed mapping, risk cannot be fully estimated for subsidence. Consequently, the probability of land subsidence is not as easily expressed in terms of specific intensity and frequency as it is for other hazards.

A more quantifiable analysis of land-related hazards may instead evaluate potential risk from karst or sinkholes. Karst formations develop in specific ways that are influenced by unique local conditions. Sinkholes can be induced through natural or human causes. Sinkholes that occur naturally usually form by the slow, downward dissolution of carbonate rock though bedrock collapse in areas that overlie caverns. Human induced sinkholes can be triggered by even a minor alteration in the local hydrology. Inadequate drainage along highways, or increased runoff from hard surfaces like concrete and pavement, can also contribute to sinkhole development.

The most important environmental issue with respect to karst is the sensitivity of aquifers to groundwater contamination. This problem is universal among all karst regions in the United States that underlie populated areas.

Vulnerability to Land Hazards

Earthquakes are low probability, high-consequence events. Although earthquakes may occur infrequently they can have devastating impacts. Ground shaking can lead to the collapse of buildings and bridges; and could disrupt gas, life lines, electric, and phone service. Deaths, injuries, and extensive property damage are also possible vulnerabilities from this hazard. Additionally, some secondary hazards caused by earthquakes include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis, and dam failure. Moderate and even very large earthquakes are possible, although usually infrequent, in areas of normally low seismic activity. Consequently, buildings in these regions are seldom designed to deal with an earthquake threat; therefore, they are extremely vulnerable.

Exposure

An evaluation of exposure identifies who and what may be vulnerable to land hazards. This analysis takes into consideration where seismic activity may occur, in addition to what assets and facilities may be located within those vulnerable areas. The community assets and critical facilities inventories below will note specific properties that are exposed to subsidence, karsts and sinkholes, or earthquakes.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to land-related hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to than others. For instance, a structure may be more vulnerable if it was not designed to withstand intense seismic activity. Additional characteristics may influence sensitivity even further.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to the impacts of potential land hazards, but this capacity is dependent upon additional factors, including a comprehensive understanding of the risks associated with land hazards, infrastructural and structural preparedness, and regulations for structures or developments that may be exposed or highly sensitive.

Table 4–23 Summary of State Owned and Critical Facilities within the 100-ft Erosion Zone in Baltimore City

County/City	Critical Facilities in the Erosion Zone	State Facilities in the Erosion Zone
Baltimore City	248	54

Source: Table 3-51, Maryland Emergency Management Agency, 2011: 153.

Table 4–24 Critical Facilities Located Within Landslide Hazard Areas in Baltimore City

Critical Facilities	Critical Facilities Building and Content Values	State Facilities	State Facilities Building and Contents Values
1,055	$77,471,867	43	$149,471,406.49

Source: Table 3-84, Maryland Emergency Management Agency, 2011: 224

Inventory of Community Assets Susceptible to Land-Related Hazards

Most earthquake-related property damage, injuries, and fatalities are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking —both of which are directly related to the earthquake size, its location and distance from the fault, and regional geology. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (mountain regions and along hillsides), and liquefaction in which ground soil loses shear strength and thus the ability to support foundation loads. In the case of liquefaction, anything relying on the substrata for support can shift, tilt, rupture, or collapse. All of Baltimore is considered to be within an expected peak acceleration zone of 8%g (refer back to Figure 3–19 on page 90 in Chapter 3). At this level any potential damage is expected to be very light.[12]

In Baltimore, sinkhole formation may be more likely than a major earthquake event. Vulnerable to urban karsts and sinkholes, however, cannot be easily associated with particular regions.

Inventory of Critical Facilities Susceptible to Land-Related Hazards

Using data from the Maryland Emergency Management Agency, Table 4–23 Summary of State Owned and Critical Facilities within the 100-ft Erosion Zone in Baltimore City, below, indicates that there are 248 Critical Facilities and 54 State facilities in the 100-ft erosion zone in Baltimore City. Likewise, there are 1,055 critical facilities, valued at $77 million, located within Baltimore's Landslide Hazard Areas (Table 4–24 Critical Facilities Located Within Landslide Hazard Areas in Baltimore City).

Estimated Losses

While the value of the facilities that are vulnerable to land-related hazards may be none, it is nevertheless challenging to accurately monetize the potential damages from an earthquake. Using HAZUS-MH Software, the 2011 Maryland Hazard Mitigation Plan reported that annualized direct economic losses from Earthquake events totaled $933,000 (as shown in Table 4–26 HAZUS MH-MR5 Earthquake Total Annualized loss in Baltimore City by building type based on a deterministic scenario, right).

The total annualized loss may be further analyzed by building type, as shown in Table 4–26 HAZUS MH-MR5 Earthquake Total Annualized loss in Baltimore City by building type based on a deterministic scenario, below. While manufactured homes are generally more vulnerable to an earthquake event, this construction type in not commonly found in Baltimore City. Rather, in Baltimore, most damage will likely be sustained by masonry structures, with an annualized loss of approximately $421,000. Dividing potential damage among building occupancy type, Table 4–27 HAZUS MH-MR5 Earthquake Total Annualized Loss by Occupancy Type, below indicates that residential structures stand to sustain the most damage, costing an annualized loss of $442,000, while agricultural structures — not often found in the City — will sustain an annualized loss of only $1,000.

Table 4–25 HAZUS-MH MR5 Earthquake Annualized Losses and Direct Economic Losses Based on a Deterministic Scenario

Annualized Direct Economic Losses	Direct Economic Losses for 1998. Event in PA with a Mag. 5.2 and Depth 10km
$933,000.00	$588,000.00

Source: Table 3-97, Maryland Emergency Management Agency, 2011: 261.

Table 4–26 HAZUS MH-MR5 Earthquake Total Annualized loss in Baltimore City by building type based on a deterministic scenario

Wood	Masonry	Concrete	Steel	Manufactured Homes
$162,000	$421,000	$ 93,000	$256,000	$ -

Source: Table 3-98, Maryland Emergency Management Agency, 2011: 261-262.

Table 4–27 HAZUS MH-MR5 Earthquake Total Annualized Loss by Occupancy Type

Agricultural	Commercial	Educational	Government	Industrial	Religion/Non-Profit	Residential
$1,000	$386,000	$21,000	$16,000	$39,000	$29,000	$442,000

Source: Table 3-99, Maryland Emergency Management Agency, 2011: 263.

Selecting Key Vulnerabilities

This plan recognizes that a number of tools for understanding natural hazard and climate impacts already exist. Perhaps most notable among these existing resources is NOAA's Coastal Services Center (CSC) Roadmap for Adapting to Coastal Risk, which includes a Risk and Vulnerability Assessment Tool (RVAT) and a Community Vulnerability Assessment Tool (CVAT). These existing tools and resources helped to establish a thorough framework for guiding the risk and vulnerability process of this plan. Learning from such tools, DP3 created an approach that was most appropriate for issues specific to Baltimore.

Table 4–28 The Top Ten Neighborhoods with the Hottest Average Summer Temperatures

Name	% Impervious Surface	Avg. Temp in Summer
McElderry Park	100.0%	107.6
Patterson Park	99.9%	106.4
Patterson Place	99.9%	106.3
Highlandtown	99.5%	106.0
Brewers Hill	100.0%	105.7
Milton-Montford	100.0%	105.6
CARE	100.0%	105.4
South Baltimore	100.0%	105.2
Rosemont Homeowners/Tenants	100.0%	105.2
Ellwood Park/ Monument	97.1%	104.6
Broadway East	99.9%	104.5

Specific facilities, assets, or neighborhoods within Baltimore may require additional care and attention when planning for natural hazards. Varying levels of sensitivity may be caused by general characteristics, such as the age of a structure, or specific conditions, including location or other external factors. For instance, to flooding and impacts from coastal hazards, Fells Point and Baltimore's Inner Harbor are highly vulnerable. Historic structures within those areas are even more so. At the same time, properties within floodplains and adjacent to major waterways, often repetitive loss properties, are likewise vulnerable to flooding. This is demonstrated, for example, in the commercial area of the Mt. Washington Mill, which has experienced frequent impacts from flooding in the past.

To the impacts of extreme heat, neighborhoods with the highest percentages of impervious surfaces, and least tree canopy, are most vulnerable (Table 4–28 The Top Ten Neighborhoods with the Hottest Average Summer Temperatures). Summer temperatures in these neighborhoods can reach 117°F, and even higher within primarily industrial areas. Conversely, the neighborhoods with the lowest average summer temperatures are more likely to have less land covered by impervious surfaces (Table 4–29 The Top Ten Neighborhoods with the Lowest Average Summer Temperatures).

Table 4–29 The Top Ten Neighborhoods with the Lowest Average Summer Temperatures

Name	% Impervious Surface	Avg Temp in Summer
Tremont	95.5%	88.7
Oaklee	99.3%	90.4
Medford	99.8%	95.9
Graceland Park	95.8%	96.1
Pimlico Good Neighbors	81.9%	96.4
O'Donnell Heights	73.0%	96.6
Fairfield Area	88.0%	97.2
Berea	77.9%	97.7
Parkside	98.6%	97.7
Hopkins Bayview	81.1%	97.8

Adaptive Capacity

ADAPTIVE CAPACITY is the ability of a system (in this case, the City of Baltimore) to adjust to changes in the environment — including climate variability and extreme shifts in weather — in order to moderate potential damages or cope with the consequences of those changes.[13] Adaptive capacity informs, and is informed by, a vulnerability assessment through important insights into the factors, processes, and structures that promote or constrain the system's (City's) ability to respond to climate change or natural hazard events.[14] Systems that are resilient to climate stressors are more adaptable and flexible and generally have a higher adaptive capacity. Relatively similar hazards could have vastly different consequences depending on a system's level of adaptive capacity. While a low adaptive capacity can increase a system's vulnerability to natural hazards, a high level of adaptive capacity may lessen the degree to which a system is vulnerable.

There are two types of adaptive capacity: generic and specific. Generic adaptive capacity includes assets and entitlements that enable a system to cope and respond to a variety of stressors.[15] For example, having a well-educated and engaged community can contribute to generic capacity. On the other hand, specific adaptive capacity is the ability to respond to and recover from a specific climatic event, such as a flood, tornado, or hurricane.[16]

Adaptive capacity, of either generic or specific dimensions, can be influenced by a number of factors. In addition to the examples noted above, resource availability, socio-political barriers, and institutional responsibility, among other characteristics, can shape adaptive capacity. While the DP3 has considered adaptive capacity of the City of Baltimore as a whole, it has needed to recognize that capacity to adapt to climate change may not be equal across all populations. Research shows that adaptive capacity among individuals may be differentiated along the lines of age, race or ethnicity, religion, and gender.[17]

Determinants of adaptive capacity are used to indicate opportunities and constraints for adaptation, as well as current assets and resources from which City may benefit. The eight determinants of adaptive capacity that are most frequently cited in scientific literature are described here.

1. **Institutions** | Includes norms and rules — both formal and informal. This may be governance mechanisms at city, state, regional, federal, or international levels, or institutional and policy frameworks. Additionally, this might include local ordinances, city plans, state and federal incentives and regulations, as well as inter-jurisdictional collaboration.

2. **Infrastructure** | Describes the basic physical structures needed for a City to function. Examples include water and sanitation systems, green infrastructure, traditional built environment, transportation networks (roads, bridges, public transportation), and energy supply systems.

3. **Wealth and Financial Capital** | Considers is the accessibility and availability of financial wealth or wealth management instruments, and includes fiscal incentives for risk management. For example, revolving funds, philanthropic initiatives, insurance, and credit can all be viewed as Wealth and Financial Capital.

4. **Social Capital Networks** | Focuses on access to — and engagement with —social groups, businesses, and organizations. Examples include public-private partnerships, organized community leadership, and interpersonal connections between city staff and external organizations.

5. **Political Capital** | Includes political leadership, political climate, decision and management capacity, and public engagement. Examples of Political Capital include leadership, motivation and vision, electoral and local politics, reputation and legitimacy, public perceptions of political leadership, and political support gained through public participation and engagement efforts.

6. **Human Capital** | Focuses on education levels, community risk perception, human labor, and capacity of the human population. Some of the best indicators of human capital may be a community's overall education level, or the skills and knowledge of city staff.

7. **Information** | Considers access to information sources and the efficiency of early warning systems. Examples include scientific understanding of climate change impacts and associated adaptation strategies, and an effective system for sharing, discussing, and conveying climate change information, as well as adaptation strategies, at various levels.

8. **Technology** | Includes technology sources, access and transmission, and technological innovations. Examples of technology include the use of Geographic Information Systems (GIS) or Doppler Radar.

What can we do?

Hazard mitigation and climate adaptation processes help to build the City's adaptive capacity. First and foremost, by creating and maintaining the DP3 Plan, Baltimore is compliant with FEMA's requirement for an All Hazards Mitigation Plan (AHMP), and is therefore eligible for federal assistance in the event of an emergency. Such assistance leverages Baltimore's ability to respond to hazard events.

Improved adaptive capacity can ensure that a system is able to maintain ongoing functions throughout shifting conditions or hazard events. According to the Intergovernmental Panel on Climate Change (IPCC), strengthening adaptive capacity may require adjustments in behavior, as well as in resource and technology use. For each determinant, there may be room for improvement:

- Incorporate mitigation and adaptation measures into institutional framework
- Enhance the resiliency of City infrastructure
- Ensure a robust, underlying network of financial capital exists across all of Baltimore
- Educate and empower residents to increase their ability to avoid and respond to hazards
- Establish policy and procedures which support hazard mitigation and climate adaptation
- Support resident growth through educational and workforce training
- Establish an effective program for communicating hazard information
- Utilize technological tools to more accurately predict accurately vulnerability to hazards

Finally, although a considerable amount of attention is often focused on risks associated with climate change, it is important to think positively. Adaptive capacity can also help Baltimore and its residents take advantage of new opportunities or benefits that will arise because of climate change. This may be challenging to grasp. However, consider, for instance, the potential for a longer growing season that may present opportunities to cultivate new kinds of produce. Seeing climate change from both perspectives encourages flexibility and a greater propensity to adapt.

Chapter 5

Strategies and Actions

Disaster Preparedness and Planning Project Vision:

Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Disaster Preparedness and Planning Project Goals:

Goal 1: Protect the health, safety and welfare of Baltimore City residents and visitors

Goal 2: Prevent damage to structures, infrastructure, and critical facilities

Goal 3: Build resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private)

Goal 4: Enhance the City of Baltimore's adaptive capacity and build institutional structures that can cope with future conditions that are beyond past experience

Goal 5: Promote hazard mitigation and climate adaptation awareness and education throughout the City of Baltimore

Goal 6: Become a Community Rating System (CRS) classified community

The National Flood Insurance Program's (NFIP's) CRS recognizes community efforts that go beyond the NFIP minimum standards by reducing flood insurance premiums for the community's property owners. The CRS program is voluntary and discounts may range from 5 to 45 percent depending on the CRS level attained. The discounts provide an incentive for new flood mitigation, planning and preparedness activities that can help save lives and protect property in the event of a flood as highlighted in the strategies and actions in this chapter.[1]

Current Climate Initiatives

Recognizing the potential risks associated with projected changes in climate, the City of Baltimore has already begun to establish initiatives to reduce our impact on the environment and increase resiliency to hazardous events. Many of these programs are reviewed in Baltimore's Sustainability Plan and its subsequent Annual Reports, and include efforts to increase natural features within the City, improve self-sufficiency, increase efficiency, and reduce greenhouse gas (GHG) emissions. Some key programs are highlighted below.

- Stormwater Utility and Clean Water Baltimore Program: The City of Baltimore, as mandated by the State of Maryland in April 2012, must raise funds to support a comprehensive stormwater management program. Stormwater remediation projects will reduce the impacts of flooding hazards.

- Urban Tree Canopy Initiatives: With a number of forestry and "green" organizations and agencies, Baltimore is pursuing its goal of increasing the Urban Tree Canopy to 40% by 2037. DP3 recognizes the potential for trees and other natural features to mitigate damage from hazard events.

- Baltimore Food Policy Initiative: The Baltimore Food Policy Initiative (BFPI) is an inter-governmental collaboration aimed to increase access to healthy and affordable foods in Baltimore's food deserts. Ensuring adequate supply of healthy food will reduce negative health impacts during hazard events.

- Green Building Standards: Baltimore Green Building Standards for commercial and multi-family buildings over 10,000 square feet aims to increase the efficiency and reduce the environmental impact of all new or extensively modified structures. Many of the DP3 actions below recommend enhancing or incorporating these standards into disaster planning efforts.

- Climate Action Plan: Baltimore's Climate Action Plan (CAP) was established to reduce Baltimore's greenhouse gas (GHG) emissions through a range of strategies targeted at reducing the amount of fossil fuel needed for everyday living. Its recommendations are critical steps to preventing additional climate impacts.

- Growing Green Initiative: The Growing Green Initiative (GGi) is an effort to promote the transformation of vacant land into green spaces that will provide economic, social, and environmental benefits to our neighborhoods. Growing Green is an umbrella for all of the "Grow Baltimore" greening efforts that address the re-use of vacant land, including Vacants to Value, Homegrown Baltimore, Clean Water Baltimore, and Power in Dirt. GGi provides a strategic approach for both short-term and long-term reuse of vacant land that combines blight elimination, tree planting, urban agriculture, and stormwater management to help mitigate the negative impacts of vacant properties and set the stage for future redevelopment opportunities.

- Energy Office: The Baltimore Energy Division strives to increase the energy efficiency, comfort, safety, healthy and durability of buildings throughout the City by upgrading and retrofitting them.

While this list is by no means exhaustive, it is indeed illustrative of some of the key efforts underway in Baltimore. Additionally, many of these initiatives and programs will be incorporated in the actions described below.

No Regret Actions

While there is significant evidence of a changing climate and the potential to reduce those changes through human activities, many continue to debate climate change. The image below, by cartoonist Joel Pett, makes a valid statement. The cartoon depicts a scene from a hypothetical climate summit where a speaker appears to be demonstrating the added benefits of reducing our impact on the climate, to which one audience member stands up and questions, "What if it's a big hoax and we create a better world for nothing?"

Would that really be so terrible? "No Regrets" actions are actions that will provide benefit and cause no harm regardless of whether or not climate change happens. The "No Regrets" approach to decision-making is a strong precautionary approach to prevent risk to health, safety, and the environment. It is important to prioritize these actions as they focus on enhancing, strengthening, and protecting Baltimore's residents and assets; either way, the City of Baltimore will benefit.

For example, fixing leaking water pipes and maintaining drainage channels are two very smart and cost-effective investments that will benefit the City even in the absence of climate change. Climate-proofing new buildings increases toughness and can save energy, both of which are smart "No Regret" actions. The City will evaluate financial, technological, informational, and legal constraints as part of implementation of all the strategies and actions listed in this chapter.

Urban Sectors

The strategies put forth in this plan are grouped according to corresponding urban sectors—infrastructure, buildings, natural systems, and public services. In the hazard mitigation and adaptation process, each sector plays an important role as they are understood to be significantly impacted by the consequences of hazard events and a changing climate. While impacts may vary, most urban systems are vulnerable to more than one hazard. Sorting the action plan by sector, rather than by individual hazard, allows for strategies to address multiple vulnerabilities simultaneously.

Furthermore, the DP3 plan is expected to be reviewed by a diverse range of agencies, businesses, industries, or other individuals. Depending on the viewer, one sector may be more relevant than another. For example, the owner of a gas station will be more concerned with the infrastructure section, and will be interested to learn how infrastructure systems are most vulnerable, as well as what can be done to increase the resiliency of their property. The sector organization recognizes the far-reaching scope of this plan and presents a more readily understandable and flexible framework. In this way, the DP3 plan becomes a resource and reference tool.

Infrastructure

One of the most pressing challenges facing states and municipalities today is the quality and capacity of built public infrastructure—the water systems distribution and treatment, schools and municipal buildings, transit systems, and other core assets upon which we all depend. The links between well-functioning infrastructure and economic growth are well documented. Inadequate or failing public infrastructure disproportionately hurts low-income people. As we saw in New Orleans after Hurricane Katrina, and in New York and New Jersey after Superstorm Sandy, low-income communities are often located in the flood-prone sections of cities, resulting in prolonged health issues associated with mold and moisture after flooding. The 1995 Chicago heat wave resulted in 750 deaths, most of which were elderly low-income residents who could not afford air-conditioning were afraid to open windows for fear of crime. However, as NOAA has stated, "heat is the number one weather-related killer in the United States." In fact, NOAA's National Weather Service statistical data revealed "heat causes more fatalities per year than floods, lightning, tornadoes, and hurricanes combined."[1] In New York City, when public transportation failed, transit-dependent low-income residents could not get to work and, because they were not salaried, could not earn wages to support their families. In Baltimore, many residents might face the same risks if the City does not sustain a system of efficient, reliable infrastructure.

Climate change should be a key consideration in the development and maintenance of existing or future infrastructure. Already, infrastructure in Baltimore has been proven vulnerable to unpredictable, extreme weather events. Extreme heat, for instance, leads to the buckling of roads, melting asphalt, and warped railroad tracks. In July 2012, a heat wave led to train tracks and pavement buckling in the Baltimore region and a US Airways jet stuck in melted pavement at Baltimore Airport.2 Additionally, heat, accompanied with the concentrated use of air conditioning, may overheat and overwhelm electrical supplies, leading to a significant power outage. In a hazard event, this increased electric cooling demand may be combined with reduced energy supply reliability, which can result in rolling brown-outs or black-outs. Similarly, a flooding event could submerge underground power generators, rendering them useless. Other hazards may contribute to inoperative public transportation, severed utility or communication lines, overflowing sewer systems and the inundation of waste management facilities, and much more. Additionally, extreme events threaten linkage infrastructures such as bridges, roads, pipelines, and transmission networks. Different forms of infrastructure are vulnerable to climate change in distinct ways and to varying degrees, depending on their state of development, resilience, and adaptability. Furthermore, infrastructure may face an immediate physical impact, or the damage may be more indirect.

Baltimore's existing infrastructure was built for the City's past conditions. However, current weather is already presenting a challenge, and a changing climate will increase the City's infrastructure vulnerabilities. Climate change could have significant implications for infrastructure. While infrastructural elements are sensitive to the climate existing at the time of their construction, due to their generally long operational lifetimes, infrastructural elements are also sensitive to climate variations over the decades of their use. For example, a substantial proportion of infrastructure built in the next five years, will still be in use long after 2030. Therefore, increasing infrastructure's resilience to the impacts of climate change is a top priority.

To increase the resilience of both new and existing infrastructure, we must be prepared to mitigate and adapt to the impacts of climate change. Preparing infrastructure for these changes will not only minimize Baltimore's risk and vulnerability, it will also maximize potential opportunities. Baltimore's infrastructure, which is an interconnected network of highly valuable assets, enables the City to grow and prosper. By proactively mitigating and adapting to climate change, Baltimore will advance its goals of reducing carbon emissions and becoming a sustainable city. This, in turn, will enhance the City's overall competitiveness, increase its resilience, and open the door to robust social, economic, and environmental growth. The proposed strategies which relate to this sector will help Baltimore establish an infrastructure network that is able to endure or adapt to the impacts of climate change.

Buildings

Baltimore's buildings, some of which have been significant features in their communities for decades or even centuries, add vibrant charm to the City. Baltimore City has an extensive and diverse collection of buildings. These structures are homes, cultural institutions, offices, schools and universities, historic landmarks, critical facilities, community establishments, and places of worship.

In the past, Baltimore's building stock has been subject to weather-related risks. In particular, flooding associated with extreme precipitation events has caused a great deal of damage (for a description of historical occurrences, see the Flooding Hazard Profile). During extreme events, buildings may be destroyed —entirely or in part — or rendered unstable due to the impacts from storm surges and flooding waters. A changing climate is likely to intensify this impact. For instance, storm surge, when combined with projected sea level rise, will pose a greater threat to Baltimore's existing coastal building stock. Additional hazards, including earthquakes, may further weaken a building's structural integrity.

Resilience of Baltimore's building stock is particularly important considering that many structures serve as refuge for City residents during severe storms and other extreme weather events. Similarly, critical emergency facilities — hospitals, fire stations, police stations, government buildings, and the like — perform essential functions during these events and increase the City's capacity to respond to, and alleviate, the impacts of a hazard. The strategies within this plan aim to protect buildings from current and future climate risks by increasing their resiliency. Additionally, the recommended actions intended to mitigate climate change impacts from buildings — which, alongside the energy needed to operate them, produce considerably high greenhouse gas emissions — by improving energy and resource conservation.

Placeholder for image of city agencies that regulate Buildings

Natural Systems

Although natural systems will indeed suffer adverse consequences as a result of climate change (and environmental health should therefore be given particular attention), this plan embraces nature for its potential as a hazard mitigation and climate adaptation tool. In many cases, natural features are capable of offsetting greenhouse gases, as well as alleviating the severity of weather events, effectively reducing long-term risks from climate change and hazards. On the other hand, if not properly maintained, natural elements such as trees and streams may themselves become a danger during an extreme weather event.

As Baltimore attempts to reduce greenhouse gas emissions and curb the effects of climate change on the City, natural systems are increasingly seen as a mitigation strategy. Trees and vegetation are valuable for their ability to absorb carbon dioxide and transform it into oxygen. This process, known as carbon sequestration, reduces greenhouse gases in our atmosphere and mitigates the extent of changes in our climate future. At the same time, this process reduces the probability of respiratory health problems during days with extreme heat. Additionally, the same trees can help to cool the City (and its water habitats), reducing the impact of the urban heat island effect.

Although trees and natural systems provide extensive benefits in an urban setting, it is important to recognize that these same systems could become a risk during a hazard event if not properly maintained. In heavy winds, trees may lose limbs or be uprooted entirely. Alternatively, a warming climate may welcome new pests or invasive species which may devastate native species of the local ecosystem. Likewise, streams without a natural buffer can become dangerous channels of flooding water during heavy precipitation events. Proper maintenance of Baltimore's natural systems will be necessary to ensure that benefits are maximized while risks are reduced. Planting dense vegetation along riparian corridors, for instance, creates a buffer from intensely flowing waters during flood events.

In addition to protecting the health and safety of Baltimore's residents, natural elements, should also be maintained for their own health. Without a strong and robust urban forest, we cannot expect to receive the same invaluable air quality improvement services. In addition to a loss of ecosystem services, the damage or destruction of trees is accompanied by other challenging consequences, including removal and replacement costs, and the considerable amount of time needed for a replacement tree to reach their full potential and value. According to the US Forest Service, a mature tree with a trunk 10 times larger than a small tree produces 60-70 times the amount ecological services.[3]

Recognizing the potential of a changing climate, Baltimore must ensure that tree and plant species will be capable of tolerating both current and future climate conditions. Priority should be given to species with high adaptive capacity, and which are therefore more likely to survive temperature increases in the future. The National Wildlife Federation recommends using a set of questions, first developed by Chicago, to guide tree and plant selections.4 Additionally, trees must be cared for and maintained. Baltimore City Forestry requires two full years of maintenance for all newly planted trees. Young tree maintenance includes mulching, watering, weeding, straightening, removing stakes, and removing root sprouts. Recently, the Forestry division improved their guidelines for tree planting and maintenance in order to promote a consistent process to nurture young trees throughout Baltimore. These actions help increase the survival rates of young trees, ensuring healthy development of Baltimore's entire urban tree canopy.

Lastly, urban biodiversity contributes to the health of the entire ecosystem. In a regional study, conducted at the University of Delaware, native and alien plant species of the Mid-Atlantic region were evaluated for their ability to support insect biodiversity. The results (the database is available for download online) can be used to determine which plants should be encouraged and which should be avoided.5

The strategies proposed in this plan aim to identify how and where nature may be managed to the City's benefit, and what actions must be taken to eliminate all avoidable risks associated with neglected natural systems.

Public Services

A major role of this plan is to expand Baltimore's preparedness for future hazards. Without a strategy for conveying information about the risks and vulnerabilities associated with these hazards, its message will fall on deaf ears. Therefore, strategies relating to public health and human services are concerned with distributing information, building resources, improving communication, and establishing response plans.

Efforts that will have the greatest capacity to mitigate climate change are often prompted by modifications to the other sectors listed above. However, without interest from the general population, or an understanding that will spark that interest, those changes are unlikely to occur. For this reason, Baltimore must encourage behavioral and other changes that will reduce greenhouse gas generation. At the same time, the City must pursue education and outreach efforts that will raise hazard awareness among residents, business owners, employees, institutions, and others. Furthermore, hazard mitigation efforts should be incorporated into all future planning documents, and across all City agencies.

Additionally, strategies should be in place that will prevent or limit health risks — including disease outbreak, physical exhaustion, and respiratory conditions, to name a few — that are triggered by extreme events. Furthermore, it will be necessary that the City build its emergency preparedness. This will require, for example, coordination between local government, NGOs, and private entities which shall establish procedures that will be employed during hazard events. Community involvement today will ensure that all of Baltimore's population is prepared, well-informed about the risks and procedures, and able to safely respond to early warnings.

After reviewing risks and vulnerabilities associated with natural hazards in Baltimore, the DP3 process developed a comprehensive list of strategies and actions in order to ensure the City's ability to adapt and mitigate the potential impacts. The following section includes sets of strategies for each sector. Individual actions associated with each strategy are included, as is information regarding intent, benefit, and stakeholders, as well as some additional details. Some actions are followed by the italicized letters O, S, M, or L in parentheses. These indicate the possible timeframe (ongoing, short, medium, long), which will be discussed further in Chapter 6 . Finally, the list below defines acronyms for the agencies and organizations noted as possible stakeholders.

BCFD Baltimore City Fire Department

BCHD Baltimore City Health Department

BCPD Baltimore City Police Department

BCPSS Baltimore City Public School System

BCRP Baltimore City Department of Recreation and Parks

BDC Baltimore Development Corporation

BDW Baltimore Development Workgroup

BGE Baltimore Gas and Electric

BOS Baltimore Office of Sustainability

CHAP Commission for Historic and Architectural Preservation

CoS Commission on Sustainability

CRS Community Rating System

CSX CSX Corporation

DES Department of Environmental Services

DGS Department of General Services

DHCD Department of Housing and Community Development

DHMH Maryland Department of Health and Mental Hygiene

DOP Department of Planning

DOT Department of Transportation

DPH Department of Public Health

DPW Department of Public Works

FEMA Federal Emergency Management Agency

FHWA Federal Highway Administration

MCC Maryland Conservation Corps

MDE Maryland Department of the Environment

MDH2E Maryland Hospitals for a Healthy Environment

MDNR Maryland Department of Natural Resources

MDTA Maryland Transportation Authority

MEMA Maryland Emergency Management Agency

MOEM Mayor's Office of Emergency Management

MON Mayor's Office of Neighborhoods

MOIT Mayor's Office of Information Technology

MTA Maryland Transit Administration

NAHB National Association of Home Builders

NFIP National Flood Insurance Program

NGO Non-governmental Organization

PSC Public Service Commission

SHA Maryland State Highway Administration

USACE U.S. Army Corps of Engineers

Hazard Mitigation and Climate Adaptation Strategies & Actions

The Strategies and Actions found in Chapter 5 define the programs, policies, and projects that the city will undertake to accomplish its resiliency goals.

STRUCTURE

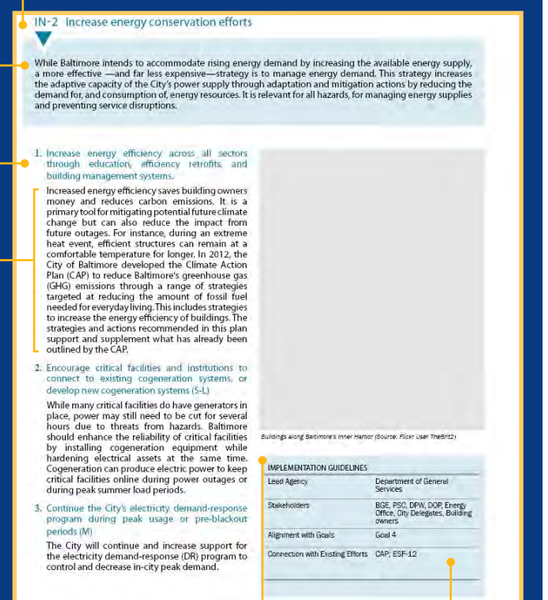
Strategies are divided into sectors and sub-sectors throughout Chapter 5. Sectors are divided into four colors: aqua (infrastructure), orange (buildings), green (natural systems), and purple (public services). Sub-sectors are indicated in bold at the top of the page.

Strategy Name
The first two letters refer to the Sector Area (IN, BL, NS or PS) and the number refers to the order of the strategy.

Strategy Description
The description of measures provides important background information describing the city's current activities to put the measure in context, some rationale and policy direction. Additionally, some descriptions provide detailed guidance that will be used in program implementation.

Actions
Actions identify specific steps that the city can take to implement each measure.

Action Description
The background of each action and reason for the action are described in more detail below the action headers.



IN-2 Increase energy conservation efforts

While Baltimore intends to accommodate rising energy demand by increasing the available energy supply, a more effective —and far less expensive—strategy is to manage energy demand. This strategy increases the adaptive capacity of the City's power supply through adaptation and mitigation actions by reducing the demand for, and consumption of, energy resources. It is relevant for all hazards, for managing energy supplies and preventing service disruptions.

1. Increase energy efficiency across all sectors through education, efficiency retrofits, and building management systems.

Increased energy efficiency saves building owners money and reduces carbon emissions. It is a primary tool for mitigating potential future climate change but can also reduce the impact from future outages. For instance, during an extreme heat event, efficient structures can remain at a comfortable temperature for longer. In 2012, the City of Baltimore developed the Climate Action Plan (CAP) to reduce Baltimore's greenhouse gas (GHG) emissions through a range of strategies targeted at reducing the amount of fossil fuel needed for everyday living. This includes strategies to increase the energy efficiency of buildings. The strategies and actions recommended in this plan support and supplement what has already been outlined by the CAP.

2. Encourage critical facilities and institutions to connect to existing cogeneration systems, or develop new cogeneration systems (S-L)

While many critical facilities do have generators in place, power may still need to be cut for several hours due to threats from hazards. Baltimore should enhance the reliability of critical facilities by installing cogeneration equipment while hardening electrical assets at the same time. Cogeneration can produce electric power to keep critical facilities online during power outages or during peak summer load periods.

3. Continue the City's electricity demand-response program during peak usage or pre-blackout periods (M)

The City will continue and increase support for the electricity demand-response (DR) program to control and decrease in-city peak demand.

Buildings along Baltimore's Inner Harbor (Source: Flickr user TheBritz)

IMPLEMENTATION GUIDELINES

Lead Agency	Department of General Services
Stakeholders	BGE, PSO, DPW, DOP, Energy Office, City Delegates, Building owners
Alignment with Goals	Goal 4
Connection with Existing Efforts	CAP, ESF-12

Implementation Guidelines Table
The tables identify responsible departments for each action (See left for the acronym table that defines the department acronyms), stakeholders, the alignment of the strategy with the DP3 goals, and connections .

Time Frame Symbol

- Short-term (1-2 years) — Measures that can help jump-start DP3 implementation within the first 1-3 years.
- Mid-term (3-5 years) — Measures that may be best for implementing within the first 3-5 years following kick-off of the DP3.
- Long-term (6+ years) — Measures that may be most feasible for implementation closer to 2020 and that can lay the groundwork for improvements beyond 2020.
- Ongoing — Measures that may be immediately implemented and/or can be continually implemented.





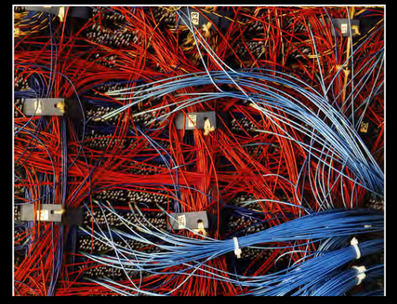






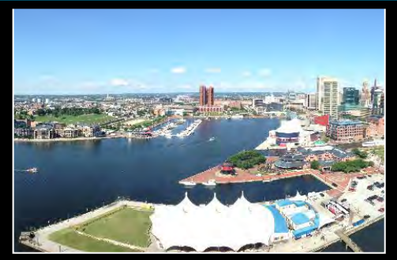






Infrastructure






ENERGY

IN-1 Protect and enhance the resiliency and redundancy of electricity system

The City's electricity supply and power grid system ensures that Baltimore's residents are not left without power in a hazard event. Most importantly, critical facilities that perform emergency response activities throughout the duration of a hazard event need reliable power supplies. Forward thinking actions facilitate Continuity of Operations Plan (COOP) during hazard events and prevent power outages of any significant scale. Beyond strengthening existing systems, increasing system redundancy is a vital measure for protecting critical infrastructure from power outages. The City will explore options for creating a redundant electrical infrastructure, including coordinated efforts with Federal programs to enhance grid resiliency, including the August 2013 Economic Benefits of Increasing Electrical Grid Resilience to Weather Outages report, authored by the President's Council of Economic Advisers and the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability, with assistance from the White House Office of Science and Technology. This strategy intends to protect and support resilient energy systems, addressing power supply through both adaptation and mitigation actions. This strategy is relevant for all hazards, with particular actions targeting impacts from predicted relative sea level rise.

1. Work with the Maryland Public Service Commission (PSC) to minimize power outages from the local electric utility during extreme weather events by identifying and protecting critical energy facilities and located within the City (S)

   It is essential to harden existing infrastructure to strengthen the City's energy networks. Transmission and distribution infrastructure such as substations need to be hardened to withstand current and future impacts from hazards. BGE is filing a plan with the MD Public Service Commission (PSC) in August, 2013 which will address this issue . BGE will work with the City of Baltimore to monitor the outcome of the PSC's Derecho and MD Grid Resiliency Task Force, which is also working to address these issues. This will help reduce the likelihood of failure and ensure that service may be restored more efficiently if failures do occur.

2. Evaluate the City of Baltimore utility distribution system, and identify "underground utility districts" using BGE's May 2013 short term reliability improvement plan (S)

   Failure of key nodes in the energy distribution system can have widespread impacts on the City's energy systems, with significant repercussions for people, businesses, and communities. In May of 2013, BGE filed a short term reliability improvement plan with the PSC as a result of the Derecho Order. This plan addresses selective undergrounding throughout BGE's service area. BGE will work with the City of Baltimore to use this plan as a guide and work with the PSC to leverage potential opportunities.

   As system components are placed underground, the City will work with BGE to ensure transformers and switches are water-resistant and, where appropriate, able to withstand saltwater inundation in order to increase resiliency of the distribution system.

3. Support BGE's collaboration with the Maryland Public Service Commission to implement various smart grid solutions that will provide the City with real-time access to data during events (S)

   After an extreme weather event, the first task of any utility is to identify the location and extent of damage. Utilities usually rely on customer reports of power outages, together with on-site inspections by crews. Gathering information in this way, though, takes time and can be delayed by problems on the ground, such as impassable roads. BGE is collaborating with local Emergency Operation Centers to provide near real-time data during major weather events that result in widespread power outages. Additionally, a PSC staff working group was developed as a result of the Derecho Order to address the issue of information sharing among utilities and Emergency Management Agencies. BGE will work with the PSC to leverage potential opportunities.

4. Identify, harden, and water seal critical infrastructure relative to electrical, heating, and ventilation hardware within the flood plain

   Facilities in flood-prone areas rely on mechanical systems that may be vulnerable to inundation. Damage to these systems can result in extended facility closures and costly repairs. The City should initiate a process for flood-proofing all mechanical, electrical, heating, and ventilation systems that are located within the 100-year floodplain.

5. Increase resiliency in our energy generation system by encouraging the development of decentralized power generation and developing fuel flexibility capabilities

   The City will work with BGE and the PSC to ensure continuous power supply throughout hazard events by increasing the resiliency of energy generation systems. Hardening power supply networks, establishing back-up generation systems, and considering alternative power generation systems can help to ensure continuity of power supply throughout hazard events

6. Develop a comprehensive maintenance and training program for City employees at facilities with backup generators to ensure proper placement, hook-up and function during hazard events

   Even with generators on-hand, facilities may still experience difficulties if those generators are located in areas that are flooded or if providers failed to secure fuel in advance. Additionally, it is not unheard of for a backup generator to fail, and they are not an absolute reliable reserve. Failure may be the result of extended periods without operation, or possibly because the workers tasked with managing their use in an emergency event are not adequately prepared to do so. BGE will work with the City of Baltimore to develop a process for insuring it can accurately determine when service has been restored to customers with multiple supply lines.

7. Install external generator hookups for critical City facilities that depend on mobile generators for backup power

   It is important to maintain a fleet of mobile generators that can be deployed on short notice. However, facilities must be prepared to accept this as a power source. City government should invest in equipment that can allow City facilities to connect to backup generators quickly in the event of a power loss.

8. Partner with the Public Service Commission and the local electric utility to evaluate protecting power and utility lines from all hazards

   During storms, high winds and downed trees threaten overhead electric poles, transformers, wires, and cables. At times, rerouting lines underground may be warranted, depending on the number of customers impacted and cost involved, but this is not always a cost-effective alternative. Street trees pose a risk to utility lines and other infrastructure, and a straightforward solution requires proper evaluation and maintenance of these features. At the same time, other options should be secured. While it is impossible to protect utility lines from "all" hazards, BGE will work with the PSC to evaluate potential steps that could be taken to better insulate the electric delivery system from hazards.

9. Determine low-laying substation vulnerability and outline options for adaptation and mitigation (S)

   Power substations are vital features of the City's power distribution network. Some, however, are low-laying facilities with high vulnerability in storm surges and flooding events. Through involvement with the MD Public Service Commission–sponsored Grid Resiliency Task Force, BGE and the City of Baltimore will investigate "hardening" the electric delivery system to better withstand extreme weather events.

10. Evaluate and protect low laying infrastructure - switching vaults, conduit and transformers

    Through involvement with the MD Public Service Commission-sponsored Grid Resiliency Task Force, BGE and the City of Baltimore will evaluate measures for protecting the electric delivery system and creating a redundant and resilient conduit infrastructure.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator
Alignment with Goals	Goals 2 and 3
Connection with Existing Efforts	Building Standards and Zoning Codes; CAP; ESF-12; MDNR
Timeframe	

IN-2 Increase energy conservation efforts

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1. Increase energy efficiency across all sectors through education, efficiency retrofits, and building management systems.

   Increased energy efficiency saves building owners money and reduces carbon emissions. It is a primary tool for mitigating potential future climate change but can also reduce the impact from future outages. For instance, during an extreme heat event, efficient structures can remain at a comfortable temperature for longer. In 2012, the City of Baltimore developed the Climate Action Plan (CAP) to reduce Baltimore's greenhouse gas (GHG) emissions through a range of strategies targeted at reducing the amount of fossil fuel needed for everyday living. This includes strategies to increase the energy efficiency of buildings. The strategies and actions recommended in this plan support and supplement what has already been outlined by the CAP.

2. Encourage critical facilities and institutions to connect to existing cogeneration systems, or develop new cogeneration systems (S-L)

   While many critical facilities do have generators in place, power may still need to be cut for several hours due to threats from hazards. Baltimore should enhance the reliability of critical facilities by installing cogeneration equipment while hardening electrical assets at the same time. Cogeneration can produce electric power to keep critical facilities online during power outages or during peak summer load periods.

3. Continue the City's electricity demand-response program during peak usage or pre-blackout periods (M)

   The City will continue and increase support for the electricity demand-response (DR) program to control and decrease in-city peak demand.

IMPLEMENTATION GUIDELINES	
Lead Agency	
Stakeholders	BGE, Building owners, City Delegates, DOP, DPW, Energy Office, PSC
Alignment with Goals	Goal 4
Connection with Existing Efforts	CAP; ESF-12
Timeframe	

IN-3 Ensure backup power generation for critical facilities and identified key infrastructure during power outages

During a power outage, it is essential that critical facilities have backup power supplies in-place. Hospitals, nursing homes, and adult care facilities rely on extensive equipment and utility services to diagnose, treat, and care for patients. These facilities, in addition to police and fire stations, and wastewater treatment plants, tend to already have backup generation installed. However, generators will sometimes fail or may be placed in high risk areas. This builds recommended resilience and disaster prevention and planning into infrastructural and energy systems through mitigation and adaptation actions. It ensures that critical and key facilities maintain continuous power supply.

1. Investigate off-grid, on-site renewable energy systems, generators, and technologies for critical facilities to ensure redundancy of energy systems (M)

   To reduce the impact of power loss on critical facilities, increased on-site electricity generation and the use of renewable energy supplies should be investigated as means to improve the ability of critical facilities to operate reliably during disruptions to the electrical grid.

2. Seek funding to purchase and install generators for all city building designated as critical to agency functions (S)

   In order to reduce blackouts, which impact emergency response times, Baltimore must ensure reliable emergency response with a consistent power supply.

3. Develop Combined Heat and Power (CHP) co-generation plants at identified critical facilities

   Even with backup generators, critical facilities could still experience power outages. The City encourages developing a cogeneration system that will generate electricity sufficient to meet base electrical demand at critical facilities and recover heat for other building processes.

4. Evaluate and ensure backup power generation is available to healthcare facilities (nursing homes, critical care facilities, hospitals, etc.)

   Hospital and other healthcare facilities tend to already have backup generation installed. However, generators will sometimes fail or may be placed in high risk areas. It is important to ensure that backup power generation supplies are present and functioning properly at vital healthcare facilities.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BGE, DGS, DHMH, DOP, DOT, DPW, MOEM
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; ESF-7; ESF-8; ESF-12
Timeframe	

LIQUID FUELS

Liquid fuels include the gasoline and diesel fuel necessary to transport people, goods, equipment and supplies into, out of and throughout Baltimore City. Fuel is used to run city buses, taxis, personal motor vehicles, planes and the large ships that bring goods into and out of the harbor. Beyond transportation, liquid fuels are used for a variety of other needs including heating water and homes and enabling backup generators to function. It is essential to evaluate the vulnerability of our liquid fuel system to the impacts of natural hazards in order to strengthen the supply chain and increase redundancy.

IN-4 Protect and manage compressed liquefied natural gas sites and (city) fueling stations before and during hazard events

Fuel supply infrastructure is vulnerable to extreme weather events. Natural and man-made disasters can cause disruptions in the supply of liquid fuels due to storm surge and flooding, storm- and heat-related power outages, or other events. Hardening of fuel assets, facilities, and stations would decrease disruptions and allow for faster restoration of operations. These efforts will reduce the likelihood of fuel shortages during hazard events. The City will provide damage prevention and adaptive capacity of stormwater and liquid fuel cells systems, particularly from flooding and sea level rise, through both adaptation and mitigation actions and address stormwater systems and liquid fuel cells facilities and sites.

1. Work with BGE to ensure existing preparedness plans for Spring Gardens liquefied natural gas site incorporate its vulnerability to present and predicted flooding, storm surge and sea level rise

The Spring Gardens liquefied natural gas site is located within a densely populated area of south Baltimore northeast of the I-95 and I-395 intersection. The 72 acre facility, on the Middle Branch of the Patapsco River, has been in use by BGE since 1855. Although the site consists of a 100-foot riparian buffer zone and created wetlands, BGE should evaluate the potential to secure the Spring Gardens compressed-liquefied natural gas site against major hazards and reduce potential damage from a hazard event so as to protect the adjacent communities.

2. Adopt building code that requires anchoring of 50 gallon storage tanks or larger

As the primary function of a storage tank is to store liquid substances, the failure of a storage tank can have several undesirable effects. Tanks in low-laying areas are vulnerable to the long-term impacts of sea-level rise and the associated impacts from potential storm surge. Additionally, tanks are vulnerable to both high wind events and high heat.

The Maryland Department of the Environment (MDE) Oil Control Program regulates above ground storage tanks and ensures they are in compliance with State and federal regulations. It is essential to have standards in place for assessing tank integrity and ensuring tanks are stable against high winds and other hazard impacts. The City will work with MDE to support design specifications for securing fuel tanks to meet the necessary legal, safety, and resiliency standards.

3. Support the Maryland Public Service Commission's effort to accelerate replacement of aging natural gas infrastructure which will harden the system against flooding

In response to legislation signed into law by Governor Martin O'Malley, on August 2, 2013 BGE filed a plan with the PSC to accelerate the modernization of its natural gas distribution system to enhance safety and reliability. BGE's plan proposes to increase the rate of replacement of outdated system materials such as pipes with new modern equipment. Under the plan, 21 percent of BGE's existing natural gas system has been identified for replacement which accounts for nearly 73 percent of all gas leak repairs. The City will work with utilities, regulators, and gas pipeline operators to harden the natural gas system and control equipment against flooding.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BGE, DGS, DOP, DOT, DPW, Veolia
Alignment with Goals	Goals 2 and 4
Connection with Existing Efforts	ESF-3; ESF-10
Timeframe	

IN-5 Evaluate and improve resiliency of liquid fuels infrastructure

Hazard events can place considerable stress on liquid fuel supplies. In order to improve the resiliency of energy systems, and ensure that City systems receive adequate power supply, it will be important to address liquid fuel cell infrastructure and mitigate disruptions and loss of power caused by hazard events. The City will work with utilities, the PSC, stakeholders and the State to develop and build upon existing strategies that will harden refineries, pipelines and terminals essential to sustaining liquid fuel supplies.

1. Design and implement a generator program that assists private gas stations in securing backup generators, especially those stations along major evacuation routes

   Gas stations are vulnerable to power outages during extreme weather events, which prevent continued fuel distribution. It is critical for the City to work with the State to ensure that private fueling stations along critical evacuation routes have access to generators to aide in efficient evacuation and response during a disaster.

2. Increase and ensure fuel availability during distribution disruptions

   After major hazard events, restoration of the fuel supply is often slow due to fuel shortages and lack of surplus. Work with various agencies to introduce regulatory measures for use in the event of fuel shortage to allow supply-demand imbalances in the system to be mitigated.

3. Ensure fuel for generators and delivery priority is given to critical facilities and emergency responders

   During and after hazard events, fuel resources may have limited capacity, resulting in long lines and gas stations and other challenges. In order to respond quickly to hazard events, vehicles and personnel essential to emergency response must have access to fuel. In extreme hazard priority should be given to emergency responders that rely on this service to continue to address the impacts from hazards.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCFD, BCPD, DES, DOT, DPW, MOEM
Alignment with Goals	Goal 2
Connection with Existing Efforts	N/A
Timeframe	

COMMUNICATIONS

IN-6 Evaluate and improve resiliency of communication systems that are in place for sudden extreme weather events

Storm surge, heavy precipitation and high winds all pose a major threat to the power grid upon which communication systems rely on. Communication systems include phone, internet and television- all of which are used to provide information and connect people before, during and after a hazard event. These systems are made up of an intricate web of cables, towers and equipment- including distribution and switching centers- that all people rely on in some capacity. In Baltimore, major power outages may result in significant disruption to business and personal communications, especially in areas where copper and coaxial cables have not been upgraded to fiber cables which are more resilient to water damage.

Communication systems play an essential role in everyday life, but are even more critical during hazard events. These systems connect emergency responders to individuals in need of their assistance, allow citizens to check in with their families and friends, provide healthcare facilities access to essential information, and assist emergency response workers in providing aide. It is vital to protect the health and welfare of residents by building resilience and disaster prevention and planning, related to all natural hazards, into communication systems; additionally, this strategy furthers Baltimore's goal to establish itself as a Community Rating System (CRS) classified community to reduce flood insurance rates.

Presently, much of Baltimore City's communications equipment is located in basements and on rooftops making it susceptible to hazards. The City will investigate vulnerabilities in current telecommunication systems and develop measures to promote redundant and resilient communications infrastructure.

1. Utilize new technologies such as fiber optics, external hook-ups, and mobile generators to improve resiliency (M)

   Fiber optic cable is the newest and most resilient type of cable, being both fully water-resistant and able to carry all types of service. The transition from traditional wire-line phone service to phone service via fiber optic cable or Internet (VoIP) should be explored in more depth.

2. Build redundancy into all public and inter-agency warning and communication systems (S)

   An effective and fast warning system is critical for conveying the threat of hazards to Baltimore's residents. Warning and communication system failure should absolutely be avoided. Establishing a resiliency program to ensure that redundancy is built into the communication system should be pursued.

3. Identify best practices for the installation and management of flood proofing of all communications infrastructure at risk of water damage (S)

   Communications and electrical equipment located in basements are extremely vulnerable to the impacts of extreme precipitation and storm surge events. Much of the existing copper cable network is not designed to sit in stormwater or corrosive salt water for long periods of time. Developing flood protection standards for new buildings while strengthening programs that encourage renovations to existing buildings ensures the adequate protection of the telecommunications equipment housed within buildings. It is essential to raise generators and switchgear, replace old copper wires, and install backup generators for all buildings, but especially so in critical facilities that are essential to maintaining City operations.

4. Implement additional nurse triage phone lines and community health centers to reduce medical surge on hospitals (S)

   In the aftermath of a disaster, it is important that Baltimore's residents are able to communicate with loved ones, but more so that they may speak to their doctors for guidance on needed medical care. Enhancing nurse triage communication may include alternative solutions such as backup phone systems, Voice over Internet Protocol (VoIP) technologies that provide off-site phone lines, or pre-disaster planning to inform residents of available emergency contact numbers.

5. Evaluate and improve early warning systems for hazard events (S)

   Early warning systems allow people to prepare for potential risks and take additional caution in their daily routines. The City should evaluate the effectiveness of existing early warning systems and identify opportunities to improve them.

6. Ensure continued operation of city governments various computer mainframes for email, control systems, and internet service by having stand-by batteries for each with a capacity sufficient for backup generation to operate (S)

   During a hazard event, communication systems may be disrupted. Residents, however, rely upon these communication systems to receive timely and clear information about hazards and the risks associated with them. It is important to ensure continuity of government communication systems with redundant power supplies.

7. Identify shared communication technology for emergency responders and government agencies to ensure continued and coordinated communication during emergency events (S)

   Shared communication technology systems are outlets that enable multiple users to simultaneously share the communication channel. This may include email and other instant messaging technologies, groupware, forums, or other platforms. This technology facilitates local, cross-system coordination of on-going communication between critical entities during emergency events through a connected network of key partners, facilitating efficient response efforts.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCPD, BCFD, BGE, DHMH, DOP, DOT, Energy Office, FCC, JIS, MOIT, Private Entities, PSC
Alignment with Goals	Goals 1, 3, and 6
Connection with Existing Efforts	CAP; COOP; CRS; MD DNR; ESF-2; ESF-3; ESF-8; ESF-12
Timeframe	

COOP PLANS CALL-OUT

TRANSPORTATION

IN-7 Integrate climate change into transportation design, building and maintenance

Baltimore's transportation system is made up of 2000 miles of roadway, seven miles of interstate highway, and 298 bridges and culverts, in addition to light rail, subway, bus, train, and boat systems. Much of the interstate system, roadways and rail lines fall within the City's floodplain. Low-laying areas such as Fells Point have the potential to be easily inundated by heavy precipitation events and high tides. Impacts from hazards and climate change will affect the construction, maintenance, and operations of many of the City's transportation systems.

Baltimore's roadways and transportation networks are vulnerable to climate change threats and natural hazards in a number of ways, including surface flooding, wave action from storm surges, and asphalt damage due to heat waves. To mitigate the impact of these threats on streets and other infrastructure, Baltimore will integrate climate resiliency features into future design, construction, reconstruction, and maintenance projects.

This strategy addresses the potential impact of all natural hazards on transportation systems particularly to bridges, but also to other transportation and infrastructure projects — through both adaptation and mitigation actions.

1. Determine the coastal storm vulnerability and complete an exposure assessment of City transportation assets (S)

   Bridges are key connection points and generally more vulnerable than other elements of the transportation system. Flooding and earthquakes pose serious risks to the structural stability of bridges, which are vital links for conveying emergency response vehicles and for facilitating the movement of citizens as they seek safety.

2. Improve stormwater management, operations and maintenance for stream flooding that erodes away bridge supports (O)

   Bridge supports are weakened by the erosion of the underlying streambed. Strengthening these supports will prevent further damage to bridges, and increase bridge resiliency during flood and storm events.

3. Incorporate compliance with earthquake standards to withstand a magnitude eight earthquake for all new, improved and rebuilt bridges (M)

   Manage the cost of structural improvements to bridges by coordinating with scheduled construction so as to proactively prepare for a potential increase in the intensity of seismic events.

4. Design bridges expansion joints for longer periods of high heat and develop a more robust inspection and maintenance process (S)

   Expansion points can warp and weaken during high heat events, rendering bridges inoperable and disrupting daily mobility. Increasing the capacity to withstand heat with prevent future bridge closures.

5. Research utilizing existing and new rating systems for all new infrastructure and road projects (M)

   A number of third-party rating systems already exist that provide frameworks for evaluating current conditions of the City's infrastructure. For example, to further supplement the Envista Program already in use, the Envision™ Rating system would allow the City to rate the benefits of potential projects. Similarly, the Greenroads Rating System could certify sustainable transportation infrastructure projects. These and other resources can guide the City's evaluation, maintenance, and upgrades of existing infrastructure to determine vulnerabilities as well as opportunities for improvement.

6. Identify, investigate, and incorporate Best Management Practices as they relate to transportation design, construction and maintenance (M)

   Explore alternative design practices to better prepare the transportation to withstand hazard events.

7. Require that backup solar powered street lights and signals be integrated along evacuation routes and high traffic areas (M)

   Hazard events may disrupt power supply to street light and signal systems. Along evacuation routes, these systems must remain operational. It is crucial to require the integration of backup solar power systems to ensure continuous power supply.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOT
Stakeholders	CSX, DOT, DPW, MTA, Private Contractors
Alignment with Goals	Goal 2
Connection with Existing Efforts	CAP; ESF-1; ESF-3
Timeframe	

IN-8 Identify additional alternative routes and modes for effective transport and evacuation efforts during emergency situations

Much of Baltimore's ability to respond effectively to a disaster is vulnerable to disruption and damage of critical transportation facilities. Road closures may impair the delivery of emergency services or supplies of food, fuel, and medicine. Similarly, inoperable transportation networks prevent efficient evacuation and may require more time to restore, thus limiting non-transportation infrastructure and economic activity.

Protect the health, safety, and welfare of Baltimore City Residents through improved emergency capacity of transportation systems by building resiliency, particularly to flooding hazards. This would identify existing evacuation routes and their vulnerability, establish a program to maintain specific emergency routes, and educate the public about the dangers of driving through flooded roadways.

1. Evaluate existing systems and develop a comprehensive evacuation plan (S)

   The safe evacuation of Baltimore's residents depends on a comprehensive and well-maintained network of routes. Improper care for these key routes can restrict their capacity to handle significant traffic, and a thorough plan for maintenance should be established.

2. Coordinate evacuation plans with regional partners (S-M)

   Ensuring that evacuation plans are coordinated with the surrounding jurisdictions will make certain that evacuation routes are continuous and safe.

3. Develop and prioritize clearance of specified transportation routes for delivery of emergency response supplies (S)

   The proper and continued maintenance of key routes will ensure that emergency response supplies will not encounter any problems.

4. Educate the public on the dangers of driving through flooded roads (S)

   Even in moderately low precipitation events, roadways may become flooded. To drivers, it's not always clear what the underlying surface conditions may be. Educating the public about the dangers of driving into sections of flooded roads will reduce instances of drivers and cars getting stuck in dangerous conditions.

Buildings along Baltimore's Inner Harbor (Source: Flickr User TheBrit2)

5. Make available a network of dedicated pedestrian and bicycle transportation routes leading into and throughout the City (O)

   As well as contributing to healthier, greener and more livable neighborhoods, walking and/or cycling provide redundancy in the transportation system in the event of an emergency or storm event, when public transit may be temporarily disrupted or vehicular access may be more difficult (for example due to debris caused by a storm in the road blocking vehicular access). A systematic evaluation of "best and safest routes" should be performed to ensure a network is available and maintained for existing conditions as well as extreme event conditions. Incorporate current and best practices for pedestrian and cycling in existing and future transportation systems (i.e. dedicated bike lanes, signage and striping, cycling-to-public transport connections, etc.).

6. Identify and collaborate with bicycle groups and repair shops to assist in emergency response and accommodate alternate transportation needs (S)

   During hazard events, roadways and other transportation networks may be impaired or unusable, leaving residents stranded or confined to a limited area. Bicycles offer an alternative mode for mobility during such an event, facilitating access for emergency responders and providing a means for residents to evacuate or meet other needs.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCFD, BCHD, DOP, DOT, MOEM
Alignment with Goals	Goal 1
Connection with Existing Efforts	CAP; ESF-1; ESF-11
Timeframe	

IN-9 Alter transportation systems in flood-prone areas in order to effectively manage stormwater

Flooding can cause considerable damage to transportation systems. To prevent this damage and build resiliency of transportation systems, particularly highways, roads, and tunnels, to flooding hazards, the City will consider both adaptation and mitigation actions that may be taken. This will prevent vulnerability to flooding, including the consideration of stormwater management programs for their potential to reduce the significance of flooding.

1. Prioritize infrastructure upgrades for roads identified at risk of flooding through the use of elevation data and Sea, Lake and Overland Surges from Hurricanes (SLOSH) model results (L)

   Sea, Lake and Overland Surges from Hurricanes (SLOSH) modeling can help identify where the City can make improvements to reduce risks associated with flooding and storm surges. Additionally, improvements can be coordinated with scheduled replacement of road infrastructure, particularly in areas that frequently suffer damage due to flooding.

2. Raise streets in identified flood prone areas as they are redeveloped (L)

   Streets in flood-prone areas are likely to require constant maintenance and upgrades. It is essential to explore raising roads to reduce impact of flooding.

3. Encourage development of Green Streets in flood prone areas and throughout the City (S-O)

   Reducing impervious surfaces and capturing rainwater, Green Streets have the capacity to absorb heavy precipitation, rather the rush it into the stormwater drain system.

4. Encourage use of permeable pavement in non-critical areas – low-use roadways, sidewalks, parking lots and alleys where soils permit proper drainage (M)

   Impervious surfaces absorb and radiate heat, as well as prevent rainwater from entering the groundwater supply. Permeable pavement, on the other hand, reduces flooding and can contribute to a reduced urban heat island effect.

5. Add pumps or other mitigation alternatives to streets as they are redeveloped (if needed) (L)

   Streets in flood-prone areas can become inundated in heavy rain events. Pumps and alternative measures can ensure that water can be quickly removed from the roadway, allowing for maintained accessibility.

6. Assess need for new culvert capacity and identify where upgrades are needed (L)

   Baltimore's stormwater system is dated and, in some places, in poor condition. Many of the features, such as culverts, were not designed to handle the current levels of precipitation, let alone projected increases in precipitation. Addressing where key vulnerabilities exist and identifying the potential for upgrades will increase the system's ability to handle future hazard events and reduce flooding.

7. Conduct an in-depth analysis of the impacts of drain fields that feed the harbor (M-L)

   Water quality in the Inner Harbor can be enhanced by reducing flooding upstream. To do this, an in-depth analysis of the drain fields that feed into the Harbor should be conducted.

8. Expand and reinforce existing stormwater education programs (L)

   Educate property owners about various ways to capture rainwater, as well as about the importance of doing so and the benefits of the stormwater utility and DPW Clean Water Baltimore program.

9. Design and implement floodgates and barriers in transportation tunnels (L)

   Tunnels are vulnerable to flooding from storm surge and heavy downpours. Floodgates, which prevent water from flowing backwards and into tunnels, can be a cost-effective strategy for reducing water infiltration and damage to these vital connections in the transportation network.

10. Encourage Federal and State Government to design and install floodgates and barriers at vulnerable transportation tunnels (L)

    Floodgates allow stormwater to flow out of waterways while preventing backflow at the same time. They provide protection against flooding. The City should work with the Federal Government to prepare for installation.

11. Upgrade existing floodgate hardware and mechanisms to control rise rate of water into all city tunnels (L)

    Existing and new floodgate systems should be able to withstand intense water rise rates, and upgrades should be considered where necessary.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOT
Stakeholders	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs
Alignment with Goals	Goals and 3
Connection with Existing Efforts	CAP; ESF-1; ESF-3; ESF-11; MD DNR
Timeframe	

IN-10 Ensure structural stability of all transportation tunnels to reduce impact from seismic activity

Tunnels are vulnerable to the impacts of seismic activity, which could damage structural integrity. Damage or failure at one of the City's tunnels would significantly disrupt the regional transportation network. The City will investigate a number of structural resiliency strategies for reducing the vulnerability of tunnels to seismic hazard events. Use both mitigation and adaptation actions to reinforce structural resiliency.

1. Repair cracks and leaks in all tunnels to reduce impact of seismic activity (M)

   Cracks and leaks create significant vulnerabilities through the weakening of tunnel facilities. Addressing these weaknesses will increase the ability of tunnels to withstand future seismic activity, and prevents further damage.

2. Follow Federal, State and Local criteria for the stabilization of Historic transportation tunnels (e.g. Howard Street) (L)

   Howard Street, an older, historic tunnel in Baltimore, is considered to be more vulnerable to hazards than other transportation tunnels. It is important to explore and pursue a combination of Federal, State, and Local funds for stabilizing this asset.

3. Install a seismically resistant fire standpipe, air monitoring, and automatic valve system in all tunnels to provide a fully automated and monitored fire suppression system (L)

   Decrease damage from fire events in underground tunnels that might occur as a result of seismic activity.

IMPLEMENTATION GUIDELINES	
Lead Agency	CSX, Amtrak, MTA
Stakeholders	Amtrak, CSX, DOT, DPW, FHWA, MDTA, MOEM, MTA
Alignment with Goals	Goal 2
Connection with Existing Efforts	CAP; ESF-1; ESF-4; ESF-10
Timeframe	

IN-11 Evaluate changes to road maintenance and construction materials based on anticipated changes in climate

Recognizing future conditions, current transportation systems may require renovation or modification. In order to prevent damage to highways and roads from extreme heat events or other hazardous conditions, road construction projects should use both adaptation and mitigation actions to address potential damage to roadway surfaces.

1. Implement a repaving strategy that reduces heat-related damage to asphalt and incorporates maintenance and operations that extend the life of the road surface

   Flooding and extreme heat, as well as seismic activity and the impact of other natural hazards, can cause significant damage to Baltimore's roadways. It is essential to prepare a reconstruction strategy to repair damaged surfaces, and include resiliency measures to reduce future damage. This will extend the life of the road surface.

2. Develop a reconstruction and repair strategy that reduces damage to concrete and incorporates better maintenance and operations

   To ensure that no vulnerability is left unaddressed, it will be important to establish a procedure for identifying and coordinating reconstruction and repair of transportation systems.

3. Develop deicing strategies and materials that are effective in extreme cold temperatures and prolonged events to stabilize roadway and bridge surfaces

   During severe winter storms, roadways and bridge surfaces may become covered in a layer of ice. To address these dangerous conditions, it is important to identify a strategy for removing this ice and ensuring safe driving conditions.

4. Design pavement sections and materials that withstand longer periods of extreme heat events

   Extreme heat can warp or cause other damage to pavement and roadway surfaces. To reduce damage during high heat events, it will be important incorporate resilient design and materials into transportation projects.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOT
Stakeholders	DOT, SHA
Alignment with Goals	Goal 2
Connection with Existing Efforts	CAP; ESF-1
Timeframe	

WATERFRONT

IN-12 Enhance the resiliency of the City's waterfront to better adapt to impacts from hazard events and climate change

Baltimore's waterfront properties are vulnerable to the impacts of coastal storms and other natural hazards. The majority of Baltimore's waterfront consists of bulkheads which are structures typically made of stone or concrete that hold shorelines in place. Adaptation and mitigation actions will increase resiliency and reduce damage .

1. Raise bulkhead height along shoreline areas most at risk (L)

   Increasing coastal edge elevations — through bulkheads, revetments, tide gates, or other shoreline structures — will harden exposed shorelines and prevent the risk of regular flooding. Raising bulkheads at select sites citywide can mitigate the effects of relative sea level rise . Throughout this process, it will be important to consider the aesthetic and functional impacts of any bulkhead changes on surrounding communities.

2. Utilize vegetation and stone to stabilize and armor unprotected shorelines (S)

   Natural features can protect adjacent communities from the impacts of coastal hazards. It is important to study the cost-effectiveness of new waterfront design guidelines that will encourage open spaces and natural areas, and to determine where and how to best utilize natural features to direct and store excess floodwaters .

3. Encourage the development of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures (L)

   Multiple areas of Baltimore are at risk of flooding during extreme weather events. Some of these areas are home to critical facilities and dense population. It is important to encourage the installation of integrated flood protection systems in targeted areas. Protection should be designed to have minimal impact on surrounding community fabric during non-storm conditions.

4. Review and enhance coastal area design guidelines to better mitigate the impacts of flooding (L)

   Coastal hazards expose facilities near waterfront areas. New guidelines should be incorporated so as to best protect the people and property adjacent to waterways and mitigate the effects of flooding.

5. Enhance and strengthen waterfront zoning and permitting (L)

   Existing zoning and permitting requirements should be reviewed, and where appropriate, be amended and strengthened to improve the design and resiliency of new and existing buildings. Resiliency measures should be incorporated into this framework to better protect properties from flood-risks.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOT
Stakeholders	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, MOEM
Alignment with Goals	Goal 4
Connection with Existing Efforts	N/A
Timeframe	

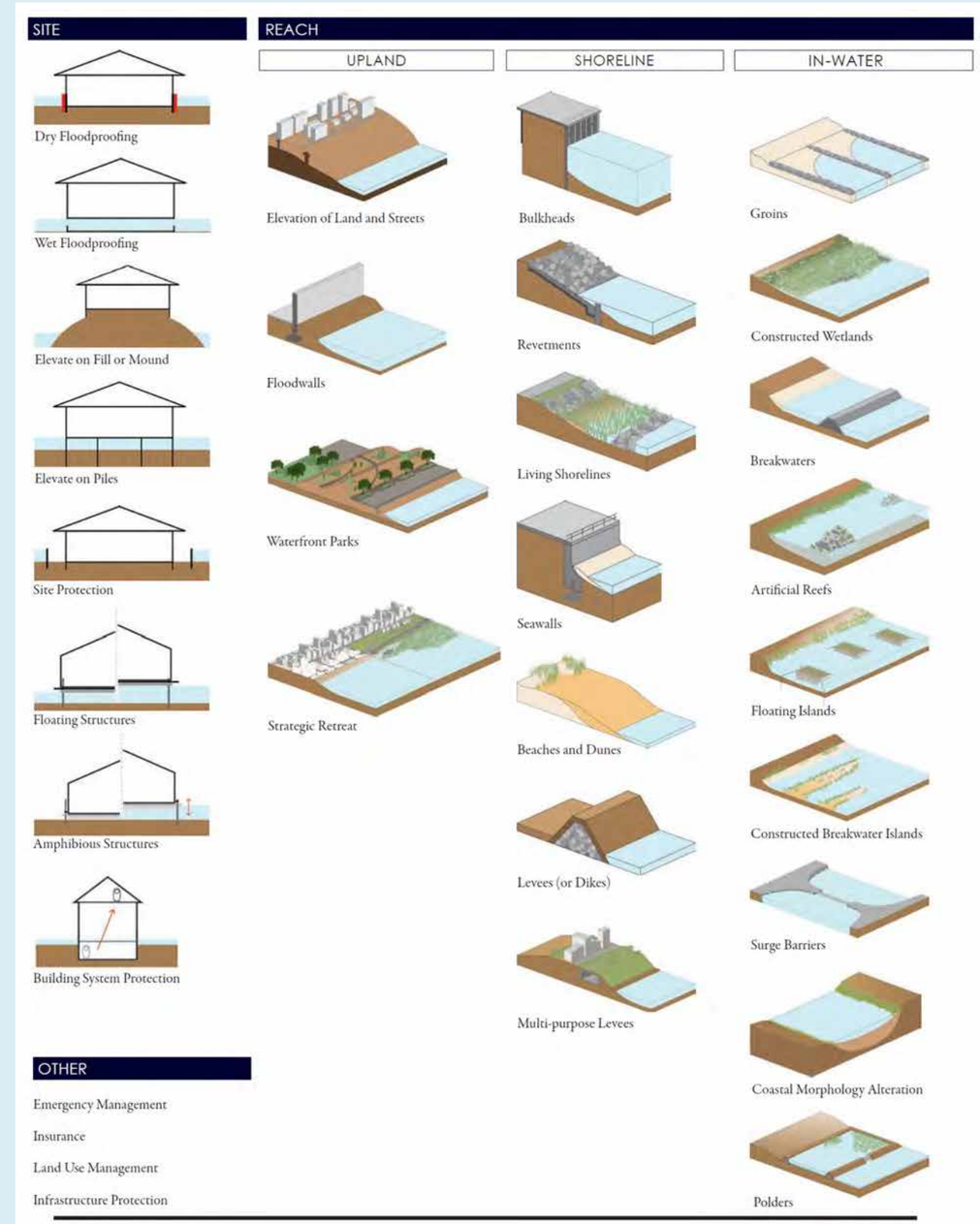


Figure 5–1 "Inventory of Adaptive Strategies," showing a variety of coastline adaptation technologies

The image above was produced by the New York City Department of City Planning in the Coastal Climate Resilience report, *Urban Waterfront Adaptive Strategies*. (The City of New York, 2013: 6).

WASTEWATER

IN-13 Increase the resilience of all wastewater systems and protect them from current and projected extreme weather events

A number of wastewater treatment assets are at risk of flooding or other damage from extreme weather events. To minimize disruptions to these systems, efforts must be implemented to protect vulnerable wastewater systems and facilities from current and projected extreme weather events.

Water and wastewater utilities will pursue implementation of resiliency projects at these facilities in conjunction with scheduled repairs and planned capital improvement projects, and as is deemed appropriate based on level of risk, historical flooding, and potential community impacts, among other criteria.

1. Ensure all water and wastewater pumping stations have off-grid, on-site energy sources and/or reliable backup power sources by increasing the number of backups and pulling electricity from different grids (L)

   Pumping stations are necessary for conveying stormwater and wastewater away from Baltimore's communities. They are, however, often vulnerable to storm surges and heavy downpours. These stations should be retrofitted with consideration of increased resiliency measures, and redundant energy systems should be installed to ensure continued operation.

2. Evaluate the sewer system to identify and develop key areas for prevention of raw sewage overflows (L)

   In heavy storm events, excessive precipitation may inundate wastewater treatment facilities. For over a decade, the City has been under a federal and State enforcement action to improve its aging wastewater infrastructure. In light of future increased intensity of storm events, this work is especially important. There are several things the City must do to prevent sanitary sewer overflows.

   This includes:

   - Cleaning and maintaining sewer pipes
   - Reducing the opportunity for stormwater infiltration and inflow into the sanitary sewer
   - Educating citizens and enforcing City Code provisions related to keeping fats, oils, and grease (which clump and clog pipes) out of the sanitary sewer
   - Maintaining a root control program to keep tree roots from damaging sewer pipes
   - Increasing and upgrading the capacity of the sanitary sewer system.

   Preventing sewage overflows is more feasible and better for the ecosystem than disinfecting them after the fact. That said, appropriate clean-up measures must be taken when overflows do occur. The City will work with utilities to identify key vulnerabilities and implement a system to ensure the disinfection of raw sewage prior to any potential overflow event that cannot be avoided.

3. Develop and adopt increased level of protection for construction, redevelopment, and design of all water and wastewater facilities that incorporate future climate projections (L)

   Adopt an increased level of protection for design and construction of all wastewater facilities based on the latest FEMA maps and modified to reflect future relative sea level rise projections.

4. Retrofit and harden low-laying pumping stations and treatment plants in flood hazard areas (L)

   Baltimore's pumping stations are necessary to convey wastewater and stormwater out of communities. However, their location, often in low-lying areas, increases their vulnerability to storm surge and flooding. These pumping stations should be retrofitted for resiliency with measures including raised or flood-proofed critical equipment, constructing barriers, or implementing redundancy measures to avoid failure of these critical treatment systems.

5. Ensure effective operations and security for wastewater treatment plants if facilities are overwhelmed by hazard event (L)

   It is essential to ensure proper treatment of waste and reduce contamination from raw sewage overflow. This will minimize the potential health and disease impacts caused by raw sewage if full treatment is not possible.

6. Establish the capability of wastewater treatment plants to function during large storm events and establish protocols for storms that overwhelm the system (L)

   Current protocols allow Back River and Patapsco Wastewater Treatment Plants to function effectively even when experiencing very high flow volumes. The limits of the current protocols should be determined and, if necessary, establish protocols for larger storms in the future.

7. Increase stormwater recharge areas and quantity management to prevent flooding from overflows (L)

   The City of Baltimore does not have a Combined Sewer System (CSO), however water can enter the system through illegal connections, flooding along sewer corridors and other channels. Enhancing stormwater infrastructure should be encouraged to reduce the amount of water entering wastewater treatment facilities. This can be attained in two ways: 1) By capturing and holding stormwater on-site, through vegetation, cisterns and rain barrels, prevents water from overwhelming drainage systems; 2) Through designing pipes and the entire system to withstand greater volumes from larger storm events. Sewerage system improvements should include resiliency planning in the design phase.

8. Conduct an assessment of the City's current water system to identify age, condition of infrastructure, capacity, weaknesses and areas for priority upgrades (L)

   Upgrading water treatment systems should take into account the potential for future impacts. Identifying vulnerabilities and increasing the protection of critical equipment will prevent future damage to these supply systems. Damage to the water systems as a result of hazard events could contaminate drinking water supplies. At the same time, waste water systems must be able to handle increased volumes and treat water supplies prior to release.

9. Conduct and utilize a detailed risk assessment to determine vulnerability of the sewage treatment plant to prevent overflows from extreme storm events

   It is important to evaluate the sewage treatment plant weaknesses and determine where improvements are most needed to increase the capacity and prevent overflows from extreme storm events.

10. Determine the elevation of sewage treatment buildings, tank construction details, and if the plant is at risk of back flow, for improvements to withstand coastal storm events

    Certain building characteristics can alter the vulnerability of a sewage treatment plant. By determining the conditions at the City's various facilities, information regarding the need for key upgrades may be revealed.

11. Retrofit wastewater treatment facility and methane gas storage system to withstand seismic activity to protect against earthquakes. Design facility to exceed current building codes

    Increasing standards beyond the previous maximum impact will proactively plan for worst case scenarios and prevent future impacts, as well as the future need for additional improvements.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	DOP, DPW, Energy Office, MOEM
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; COOP; ESF-3; ESF-12
Timeframe	

IN-14 Integrate resiliency, redundancy, and structural stability into the City's drinking water system to ensure safe and reliable water storage and distribution

Protect the health of residents through enhanced resiliency, redundancy, and structural stability of the City's drinking and water supply systems, including dam facilities and infrastructure systems, from all natural hazards. Use both mitigation and adaptation actions.

1. Repair leaks and improve connection from all City reservoirs and the Susquehanna River (S-L)

   The City recognizes that every single drop of clean water is precious. This is particularly true when water supplies are low. It is essential to implement appropriate repairs to City drinking water system infrastructure. These repairs will enhance the reliability of the Baltimore's water supply and maintain flexibility during normal operations, as well as during periods of a depleted supply, or when water quality is affected by heavy rain or heat waves.

2. Provide water conservation education, and continue to protect our watersheds to assist in maintaining water quality (S)

   To avoid the impact of future dry periods or droughts, efforts to educate citizens and property owners about water conservation techniques and to encourage the use of grey water systems as water conservation and landscape maintenance can prevent excessive water use and will conserve drinking supplies. Additionally, efforts must be made to protect our watersheds by supporting and implementing the Reservoir Watershed Management Agreement. The City should work with the surrounding Counties to identify improvements that will maintain water quality, as well as key efforts to prevent future impacts to the water quality during hazard events.

3. Ensure dam emergency plans account for impacts of climate change (M)

   Damage or failure at a City dam facility can cause significant damage. While emergency plans consider methods for preventing failure or reducing impact of damage, they should consider projected changes in climate.

4. Identify and document post damage responsibilities in memorandums of understanding as addendums to the Reservoir Watershed Management Agreement (S)

   The City should ensure that dams will not fail in the future due to more frequent and intense precipitation events by identifying and documenting post-damage responsibilities into planning documents and Reservoir Watershed Management Agreements.

5. Review dam capacity, load and failure points and review them against 1,000 year and 10,000 year precipitation events (M)

   It is necessary to evaluate dam conditions and determine each facility's potential to withstand excessive precipitation caused by 1,000- and 10,000-year events.

6. Conduct a study to determine seismic design standards and seismic resiliency of drinking water distribution system (tunnels, piping, clean water pump stations, dams, shafts, and tanks) (M)

   Underground drinking water distribution systems are vulnerable to seismic activity. Failure of, or damage to, certain facilities or systems may have significant impact on drinking water sources, including contamination. It will be critical to identify vulnerabilities from utilities or other facilities by working with the utility to explore methods for risk reduction and increasing the resiliency of the distribution system.

7. Increase stormwater recharge areas and quantity management in watersheds feeding the reservoirs (S)

   Many drinking water supplies rely on groundwater systems, which must remain healthy and continue to offer high quantities of water. Diverting rainwater away from infrastructure and back into the ground recharges the reservoir systems efficiently prevents pollution from entering the water supply. Ensuring that rainwater remains on-site, where it falls, will increase groundwater recharge.

8. Evaluate the impacts of sediment loading on reservoir capacity (S)

   During rain events, sediment is carried downstream and often settles at the bed of water reservoirs. Without removal, sediment builds up and reduces the capacity for reservoirs to store water, limiting drinking water supplies. These impacts need to be more clearly understood so that the utility may identify methods for addressing sediment build-up and increasing the ability of reservoirs to store drinking water.

9. Manage watershed forests to provide maximum benefits for water quality and to maintain resiliency during extreme weather events (S)

   The quality of drinking water systems should be maintained every day. Trees have the capacity to absorb and filter rainwater. Additionally, when properly maintained, trees can reduce wind intensity. Caring for watershed forests will enhance the benefits provided by trees, and better protect drinking water quality. It will be important to prioritize and encourage an increase of forest cover within reservoir watersheds and targeted areas, and encourage forest management practices to strengthen the health and capacity of forest systems to protect drinking water quality.

10. Adopt new policies on salt application to prevent high salinization on drinking water supplies (M)

    While salting roadways allows for use during heavy winter storm events, the process has a negative impact on the environment and our water ways. As such, it degrades the quality of drinking water supplies upon which we rely.

11. Establish a structured Firming Program to maintain adequate storage and water quality in the source-water reservoirs during drought conditions

    The City should investigate the potential of a water "firming program" that will reduce water depletions by protecting and increasing supplies. Water supply "firming" secures supplemental sources or reserves in order to increase the reliability of current the capacity during periods of limited or reduced supplies. To conserve water during droughts and water shortage periods, it is important for the City to establish its authoritative power to implement water conservation measures as needed during emergency events. Additionally, it will be important for the City to consider alternative methods for conserving water resources and distributing supplies during emergency events.

12. Maintain appropriate agreements with Susquehanna River Basin Commission (SRBC) and the Exelon Power Company to ensure adequate water withdraws from the Susquehanna River during drought emergency

    During a hazard event, the Susquehanna may be an insufficient supply of drinking water. It will be important to explore and identify alternatives for emergency water supply sources and to consider and evaluate the potential for citywide requirements regarding water conservation, including enforcement measures and procedures, to ensure that adequate water is available during low-supply periods and that adequate supplies are available for emergency use.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility
Alignment with Goals	Goals 1, 2, and 6
Connection with Existing Efforts	CAP; CRS; ESF-3; ESF-5; ESF-8; ESF-10
Timeframe	

IN-15 Conduct an assessment that evaluates and improves all pipes' ability to withstand extreme heat and cold

Much of Baltimore's water system is dated and in need of upgrades. It is important to build extreme weather resilience and disaster prevention into water and wastewater systems by using both adaptation and mitigation actions. Additionally, structural and infrastructural upgrades must be made to reduce loss of water supply from the distribution system.

1. Replace old and malfunctioning pipes with new pipes or retrofit existing pipes with new lining

   Pipes that have already begun experiencing problems, or older pipes which are more vulnerable to the impacts of hazards, should be upgraded using the best available technology.

2. Evaluate and utilize new technology that allows for greater flexibility in pipes as they are replaced

   It is essential to prepare for future changes in hazard events and proactively upgrade pipe systems to prevent cracking and bursting.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	DOT, DPW, Water and Wastewater Utilities
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; CRS; MD DNR; ESF-3; ESF-4
Timeframe	

STORMWATER

IN-16 Enhance and expand stormwater infrastructure and systems

Future changes in precipitation frequency and intensity may require reconsideration of the design of existing stormwater infrastructure systems.

Increase resiliency and disaster prevention measures related to stormwater systems by enhancing drainage systems in stream corridors and improving and repairing stormwater conveyance popes and outfalls.

1. Implement the requirements of Baltimore's MS4 (separate stormwater and sewer system) permit (S)

   The City of Baltimore operates under a Municipal Separate Stormwater and Sewer System (MS4) permit, which protects water-quality and requires that Baltimore prevents pollution as much as possible. It is critical that the requirements of these permits are fully met.

2. Prioritize storm drain upgrades and replacement in areas with reoccurring flooding (S)

   While proximity to a floodplain or floodway can increase vulnerability to flooding, certain measures can reduce this vulnerability. Inadequate or older pipes, which cannot accommodate the excessive amounts of stormwater, should be upgraded so as to handle extreme rainfall and storm surge events.

3. Install backflow-prevention devices or other appropriate technology along waterfront to reduce flood risk (M-L)

   Backflow-prevention devices are used to ensure that water does not flow back through drainage infrastructure. Through the installation of backflow-prevention devices, the City can improve the performance of the drainage network and prevent risk of flooding impact along the waterfront.

4. Preserve and protect natural drainage corridors (S)

   It is important to utilize natural drainage corridors and green infrastructure to capture more stormwater runoff and enhance the ability of the existing infrastructure to cope with environmental changes.

5. Review and revise storm drain design on a continuous basis, to accommodate projected changes in intense rainfall (O)

   The City's storm drains will require continual revision to incorporate new and projected changes in intense rainfall. This will ensure that the storm drains maintain adequate capacity.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	Community Groups, DOT, DPW, MOEM, MDNR, NGOs, Private Developers, Stormwater Utility
Alignment with Goals	Goals 1, 3, and 6
Connection with Existing Efforts	CRS; MD DNR
Timeframe	

IN-17 Modify urban landscaping requirements and increase permeable surfaces to reduce stormwater runoff

Landscaping increases resilience and disaster prevention of stormwater systems related to flooding. Allow for more opportunities for rainwater to be absorbed by the ground and increase vegetative surfaces while reducing impervious surfaces.

1. Support existing stormwater requirements and continue to evaluate and improve Best Management Practices (M)

   Conventional stormwater management can at times be an inefficient process and cannot, or should not, be relied upon to handle intense rainfall. The City has incorporated Environmental Site Design strategies into stormwater management regulations as an element of MS4 permits in order to increase the ability to accommodate heavy rainfalls; recognizing that the Maryland Department of the Environment (MDE) establishes minimum stormwater management requirements; the Department of Public Works will coordinate its efforts with MDE.

2. Encourage urban landscaping requirements and permeable surfaces into community managed open spaces (S)

   As more communities are encouraged to adopt vacant land, utilize the Growing Green Initiative and the Green Pattern Book to educate residents, non-profits, and faith-based organizations on practices that reduce impermeable surfaces and use landscaping and trees to capture on-site rainwater. It will be important to recognize site history and soil health.

3. Utilize water conservation elements such as green roofs, rain gardens, cisterns, and bioswales on residential, commercial, industrial, and City-owned properties to capture stormwater (S-M)

   Water conservation measures lessen rainwater's load on infrastructure, and rainwater capture strategies will collect rainwater reserves for using during low-precipitation periods. The City's natural systems and features are important to capture and treat rainwater where it falls. Green roofs, rain gardens, and bioswales (small ditches that retain water during heavy rainfalls) are supplemental techniques for increasing natural elements for the purpose of capturing and treating rainwater, allowing for groundwater recharge.

4. Encourage permeable paving on low-use pathways (M)

   It is important to maximize permeable surfaces through the use of permeable paving, landscaping techniques and under drain systems. Permeable pavement should be considered in the areas of the City without class D soils. In those areas, a reduction in impervious surfaces will increase the capacity of Baltimore's land to absorb rainwater, while reducing the demand on the stormwater system.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BDC, BCRP, BDW, Citizens, DHCD, DOP, DOT, DPW, NGOs, Private Developers
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; ESF-3; MD DNR
Timeframe	

IN-18 Evaluate and support DPW's stream maintenance program

Increase resiliency and disaster prevention measures to protect stormwater systems from flooding and sea level rise hazards. Utilize both adaptation and mitigation measures to improve natural stream systems.

1. Review and improve status of standing maintenance requirements (O)

   A poorly maintained stream can become a liability, whereas a properly maintained stream system can effectively reduce the likelihood and impacts of flooding. It is crucial to review existing stream maintenance requirements to identify where adjustments can be made.

2. Ensure adequate funding is in place to support stream maintenance (O)

   Streams help to manage stormwater runoff, but these systems are sometimes degraded. It is important to explore various City, State, and Federal agencies to identify funding resources to ensure that stream systems are properly maintained.

3. Identify opportunities where stream restoration efforts will off-set maintenance costs (O)

   Key stream features, when maintained or improved, can have significant cost-savings benefits. Identifying where stream restoration will off-set other maintenance costs.

4. Identify interdependencies and benefits of stream maintenance with other transportation programs (O)

   The City should demonstrate that transportation projects have the potential prevent damage as well as even to improve the health of stream systems. Potential benefits of interdependencies with stream maintenance programs should be investigated and identified, in addition to specific challenges.

5. Clear streams on a regular basis, prioritize dredging the stream beds, and increase inspection and cleaning of culverts and storm drains to prevent flooding (O)

   Key areas should be regularly maintained to increase the capacity of the stream system to handle heavy downpours and reduce any potential damage.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	DOT, DOP, MDE, MDNR, MOEM, USACE
Alignment with Goals	Goals 2, 3, and 6
Connection with Existing Efforts	CRS; ESF-3
Timeframe	

IN-19 Support and increase coordination and information sharing across jurisdictions to better enable mitigation of cross-border impacts on the regions watersheds (e.g., understanding flood conditions upstream in the County)

Enhance adaptive capacity of the City by coordinating stormwater management efforts with surrounding jurisdictions to reduce flooding and improve water quality. Utilize both adaptation and mitigation actions.

1. Partner with local counties to evaluate major tributaries in all watersheds to determine best management practices for capturing run-off and slowly releasing it (stormwater quantity management) (O)

   Cross-jurisdictional efforts to address rainfall across the region recognize the extensive range of watershed systems and can effectively manage and prepare hydrological systems for future hazard events. This is a major action in the City's Sustainability Plan and the City-County Watershed Agreement.

2. Encourage information sharing within the Chesapeake Bay community to assist in developing best management practices

   As part of the Chesapeake Bay Watershed, Baltimore hydrological system is a critical national asset. By communicating with agencies and jurisdictions of the greater Chesapeake Bay community, the City can determine best management practices and identify priority improvements.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	BCRP, County Governments, DOP, DPW, MCC, MDNR, NGOs, Stormwater Utility
Alignment with Goals	Goal 4
Connection with Existing Efforts	MD DNR
Timeframe	

SOLID WASTE

IN-20 Reevaluate and support a comprehensive debris management plan for hazard events

Build resilience and disaster prevention into solid waste and stormwater systems through adaptation and mitigation actions.

1. Investigate best practices for managing and disposing of downed trees, yard waste, building debris, as well as additional household garbage (S)

   Loose debris can become dangerous during hazard events, clogging storm drains or causing private property damage. After a hazard event, this debris can overwhelm City services and require extensive cleanup efforts. It is crucial to investigate alternative strategies for managing and disposing of post-hazard debris and waste.

2. Expand and integrate existing programs to reduce or intercept debris before it gets into the streams and harbor (M)

   Trash and debris on streets will slowly move into stormdrains which convey this waste into the harbor, at which point it has infiltrated a major waterway of the Chesapeake Bay Watershed. Once in the harbor, trash and debris are difficult to recover, and can have negative impacts on businesses and industries adjacent to the Harbor. By collecting this trash and debris before it enters storm drains, the City can avoid the costly process of cleaning the Harbor.

3. Develop and promote solid waste management actions for citizens to implement before a hazard event (S)

   Proactive management will prevent the impacts during a hazard event and reduce the need to recover afterward. To address potential exposure of the solid waste network, Baltimore should harden its waste collection and disposal facilities to ensure continued waste collection and disposal throughout future events, as well as minimize any impacts that might result from flooding of facilities that store solid waste.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	Planning, MOEM, R&P, MOEM, BGE, NGOs
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; ESF-3
Timeframe	

POLICY AND GOVERNMENT DECISION-MAKING

IN-21 Encourage the integration of climate change and natural hazards into private and State planning documents, systems, operations, and maintenance

Increase overall resiliency and disaster prevention efforts in private and statewide planning documents, systems, operations, and maintenance. Consider transportation systems, emergency response actions, and air quality measures.

1. Incorporate consideration of hazards and climate adaptation efforts into all plans, systems, operations, and maintenance (M)

   It is important to continually review climate change and hazard information to be incorporated into all City plans, operations, and maintenance frameworks to ensure citywide preparedness.

2. Ensure Red Line planning incorporates adaptation strategies (S)

   As a major project, the Red Line must consider the long-term impacts of future hazards and incorporate adaptation strategies into project development. Current Red Line design is building to a Flood Protection Elevation of 11-feet (NAVD88). The 100-yr (tidal) flood is approximately 5-feet (NAVD88) and Isabel was a 500-year event at 7-feet (NAVD88). The proposed design elevation at 11-feet is 6 feet above Base Flood Elevation (BFE).

3. Ensure hazard scenarios, utilized in vulnerability assessments, are at a minimum 25% greater in intensity and impact than historical record events to date (O)

   Recognizing the increasing frequency and intensity of hazard events, it is important to plan for events that will be more dangerous than previous experiences.

4. Develop guidelines for hospital, health care facilities and other institutional entities (e.g. Universities) (O)

   Hospitals can become more efficient in their ability to respond to hazard events by developing and adopting clear guidelines for actions during emergencies.

5. Partner with regional air quality institutions to integrate air quality measures and messaging into City climate change policy efforts (O)

   The City should work with major institutions to minimize and mitigate the risk of air quality problems, by addressing major air quality concerns into climate change policy initiatives. Additionally, a framework for communicating about air quality concerns should be developed.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	MOEM, DOT, Health Care Community, Hospitals, MD2HE, MEMA, MTA, MOEM, SHA
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; ESF-1; MD DNR
Timeframe	

IN-22 Develop City policy which requires new city government capital improvement projects to incorporate hazard mitigation principles

Enhance Baltimore's adaptive capacity through policy improvements that cost effectively incorporate mitigation actions into ongoing construction and physical maintenance projects.

1. Discourage new public projects in hazard-prone areas such as floodplains or the coastal high hazard areas

   It is understandable to forgive existing construction that has taken place within flood-prone areas. However, knowing the dangers, and the costs associated with flooding impacts, development within flood-prone areas should be minimized to only include facilities that can only function if placed in high risk areas.

2. Utilize hazard mitigation design requirements that exceed minimum standards for critical facilities

   Planning ahead, the City should prepare for the worst so as to increase resiliency, particularly of critical facilities. Expecting hazards that are more intense than previously experienced, the City cannot risk using low standards.

3. Use comprehensive infrastructure assessments to identify infrastructure in need of replacement and prioritize funding for those projects

   It is important to prioritize key improvement projects to be sure that the most vulnerable infrastructure assets are strengthened first.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BCHD, BCRP, DGS, DOP, DOT, DPW, Energy Office, MOEM
Alignment with Goals	Goal 4
Connection with Existing Efforts	ESF-3; ESF-5
Timeframe	



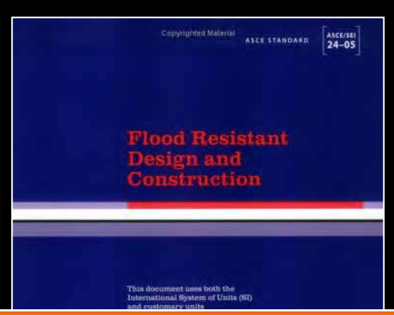






Domino
Sugars

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ASCE STANDARD
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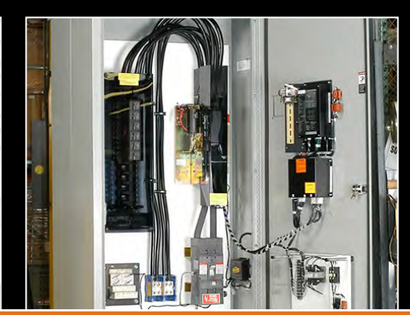
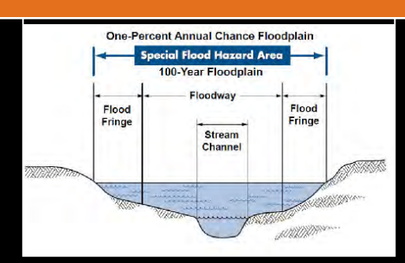
Flood Resistant Design and Construction
This document uses both the International System of Units (SI) and customary units.

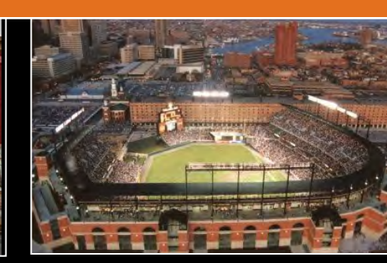





Buildings





One-Percent Annual Chance Floodplain
Special Flood Hazard Area
100-Year Floodplain
Floodway
Flood Fringe
Stream Channel
Flood Fringe



CITY CODES AND DESIGN GUIDELINES

BL-1 Develop and implement hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.

Prevent structural damage from all natural hazards to critical facilities through adaptation and mitigation actions. Strengthen existing building codes and land use regulations, focusing on efforts to enhance the resiliency of energy systems and reduce vulnerability from flooding .

1. Conduct educational outreach for city-owned, residential, commercial, and industrial buildings about proper storage and disposal of hazardous materials and heating oil (S)

   Prevent additional health and safety risks by educating about the requirements regarding proper care and storage of hazardous materials, which are vulnerable during hazard events and could increase the risks associated with hazard impacts.

2. Require hazardous materials stored in city-owned, residential, commercial, and industrial buildings within the floodplain to be elevated a minimum of three feet above the freeboard (M)

   Hazardous materials that are exposed to flood water can become a significant danger. It is crucial to review methods for increasing hazardous material protection within the floodplain by requiring higher elevations, considering potential standards for retrofitting existing systems.

3. Require new critical facilities to be designed with redundant operating systems (L)

   To improve the resiliency of any new critical facility, it is important to amend Building Codes to require a higher level of protection and critical systems redundancy.

4. Require pre-wiring for generators at all facilities designated critical to agency operations and hazard response (M)

   Critical facilities allow for proper emergency response during hazard events. It is important to consider new regulations to pre-wire certain facilities to accept generators to ensure that critical facilities have redundant power supplies.

5. Develop stricter flood regulations for critical facilities (M)

   While all floodplain regulations should be updated to accommodate climate change, this is especially true for critical facilities which provide emergency response services. Stricter regulations should be required for these critical facilities.

6. Develop partnership with private fueling stations to provide backup generators in exchange for a commitment to fueling emergency response vehicles during a hazard event

   Emergency personnel must be able to respond quickly, providing continuous fueling to vehicles that are critical for emergency response. By partnering with private fueling stations, the City can ensure that these facilities remain in operation during a hazard event so as to permit fueling of emergency response vehicles.

7. Ensure storage of and access to fuel for generators in critical facilities

   Redundant power systems require adequate resources. Critical facilities should not be without adequate supply of fuel to power generators during hazard events.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BGE, DGS, DOP, DPW, Hospitals, Material Storage Sites
Alignment with Goals	Goals 2, 5, and 6
Connection with Existing Efforts	CRS; ESF-3; ESF-5; ESF-10
Timeframe	

Flood terms related to buildings- place holder

BL-2 Enhance City building codes that regulate building within a floodplain or near the waterfront

Baltimore Building Codes should be amended to help protect building systems and enable continued building operation in a flooding event. It is essential to identify ways to facilitate the voluntary construction of new, more resilient building stock and to encourage voluntary retrofits of existing vulnerable buildings over time. Build the City's resilience to flooding and sea level rise hazards through enhanced building codes and regulations in flood-prone areas. Use both adaptation and mitigation actions to increase disaster prevention measures.

1. Design new projects to be resilient to a mid-century sea level rise projection and adaptable to longer-term impacts

   In order to reduce future flooding impacts and the need to possibly relocate facilities due to sea level rise, projects should be required to be resilient to a mid-century sea level rise projection.

2. Incorporate climate change and coastal hazard considerations into building codes by increasing freeboard requirements to two feet as buildings are redeveloped and renovated (S)

   The City should prepare for increased flooding events and future sea level rise and incorporate resiliency to coastal hazards into building design through building code requirements. In early 2012, Governor O'Malley released an executive order on Climate Change and "Coast Smart" Construction that requires all State agencies to consider and evaluate coastal hazards in development and construction projects in order to avoid or reduce impacts. In June 2013, to expand the scientific research, Gov. O'Malley and the Maryland Climate Change Commission released the Updating Maryland's Sea-Level Rise Projections report.

3. Continue to regulate to the existing tidal floodplain delineation as adopted 2 February, 2012 (S)

   While using the existing tidal floodplain delineation, exceptions cannot be made. Current regulations will remain in place and should be seen as strict requirements. The current floodplain delineation captured the impact of Isabel. The proposed tidal floodplain delineation reflected that Isabel was a 500-year event. Current regulations, including the one-foot freeboard requirement, will remain in place for the current floodplain delineation and should be seen as a reasonable requirement.

4. Incorporate outfall elevation regulations (S-M)

   It is important to incorporate outfall pipe elevation regulations into the maintenance and improvement of water infrastructure to increase the system's capacity to handle excessive flows and higher tides.

5. Develop Construction Best Practices for development within floodplains (S)

   Even with tighter regulations of development within floodplains, construction practices, if not suitable, can leave a building vulnerable to flood hazards. It is essential to ensure proper design through the development of Construction Best Practices guidelines.

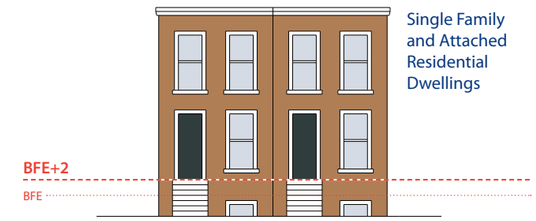
6. Train all code enforcement and building inspectors about flood proofing techniques and the local floodplain ordinance (M)

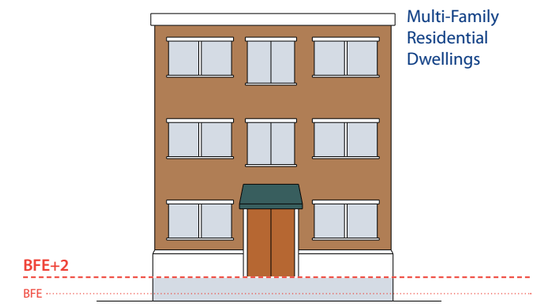
   Code enforcement workers and building inspectors should be prepared to look for vulnerabilities in buildings within the floodplain so as to identify key upgrades for preventing future damage.

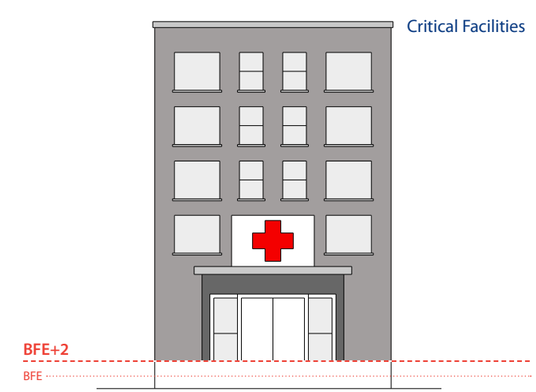
7. Encourage green roof installations to include vegetative and reflective technologies for all new commercial, industrial, multifamily, and city-owned development (M)

   Vegetated roofs provide energy savings benefits, reduce the urban heat island effect, and increase rainwater capture. Where feasible, the use of vegetated roofs for all new commercial, industrial, multi-family, and city-owned developments should be implemented.

IMPLEMENTATION GUIDELINES	
Lead Agency	Department of Planning
Stakeholders	Baltimore County, BDW, DHCD, DOP, DPW, MDE, Utilities
Alignment with Goals	Goals 3 and 6
Connection with Existing Efforts	CAP; CRS; ESF-3; ESF-5; ESF-12
Timeframe	







BL-3 Strengthen City zoning, floodplain and construction codes to integrate anticipated changes in climate

Increase the resilience of Baltimore's buildings and properties to all hazards by addressing land use and stormwater and floodwater management systems. City codes and standards must continue to develop and incorporate climate risks to both protect existing buildings and strengthen new and substantially improved buildings. Utilize both adaptation and mitigation actions to improve building codes and regulations will increase the resiliency of Baltimore's building stock.

1. Review zoning code and strengthen language (where necessary) in order to better protect citizens and increase resiliency in buildings (M)

   City planning, design, and land use are all important aspects of resiliency to flooding hazards. It is important to review existing codes to assure that residents and buildings are adequately protected. Citywide zoning code changes can provide flexibility. Baltimore has recently undergone a comprehensive zoning code rewrite, to which DP3 strategies and actions will be reviewed.

2. Review and amend existing building and floodplain regulations to require more flood resistant new and existing structures when located in the floodplain (M,O)

   New construction and renovation projects should increase resiliency to flooding hazards. It is important to review and amend existing codes, where necessary, to require the use of flood resiliency strategies.

3. Utilize open space category in zoning code to protect sensitive areas (e.g. stormwater sites, steep slopes, floodways, etc.) (M)

   Recognizing the mitigation potential of natural systems and features, identify opportunities to utilize key properties to protect vital landscapes and incorporate the open space land use designation to do so.

4. Review and increase Flood Protection Elevation (Base Flood Elevation + Freeboard) standards to the highest available State, Federal or local elevation level (S)

   It is essential to plan ahead and prepare for more frequent and intense flooding events. Accordingly, Flood Protection Elevation should be set to a higher standard. This is done by requiring Freeboard (an additional vertical height requirement) on top of the Base Flood Elevation when designing, planning and regulating within the floodplain.

5. Evaluate and update stormwater management regulations to avoid increases in downstream flooding (S)

   Measures taken upstream and reduce negative impacts downstream during hazard events. The City should identify priority improvement projects and update stormwater management regulations, where appropriate, to avoid downstream flooding.

6. Adopt design requirements that include wet and dry flood proofing techniques (S)

   The City will review for adoption, whole or in part, the ASCE 24-05 *Flood Resistant Design and Construction*. ASCE 24 establishes the minimum requirements and expected performance for the design and construction of buildings and structures in flood hazard areas. It is not a restatement of all the NFIP regulations, but offers additional specificity, some additional requirements, and some limitations. Buildings designed according to ASCE 24 are better able to resist flood loads and flood damage than those structures meeting the NFIP minimum requirements. It is important to adjust requirement to modify building design standards and increase the use of flood-proofing techniques to reduce building damage from storm events.

7. Review and consider adoption of the International Green Construction code (S,O)

   It is critical to ensure the flexibility to adopt the Green Construction code by establishing several levels of compliance, starting with the core provisions of the code, and then offering "jurisdictional requirement" options that can be customized for individual projects.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BDC, City Government, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners
Alignment with Goals	Goals 3, 4, and 6
Connection with Existing Efforts	CAP; CRS; ESF-3; ESF-5
Timeframe	

BL-4 Update a list of flood prone and repetitive loss buildings to consider for acquisition

In some cases it is too expensive or physically impossible for building owners to elevate or flood-proof their property. Where properties suffer from repetitive losses due to flooding, it is important to consider ways to increase their resiliency through physical improvements, or purchase and remove them from the floodplain by demolishing them. Acquisition of flood prone properties requires collaboration between many city agencies, residents and property owners in the area which is often difficult; it is also an expensive option. The City will focus its efforts on updating the list of flood prone and repetitive loss properties which will help prioritize and guide mitigation funding and future acquisitions.

1. Continue to acquire property (including repetitive loss properties) in the special flood hazard areas where feasible and appropriate (O)

   Where possible, acquire properties within flood-prone areas to prevent repetitive damage to private property.

2. Prioritize Hazard Mitigation Assistance funding for mitigation of repetitive loss properties and severe repetitive loss properties (O)

   In order to reduce the frequency of damage from flooding, it is important to identify key properties for mitigation efforts.

3. Develop a creative financing program for flood resiliency in industrial buildings

   It is crucial to explore alternative financing sources for projects in industrial buildings to encourage pursuit of flood resiliency measures.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	DHCD, DOP, MEMA, MDE, Office of Real Estate
Alignment with Goals	Goals 2 and 6
Connection with Existing Efforts	CRS; ESF-3; ESF-5
Timeframe	

STRUCTURAL

BL-5 Improve wind resiliency of new and existing structures

Scientific projections suggest an overall increase in the frequency of the most intense storm events that are accompanied by wind hazards. Current Building Code requirements should take into consideration this projected increase. Recognizing that older buildings that predate modern standards are particularly vulnerable, efforts should address renovations to both new and existing structures. The City will review existing building codes and identify where wind-resistance specifications must be made for both façade elements and rooftop structures and equipment.

1. Review local building codes to determine if revisions are needed to improve the structures ability to withstand greater wind velocities and storm impacts (S)

   To address the uncertainty of future wind events, and to improve Baltimore's approach to protecting buildings from wind risks, consider revisions to existing codes where greater wind velocities or storm impacts are possible. Taking a precautionary measure, Baltimore will amend Building Code to clarify current wind-resistance specifications, so as to increase Baltimore's extreme weather resiliency through structural improvements. The City will use both adaptation and mitigation actions to prepare for future high wind and storm events.

IMPLEMENTATION GUIDELINES	
Lead Agency	DHCD
Stakeholders	BDC, Commercial Building Owners, DGS, DOP, MDE, MOEM, Private Developers
Alignment with Goals	Goal 2
Connection with Existing Efforts	ESF-3; ESF-6
Timeframe	

2. Retrofit emergency shelter windows to withstand winds associated with coastal storm events (L)

   To increase the resiliency of the City's emergency shelters, which protect residents during hazard events, buildings should be retrofitted to upgrade windows so as to withstand higher wind speeds.

BL-6 Evaluate various seismic design enhancements using prototypical Baltimore City building types

In 2011, Baltimore experienced a magnitude 5.8 earthquake, originating in Virginia. Due to this event, it is essential to increase Baltimore's resiliency to earthquakes and other seismic events.

1. Determine engineering effectiveness and cost-benefit of various earthquake mitigation measures using computer modeling

   It is important to utilize computer software to identify the potential risks association with seismic activity, and determine the effectiveness and cost-benefit of structural mitigation measures.

IMPLEMENTATION GUIDELINES	
Lead Agency	DGS
Stakeholders	BDC, Commercial Building Owners, DGS, DOP, MDE, MOEM, Private Developers
Alignment with Goals	Goal 2
Connection with Existing Efforts	ESF-3
Timeframe	

BL-7 Retrofit existing buildings in the designated Flood Area to increase resiliency

It is critical to improve flood damage prevention measures by increasing structural resiliency through mitigation actions such as retrofits and upgrades. To accomplish this, engineering alternatives will be studied, where assets cannot be moved, and measures will be developed that identify how to best increase structural resiliency within the designated Flood Areas.

1. Target and encourage flood resiliency retrofits for buildings in the designated Flood Area

   Larger buildings have higher risk for impacting a greater number of people, and should therefore be encouraged to implement resiliency retrofit measures, including the relocation of critical mechanical and operation equipment, structural reinforcement, building to a higher than otherwise required base flood elevation, or other strategies. It should be noted that all new work must meet floodplain development requirements. Also, if the cumulative structural improvements (i.e. over a 10 year period) exceed 50% of the structures value (not including land), then the whole structure would need to be brought up to floodplain code.

   Explore and develop a creative financing program for residential and commercial properties to assist with retrofitting buildings. This may require evaluation of FEMA's Public Assistance Policy 9525.1 Post-Disaster Property Tax Reassessment which may assist in reducing financial burdens on commercial property owners who suffer significant structural damage and are faced with major costs of repair.

2. Prioritize retrofitting and increasing resiliency of Public Housing units in the designated Flood Area and other high risk areas

   It is important to evaluate and prioritize resiliency investments for Public Housing developments to incorporate new flood resiliency measures and ensure protection of vulnerable populations. The Housing Authority of Baltimore City (HABC) serves nearly 20,000 residents with an inventory of nearly 11,000 units. Residents include seniors, low-income households, working class and other vulnerable populations. Due to their initial placement, many Public Housing buildings, both public and private, are particularly vulnerable to natural hazards and require resiliency upgrades. Upgrading buildings electrical and mechanical equipment and flood-proofing essential systems are just some of the methods necessary to increase resiliency and protect residents.

3. Educate building owners within the floodplain to ensure that all electrical, mechanical, and key building systems are above the base flood elevation and meet existing codes

   There are approximately 5,968 buildings located in the City's regulated 100-Year and 500-Year floodplains. Working with building owners and developers, the City will identify methods to reduce damage to utilities caused by flooding through behavioral and operational changes. An educational program should illustrate strategies for preventing flooding impacts—which may include relocating compressors to roofs or off of the ground, or properly storing materials above the flood protection elevation.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BDC, DHCD, DPW, Federal and State Partners, MCC, MON, NGOs, MOEM
Alignment with Goals	Goal 2, 3, and 6
Connection with Existing Efforts	N/A
Timeframe	

NFIP Call Out

Insurance transfers risk from an individual Policy holder to a larger risk sharing pool. The insurance system is based on the principle of risk-based premiums: those with greater risk (i.e., those more likely to suffer damage and require a claims payment from an insurance provider) should pay higher premiums than those with less risk. Thus, an owner of a property in an area prone to floods and hurricanes should pay more for insurance than the owner of a property in an area with less risk. The reason insurance providers must charge risk-based rates is that these rates are necessary for providers to remain financially solvent and have sufficient resources to pay policyholder claims in the event of losses.

NON-STRUCTURAL

BL-8 Improve resource conservation practices in all City owned buildings

Increase resiliency of City Government buildings by increasing efficiency of internal energy systems, and increased measures for energy conservation. Energy use reduction is important for regional energy supply protection during extreme heat events and other high energy demand situations.

1. Install energy-efficient and low-water-use equipment during renovations in all City-owned buildings (M)

   By reducing energy demand and increasing water conservation measures, buildings are better suited to avoid or reduce impacts associated with hazard events. City-owned facilities should incorporate energy efficient and low-water-use equipment into scheduled renovation projects.

2. Support energy efficiency and weatherization as part of Baltimore City schools ten-year plan (S)

   Providing emergency shelter during hazard events, and serving as key community facilities throughout the year, school facilities will require additional measures to increase resiliency and prevent damage. To mitigate climate change and reduce energy demand, while at the same time increasing a building's capacity to withstand hazard events, energy efficiency and weatherization should be incorporated into the Baltimore City School System's ten-year plan.

3. Update Baltimore green building standards by offering multiple compliance paths for new and substantially renovated construction

   Baltimore should provide an example and model for green building within the City and set a precedent that will encourage more green building projects, thus increasing resource efficiency.

IMPLEMENTATION GUIDELINES	
Lead Agency	DGS
Stakeholders	MOEM, BCPSS, DCHD, DGS, DOP
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; CHAP
Timeframe	

BL-9 Conduct educational outreach to increase resource conservation practices in private buildings

Increase hazard mitigation awareness through resource conservation educational materials and programs for the general public and businesses. Include information about utilities, water use, energy savings programs, hazardous materials, and electricity demand.

1. Conduct educational outreach and provide information about savings related to reduced water use (S)

   Conserving water resources reduces reliance on the City's systems during low supply events. The City encourages additional educational outreach efforts to convey the importance and benefits of water conservation measures.

2. Educate and provide resources and information about utility rebate programs

   To encourage energy efficiency, water conservation, and weatherization efforts, it is important to develop an educational program into existing communication efforts.

3. Provide energy efficiency education to include information on conserving electrical power. Emphasize reductions during summer peak demand hours (S)

   Reducing energy demand could lessen the burden on the power supply system during high heat events. It is important to build upon existing educational programs that provide information regarding energy efficiency and conservation, such as the Baltimore Energy Challenge (BEC).

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BCPSS, BGE, BOS, DOP, Exelon, MON, NGOs, MOEM
Alignment with Goals	Goal 5
Connection with Existing Efforts	CAP; ESF-5; ESF-11
Timeframe	

BL-10 Use HAZUS-MH computer modeling to determine losses generated by coastal storms

Protect the health, wellness, and safety of Baltimore residents by evaluating mitigation practices as the results speak to potential losses generated by coastal storms and extreme wind, flood and earthquake events through the use of computer modeling technology. Determine possible mitigation measures, and identify adaptation responses.

1. Utilize engineering studies and cost-benefit analyses to identify additional mitigation needs and actions

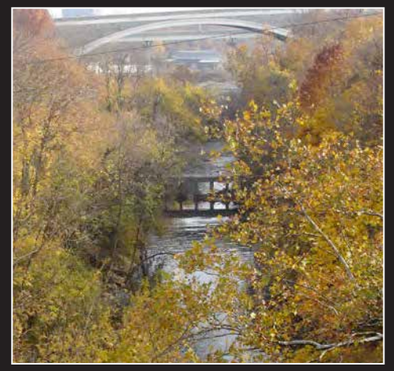
   Through the use of engineering studies and cost-benefit analyses, the City will consider and identify where additional steps may be taken to mitigate the impacts of hazard events.

2. Evaluate various building design enhancements to reduce losses generated by earthquakes, floods, and storm surge

   Considering the potential future impacts of natural hazards, more efficient building design techniques will be evaluated and encouraged. Update seismic engineering requirements to current national standards. Take into account soil and foundation underpinning. Require seismic detailing and inspections to ensure compliance. Perform seismic study of existing tall buildings. Retrofit buildings to exceed new building code seismic provisions.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	DHCD,FEMA, MEMA, MOEM, NOAA
Alignment with Goals	Goal 1
Connection with Existing Efforts	ESF-3
Timeframe	














Natural Systems



URBAN PARKS AND FORESTS

NS-1 Utilize green corridors and parks to help protect surrounding communities from the impacts of hazard events

Leverage natural features to protect the health, wellness, and safety of Baltimore residents. Regard natural elements such as stream corridors and trees for their capacity to mitigate the impacts of hazard events. This strategy is primarily focused on mitigation actions, but recognizes that increased natural capacity can positively influence climate adaptation efforts.

1. Evaluate green corridors and parks for possible improvements for floodplain management (M)

   Baltimore will seek to protect parks and increase the capacity of its park system to absorb floodwaters (from storm surge and heavy precipitation) through tree plantings, stormwater management and stream restoration.

2. Increase the resiliency of park facilities and buildings

   Though park facilities and buildings may not provide an emergency service, they are nonetheless vital amenities for the communities they serve. Baltimore will work to protect these facilities from the impacts of climate change and to enable them to quickly re-open when impacts do occur.

IMPLEMENTATION GUIDELINES	
Lead Agency	BCRP
Stakeholders	DOP, Community Groups, DPW, NGO's
Alignment with Goals	Goals 1 and 6
Connection with Existing Efforts	CAP; CRS; MD DNR
Timeframe	

TREES IMAGE

NS-2 Increase and enhance the resilience and health of Baltimore's urban forest

Baltimore's urban forests and trees offer countless environmental benefits, but are vulnerable to climate change-related impacts and hazards, including storm surge, wind, and changes in average temperatures. Increasing Baltimore's tree canopy will improve stormwater management, increase air quality and reduce impacts from the urban heat island.

1. Anticipate the impacts of future changes in temperature and weather on the urban forest by developing a comprehensive list of plant and tree species known to have a broad range of environmental tolerances (S)

   With changing climate trends, much of today's landscape may not be able to withstand future temperatures, rainfall patterns, or other conditions. Landscaping and habitat conservation efforts must consider plant species that are appropriate for today's climate, as well as able to withstand future conditions to prevent widespread loss of vegetation. It will be important to refer to Baltimore City Recreation and Parks' comprehensive list of appropriate tree species for street tree plantings.

2. Establish and routinely update a comprehensive tree inventory to anticipate insect and forest structural impacts of climate change (S)

   It is essential to maintain an ongoing inventory of trees to be used to identify significant impacts and areas in need of restoration.

3. Establish a comprehensive maintenance program that includes pruning for sound structure and the removal of hazardous limbs and trees. First focus on areas where vulnerable infrastructure is nearby such as energy supply and roads (M)

   Baltimore will establish a comprehensive tree maintenance program and modify standard tree inspection and pruning efforts to prioritize trees in areas vulnerable to extreme weather events.

4. Continually adjust and modify planting details and specifications to assure the health and longevity of trees (S)

   Utilizing the tree inventory, identify locations to assist with tree growth and reducing the high rate of tree mortality and failure during storms.

5. Increase the urban tree canopy and target areas with urban heat island impacts (O)

   Trees are recognized for their ability to provide significant air quality and cooling benefits. It is important to assure that planting efforts increase tree canopy coverage in targeted areas to reduce the impact of extreme heat events.

IMPLEMENTATION GUIDELINES	
Lead Agency	BCRP (Forestry)
Stakeholders	USFS, BGE, Community Groups, DOP, DOT, DPW, MDNR, NGOs
Alignment with Goals	Goal 1
Connection with Existing Efforts	CAP; MD DNR
Timeframe	

NS-3 Create an interconnected network of green spaces to support biodiversity and watershed based water quality management

Enhance Baltimore's adaptive capacity through the establishment of an interconnected system of green spaces and natural features which increase biodiversity and reduce stormwater runoff. Actions focus on using vacant properties to create new green spaces and linking these to existing parks, stream valleys, and public lands.

1. Utilize the Growing Green Initiative (GGi) to increase green spaces in areas where there is available vacant land in order to reduce the heat island effect (O)

   In areas that are vulnerable to heat-related hazards, the increase in green spaces is desirable. The Growing green Initiative can serve as a tool for communities, non-profits, and public agencies to reduce impervious surfaces by establishing new gardens, forests, green stormwater infrastructure, and parks.

2. Convert vacant land and row houses into meaningful and connected open space (O)

   Baltimore's distressed neighborhoods often have large amounts of vacant properties but lack parks and green spaces. The opportunity to create green stormwater facilities, parks, and other types of community green spaces should be used as criteria for targeting whole block blight demolition and re-using of vacant lots for community benefit and to help link residents to adjacent parks and open spaces.

3. Complete a habitat analysis and plan for the City

   The City should promote and encourage habitat preservation and restoration throughout the City and explore options for creating an interconnected network of green patched and corridors. This will require an analysis of existing conditions and the development of a plan and supporting strategies and policy recommendations to enhance the quality, biodiversity and connectivity of Baltimore's green spaces and habitat patches.

4. Create a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation

   It is important to explore more and larger green infrastructure programs to absorb stormwater, mitigate local flooding, decrease urban heat island effects, increase pedestrian and traffic safety, and beautify neighborhoods. This includes expanding the use of green infrastructure at appropriate locations in City streets to improve water quality in combined sewer areas.

5. Certify Baltimore as a Community Wildlife Habitat through the National Wildlife Foundation (NWF)

   A Certified Community Wildlife Habitat, a certification offered by the National Wildlife Foundation (NWF), provides habitat opportunities throughout the community- in yards, on school grounds, in community gardens and in parks and other public spaces. Baltimore will become certified by certifying yards, parks and schools through NWF and educating residents about sustainable gardening practices.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies
Alignment with Goals	Goal 4
Connection with Existing Efforts	CAP; MD DNR
Timeframe	∞

NS-4 Expand, protect and restore riparian areas in the city

Baltimore will pursue cost-effective methods for using stream valleys and associated natural features to protect adjacent land and communities from the impacts of flooding hazards. Utilize adaptation and mitigation actions to address the capacity of riparian buffers.

1. Conduct regular maintenance of stream restoration projects and stormwater quality facilities

   Stream systems can serve to buffer the impacts of severe weather events. Proactively maintaining these systems will increase the capacity to withstand significant precipitation levels.

2. Evaluate current regulations regarding stream buffers and floodplains and modify them (if appropriate) to assure they adequately protect perennial stream corridors

   Baltimore will restore freshwater streams and restore or construct wetland systems to manage stormwater runoff and reduce the impacts of extreme weather events. Riparian buffer planting protect stream edges and provide a safe edge during flood events. Some areas of the City are more likely to experience increased flooding impacts. As the floodplain is expected to rise and expand, more land must be dedicated to establishing and restoring natural stream buffers.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BCRP, DOP, DPW
Alignment with Goals	Goal 1
Connection with Existing Efforts	MD DNR
Timeframe	∞

For design: put in a diagram of flood proofing strategies from DCP and different flood proofing methods

NS-5 Preserve and create new coastal buffer efforts and support creating more wetlands and soft shoreline along coastal areas

Enhance ecological buffers along coastal areas to increase floodwater management and resiliency to flooding and sea level rise. Protect the health, safety, and welfare of Baltimore's residents with both adaptation and mitigation efforts.

1. Integrate natural buffer requirements, such as wetlands and soft shorelines, into new development or redevelopment (S)

   Explore innovative coastal protection techniques, such as soft infrastructure investments, for flood and wave risk reduction. Likewise, wetlands can act as natural buffers that protect upland communities by retaining some water and absorbing wave strength during storm conditions.

2. Complete stream restoration projects in Baltimore City and County stream valleys that lead into the coastal wetlands so as to increase habitat and reduce sedimentation (L)

   Efforts to protect stream systems upstream will prevent damage downstream and maintain a healthy hydrological system. This will require cooperation with Baltimore County and other jurisdictions outside of Baltimore.

3. Identify and evaluate areas in the Critical Area buffer to prioritize ecological buffer restoration efforts

   Key areas are in need of additional or immediate improvements, and prioritized restoration efforts will increase the stream system's resiliency. It is critical to ensure the flexibility to adopt the Green Construction code by establishing several levels of compliance, starting with the core provisions of the code, and then offering "jurisdictional requirement" options that can be customized for individual projects.

The natural systems sub-committee recognizes that enhancing and improving the resilience of Baltimore's water supply is an essential natural systems element. This is reviewed in the infrastructure section under IN-14.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BCRP, BDC, DOP, DPW, NGOs, State Agencies, Waterfront Partnership
Alignment with Goals	Goals 1 and 6
Connection with Existing Efforts	CRS; MD DNR
Timeframe	

Wetlands and coastal adaptation images

WATER SUPPLY AND MANAGEMENT

NS-6 Require the City's drought management plan to account for changes in climate

Enhance the adaptive capacity of the City's Water Supply with increased drought preparedness. This strategy is primarily focused on mitigation actions. The Maryland Department of the Environment, through the Maryland Statewide Water Conservation Advisory Committee, released the Statewide Drought Monitoring and Response Plan in 2000 to outline methods for monitoring, as well as steps to respond to, drought conditions. In this plan, the City of Baltimore rests within the Central Region for drought monitoring and response. The Susquehanna River Basin Drought Coordination Plan, also produced in 2000, includes Baltimore City within the lower basin area. This plan notes that the U.S. Army Corps of Engineers has developed drought management plans for each reservoir project in the Susquehanna River Basin. It will be important that these and other drought management plans are updated to reflect the most recent conditions and vulnerabilities.

1. Map drought risks and water availability via climate change scenarios

   The City should identify future risks and vulnerabilities of the water supply system to better understand the risks association with drought and climate change-related hazards.

2. Update drought management plans to recognize changing conditions (S)

   Projected changes in future conditions should be incorporated into drought management plans to prevent future impacts.

IMPLEMENTATION GUIDELINES	
Lead Agency	DPW
Stakeholders	BCHD, Water Utility
Alignment with Goals	Goal 4
Connection with Existing Efforts	CAP
Timeframe	

NS-7 Integrate climate change and natural hazards planning into small watershed action plans (SWAPs)

The City will integrate climate change and hazard mitigation into Small Watershed Action Plans (SWAPs) to protect water quality and quantity. Increase the adaptive capacity of the City's stormwater and floodwater management system. Use adaptation and mitigation actions.

1. Review existing watershed management plans and identify future actions to address climate impacts

   The City will enhance efforts to protect its watersheds and review opportunities to revise existing management plans to implement watershed protection efforts that address potential future impacts associated with climate change.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	DOP, DPW, NGO's
Alignment with Goals	Goal 4
Connection with Existing Efforts	CRS; MD DNR
Timeframe	

NS-8 Conduct detailed ongoing analysis of climate information, trends in storm events and hydrology to support policy changes responding to climate change

Use detailed analysis of accurate data to support flood policies to protect the health, safety, and welfare or Baltimore's residents from changes in sea level rise. This strategy is primarily concerned with adaptation measures Baltimore must use to update all City planning and emergency preparedness efforts.

1. Expand the use of climate information (e.g. seasonal forecasts) in water resources planning and management (S)

   The City must recognize the environmental and climatological conditions that impact water resources and incorporate the information into resource planning and management to better understand and prepare for hazard impacts.

2. Research and actively monitor trends in storm events, stream flow and other conditions affecting hydrology and water (O)

   As scientists expect conditions to change over the coming century, the City intends to respond effectively to hazard events. To do so, the City will seek to identify and utilize appropriate tools for monitoring trends in storm events and environmental conditions.

3. Update flood maps to reflect changing risk associated with climate change (S)

   Flood maps should be updated regularly to reflect changing risks associated with climate change. The City will work with FEMA to revise existing flood maps to recognizing existing and future risks from flooding.

4. Continuously improve and enhance flood vulnerability data (O)

   Flood vulnerability data is constantly evolving. The City should continue to take steps to improve and enhance this data and incorporate new information into citywide efforts to reduce impacts associated with flooding.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BDC, FEMA, MDE, MDNR, MEMA, NGOs, State Agencies, Waterfront Partnership
Alignment with Goals	Goals 1 and 6
Connection with Existing Efforts	CRS; MD DNR
Timeframe	

Public Services

EMERGENCY PREPAREDNESS AND RESPONSE

PS-1 Strengthen emergency preparedness coordination between local government, NGOs, and private entities by updates to the City Emergency Operations Plan (EOP) and related Emergency Support Functions (ESF)

Increase Baltimore's adaptive capacity by coordinating communication and interaction between various entities using both adaptation and mitigation actions to address all natural hazards.

1. Identify and develop a common database that all city government agencies and departments should utilize for hazard information, preparedness and response (S)

   A single, comprehensive database that provides hazard information should be accessible by all government agencies and departments. It is important to explore the potential use of this resource.

2. Ensure consistency and integration with existing and future response plans within and between agencies (O)

   Efficient and effective emergency response will require cooperation and dependability across government agencies and existing plans should be reviewed for inconsistencies. Develop proper, adequate and consistent training that is specific, practical and readily accessible to operational personnel, supervisors, and commanders. Agencies should review annually the City's Emergency Operation Plan to identify ways to integrate new resources and/or changing responsibilities.

3. Continue to identify and improve coordination with Key Partners including private sector, State partners, Federal partners, community, universities and industry leaders through Local Emergency Planning Committee (O)

   During a hazard event, communication and coordination between the City and other key partners will ensure that response efforts and easily implemented. It is essential to identify where existing communication should be established or improved.

4. Coordinate outreach efforts of the Mayor's Office of Emergency Management, Mayor's Office of Neighborhood and Constituent Services and Baltimore City Health Department to leverage messages related to all-hazards emergency preparedness (M)

   During a hazard event, and immediately after, communication among agencies and with residents should provide reliable information. To improve the flow of accurate and reliable information, the City will use existing interagency working groups to develop standardized communications protocols for use during hazard events, to ensure that critical messages regarding hazard emergency preparedness is conveyed.

5. Develop strong working relationships with local experts to provide technical assistance to refine and improve city government emergency preparation

   Using technical assistance and recommendations from local experts, the City will be able to enhance emergency preparation.

6. Review and improve specific response plans contained in the EOP and related ESFs that relate to extreme weather events (snow, heat, flood, wind, electrical outages, and other hazard events)

   The purpose of this Emergency Operations Plan (EOP) is to define the actions to be taken by Baltimore City government, State and Federal agencies, and other non-governmental organizations in the event of an emergency. In order to effectively respond to any natural hazard emergency situation in Baltimore City, this plan recommends reviewing existing response plans, identifying gaps, and improving response efforts. This will require a coordinated effort among all participants and stakeholders .

7. Ensure equipment purchases and communication systems are compatible across agencies and jurisdictions (O)

   During a hazard event, there is limited time to react to serious impacts. By ensuring that equipment and systems are consistent across agencies, the City can quickly respond to and address any mechanical or electrical needs.

8. Encourage all animal rescue and care shelters to further develop their internal plans for animal's health and safety during and after a hazard event

   Fear for animal safety often prevents individuals from appropriately reacting to hazard warnings. Additionally, animal shelters, which contain large numbers of animals, may not be adequately prepared to react during and after a hazard event. It is important to encourage all shelters to prepare for hazard events and establish an internal hazard response plan.

9. Ensure all animal rescue and care shelters located within the floodplain are provided the support to apply for and obtain funds to relocate

   Animal shelters within floodplains are more vulnerable. It is important to work with key partners to identify resources and support that will help these facilities relocate or flood proof.

10. Develop and implement a case study of hospital-based practices that foster community resilience to climate change

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCFD, BCHD, BCPD, Community Groups, County Governments, DOP, DHMH, Humane Society, MOEM, MOIT, MON, PSC
Alignment with Goals	Goal 4
Connection with Existing Efforts	CAP; MD DNR
Timeframe	∞

PS-2 Develop a Hazard Awareness Program

Increase hazard awareness with the creation of an ongoing outreach program. Consider both adaptation and mitigation actions to increase Baltimore preparedness for all hazard events.

1. Create a standardized early warning system for members of the public (S)

   In order for Baltimore's residents to prepare and quickly respond during a hazard event, a clear, easily understandable and standardized early warning system is needed for notifying the public of potential hazards.

2. Evaluate and improve community health center strategies for communicating with patients during an emergency

   As a part of emergency response efforts, health centers should be prepared to communicate with patients during an emergency. It is critical to evaluate the competency of these systems and identify opportunities to enhance these strategies.

3. Educate citizens about the existing early warning systems and actions they should take when alarms sound

   Prior to a hazard event, Baltimore's residents should be aware of the early warning system already in place. Knowing how it works, through what outlets they can receive warning information, and the information that various terminology or messages may convey will ensure that residents can understand emergency information and will be prepared to quickly respond.

4. Prepare and integrate occupational health and safety messages and instructions for first responders (O)

   Integrating hazard safety into occupational health and safety messages helps to ensure worker protection and publicly conveys hazard preparedness messages through a public interface.

5. Hold climate specific seminars, in partnership with MDH2E and MHA, for hospital emergency and sustainability managers

   Hospital facilities are critical facilities that will be under considerable pressure during and after a hazard event. It is important to prepare educational programs to instruct hospital emergency and sustainability managers about their responsibilities during hazards, as well as what actions should be taken.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCHD, DHMH, DOP, MDH2E, MEMA, MOEM
Alignment with Goals	Goals 1 and 5
Connection with Existing Efforts	CAP; ESF-11
Timeframe	∞

PS-3 Designate community leaders and organizations that can assist and provide support during hazard events

Leverage community resources and empower individuals to increase efforts to protect Baltimore residents from all natural hazards. This strategy is concerned with measures for climate adaptation and emergency preparedness.

1. Prior to a hazard event, identify lead contacts serving vulnerable populations and coordinate actions to maximize safety and information sharing (O)

   So as to guarantee the proper dissemination of emergency and early warning information, the City should identify key points of contact who can convey safety information prior to, during, and after a hazard event.

2. Develop a community group coordination plan and implementation guide (M)

   To assist community representatives with the task of conveying hazard information, the City should develop a community group coordination plan and implementation guide.

3. Identify and evaluate plans already in place and work to improve utilization of community based leaders to assist in preparedness and response (L)

   It is important to consider how existing plans may be leveraged to establish community-based preparedness and response programs.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, MOEM, MON
Alignment with Goals	Goal 1
Connection with Existing Efforts	CAP; MD DNR
Timeframe	∞

PS-4 Integrate climate change and natural hazards planning into all City and community plans

In the past, climate adaptation and resiliency have not been significant considerations when prioritizing city projects. The City encourages interagency and cross-jurisdictional partnerships to ensure that resiliency is a factor. Likewise, Baltimore advocates for similar changes in the planning and evaluation of major projects and plans.

It is important to incorporate resiliency and disaster prevention in all City and community plans to address all natural hazards. Incorporate climate adaptation measures into City policy.

1. Develop guidelines to include proactive resilience planning into plan development process

   Incorporate resiliency efforts into plan development and establish a framework which can guide agencies through this process.

2. Incorporate language that strengthens the ability of city government officials to enforce rules and restrictions that support public health, safety and welfare related to hazard events and conditions (M)

   When incorporating hazard planning into existing programs and plans, language should be used which will present government officials with the power to enforce rules and regulations that support public health, safety, and welfare.

3. Partner with Maryland Department of Health and Mental Hygiene or other pertinent entity to develop institutional checklist and materials for health care specific resilience plans

   Better prepare hospitals for future hazards and increase capacity and ability to respond to hazard events.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCFD, BCHD, BCPD, DHCD, DOP, MOEM, State/Fed. Agencies
Alignment with Goals	Goal 3
Connection with Existing Efforts	CAP; MD DNR
Timeframe	

PS-5 Better equip emergency workers for natural hazards

Increase Baltimore's adaptive capacity by preparing emergency workers for hazards associated with disease outbreaks. This strategy focuses on adaptation measures and emergency preparedness.

1. Research and identify personal protective equipment (PPE) needs based on specific hazards (O)

   It is important to investigate how first responders can be better prepared and equipped to respond to a variety of potential hazards.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCFD, BCPD, MOEM
Alignment with Goals	Goal 4
Connection with Existing Efforts	CAP
Timeframe	

Integrating DP3 with Existing Efforts | THIRA and COOP

Hazard Mitigation and Climate Adaptation planning are not the only tools used to identify hazards and vulnerabilities prior to emergency planning. Other similar efforts include the Emergency Operations Plan, Threat and Hazard Identification and Risk Assessment, Continuity of Government, and the Continuity of Operations Plan. Findings and outcomes, through the DP3 process, will be used in informing these other processes. The Threat and Hazard Identification and Risk Assessment (THIRA) is one such example. THIRA is a FEMA tool designed to help jurisdictions understand the threats and hazards they face. Threats considered under THIRA include natural hazards but also technological hazards (e.g. airplane crash, power failure, train derailment, etc.) and human-caused incident(s) resulting from intentional actions (e.g. civil disturbance, school violence, terrorist acts, etc.). In completing the risk assessment, THIRA matches impacts with hazards and defines these impacts within 'core capabilities' (i.e. resources to address the impact). Impacts include displaced households, fatalities, injuries/illnesses, direct economic impacts, indirect economic impacts from supply chain system disruption, and disruption to infrastructure are some but not all of the impacts considered.

Preparing for response, Baltimore identifies resources/capabilities and defines the response. This process results in understanding existing capabilities and capacities to know what might need to be supplemented, improved, or sustained. For example, hurricanes are an annual hazard for Baltimore City. The context used for the THIRA is a storm that makes landfall in the Baltimore region as a category 2 hurricane. The impact includes 80% of the region without power, damage to critical infrastructure, localized looting, etc. Within the core capability of Mass Care, we expect to shelter 7,500 people throughout the region, and 20% of that population has an access or functional need. The corresponding capability assessment will show us if we can achieve that target and what gaps, if any, need to be addressed if there is a shortfall.

While several core capabilities of THIRA fall under the mission area of mitigation, the main focus of the THIRA is on disaster response. The DP3, on the other hand, is a much deeper look into reducing and eliminating long-term risks from natural hazards. The THIRA also includes threats, which is a term for terrorism or manmade disaster, while the DP3 only includes natural hazards in its scope. Taken together, the THIRA and DP3 cover natural and manmade disasters that could befall Baltimore City and identify strategies and resources necessary to reduce our vulnerability to any disaster.

COOP – Ready to Respond

Continuity of Operations (COOP) planning is necessary to ensure essential functions of government can take place in a catastrophic disaster. COOP plans are agency-specific and identify personnel and resources necessary to maintain operations essential to its mission. For example, the Baltimore City Fire Department must be able to respond to and suppress fires even if it is not fully staffed or firehouses are destroyed. COOP plans must include, at a minimum: key personnel, essential functions, and a backup facility.

DP3 strengthens COOP plans by identifying long-term hazards and the possible extent of the impacts (e.g. maps, data, risk assessment). COOP planning typically only looks at existing structures and essential functions. COOP planning, when paired with DP3, helps agencies self-identify vulnerabilities (to natural hazards) with both primary sites as well as backup facilities. By integrating these processes, the impacts of natural hazards are more clearly defined. In doing so, COOP plans are reinforced and steps to mitigate hazard events in the future may be better prioritized. Furthermore, linkages with additional hazard mitigation tools (EOP, COG, THIRA, etc.) can continue to build the City's resiliency.

HEALTH

PS-6 Anticipate and address potential disease outbreaks caused by extreme weather events and changing climatic conditions

Increase adaptive capacity and prepare for potential disease outbreaks as a result of extreme weather events. This strategy is concerned with adaptation measures and emergency preparedness.

1. Support studies of heat and flood related vector borne diseases in the Baltimore the region based on changing temperature and moisture (O)

   Prevent injury or loss of life due to disease outbreaks through the exploration of studies regarding heat and flood related impacts.

2. Evaluate existing programs that detect disease outbreaks to determine their flexibility to respond to new conditions

   As conditions change, the City is likely to encounter new diseases which may be created by the conditions during or after hazard events. It is essential to evaluate existing programs and surveillance methodologies to determine their capacity to detect and respond to new and changing conditions.

IMPLEMENTATION GUIDELINES	
Lead Agency	BCHD
Stakeholders	BCHD, CDC, DHMH, MDNR, MEMA, MH2E, MOEM, State Agencies
Alignment with Goals	Goal 4
Connection with Existing Efforts	CAP; MD DNR
Timeframe	∞

PS-7 Protect Baltimore residents from the effects of hazard events and plan for more frequent hazard instances

Protect the health and safety of Baltimore's residents by preparing for more frequent hazard instances related to extreme heat. This action addresses both adaptation and mitigation measures, and is concerned with emergency preparedness.

1. Re-evaluate and update existing heat alerts, advisories, and updates to healthcare and emergency service providers (S)

   It is important to re-evaluate and update hazard alerts so as to ensure adequate communication. This will reduce the health impacts caused by high heat events.

2. Ensure that residents and visitors have access and transportation to cooling centers during extreme heat events (O)

   During high heat events, residents should have access to cooling centers or similar options. It is important to explore key gaps in these assets in order to reduce health impacts.

Source: www.wbaltv.com

3. Evaluate code red plans to ensure all agencies adequately protect their own workers (S)

   By evaluating code red plans, the City can promote first responder readiness and general safety at cooling centers which may require additional security measures.

4. Consider extending hours for public wading pools during extreme heat events (M)

   Residents should have access to cooling center or similar facilities during extreme heat events. In some places, these facilities have limited hours. An investigation of facilities is necessary to consider ways to extend hours of operation during extreme heat events.

5. Include information about Code Red in the event permitting process, and incorporate language that allows BCHD to cancel outdoor events

   Through the Code Red system, citizens are better informed about the dangers of high heat days. Time spent outside during extreme heat events can be decreased through better information.

6. Work with Regional, State and Local partners to improve air quality and reduce respiratory illnesses

   Air quality improvement must be a regional goal, as activities in one area can significantly impact the surrounding air. It is important to communicate and partner with surrounding jurisdictions, as well as with Regional, State, and other Local partners to identify key actions for improving air quality and reducing cases of respiratory illnesses.

7. Create and implement programs to manage combined health impacts of heat and air pollution

   Poor air quality is made worse with high temperatures. This means that the negative health impacts, such as respiratory illnesses, will become a greater problem. It is critical to establish a program that will identify and address the combined health impacts of extreme heat and poor air quality hazards to implement strategies that will reduce the associated risks and hazards.

BALTIMORE CITY COOLING CENTERS
Centers open 9am–7pm on weekdays, 11am–7pm on weekends.

Northern Community Action Center
5225 York Road | (410) 396-6084

Southern Community Action Center
606 Cherry Hill Road | (410) 545-0900

Northwest Community Action Center
3939 Reisterstown Road | (443) 984-1384

Southeastern Community Action Center
3411 Bank Street | (410) 545-6510

Eastern Community Action Center
1400 E. Federal Street | (410)396-9468

The following SENIOR CENTERS are open during a Code Red Heat Alert from 9am–7pm on weekdays only.

Waxter Center for Senior Citizens
1000 Cathedral Street | (410) 396-1324

Oliver Center
1700 Gay Street | (410) 396-4861

Sandtown-Winchester Senior Center
1601 N. Baker Street | (410) 396-7724

Hatton Center
2825 Fait Avenue | (410) 396-9025

John Booth
229 1/2 S. Eaton Street | (410) 396-9202

Zeta Center
4501 Reisterstown Rd. | (410) 396-3535

Additional cooling centers may be opened during an extended heat event. Please call 311 before leaving home for the latest cooling center hours and information.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCHD, BCRP, Community Groups, DHMH, Licenses and Permitting, MDE, MOEM, Transportation partners
Alignment with Goals	Goal 1
Connection with Existing Efforts	CAP
Timeframe	∞

EDUCATION AND OUTREACH

PS-8 Conduct climate, resiliency, and emergency planning education and outreach

Increase hazard awareness related to all natural hazards through education and outreach. Consider emergency preparedness enhancements through hazard response education and risk communication. Use both adaptation and mitigation actions.

1. Incorporate environmental health and climate change into curriculum at schools, universities and health care facilities

   Incorporating environmental health and climate change information into curriculums encourages people to become stewards of the environment and motivates them to make a change.

2. Educate communities on how city agencies respond to hazard events, their role in an event, and how agencies work together (O)

   It is important to ensure that residents know who to call for what issue during a hazard, reducing response times.

3. Educate and train community groups to participate in responding to hazards (O)

   Communicate with the public to ensure that communities are better prepared for disaster situations. Include disaster preparation and response steps from FEMA/CDC in outreach efforts conducted with community leaders.

4. Generate a comprehensive community-specific all hazards outreach campaign (S)

   Increase general educational outreach programs to educate communities. This will engage residents and prepare them for climate change, reducing future impacts from a hazard.

5. Develop and communicate a simplified process for Baltimore residents to follow after a hazard event (S)

   The City should establish an easy to remember method for obtaining up-to-date information about emergency conditions (e.g. Code Red) and any available resources, such as cooling centers. This should include information regarding climate change impacts, how residents may be impacted, and recommended protective measures.

6. Create curriculum for hospitals to teach communities about climate change as part of hospital community benefits programs (M)

   Climate change curriculums at hospitals can educate residents about opportunities to prepare for climate change and hazard events (educating about future conditions, where to get information, how to stay safe, whether to seek shelter or evacuate, etc.).

7. Utilize existing preparedness messaging to include information on universal precautions to insect-borne and other infectious diseases (S)

   Preparedness messaging should be utilized to increase citizen awareness of hazards and the potential increase of infectious diseases in the area. As a result, this effort could change resident behavior.

IMPLEMENTATION GUIDELINES	
Lead Agency	MOEM
Stakeholders	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals
Alignment with Goals	Goal 5
Connection with Existing Efforts	CAP; MD DNR
Timeframe	

PS-9 Improve awareness and education about the importance of flood insurance and preparation for Baltimore citizens

Insurance plays a significant role in providing citizens and businesses with financial protection against impacts from natural hazards. In order for insurance to be most effective, consumers must be aware of their risks and must clearly understand the coverage provided by their insurance policies, incorporating what the policies may include or exclude.

Additionally, both insurance providers and policy holders should be aware of the extensive efforts that Baltimore is taking to minimize damage from flooding hazards through the efforts outlined in this report. Increasing the overall awareness and understanding of flood insurance, risks associated with flooding, and the City's efforts to address and mitigate flooding impacts will foster a more robust insurance market that serves to benefit all participants.

1. Create an educational program centered on flood hazards, coastal construction practices and evacuation procedures (S)

   It is critically important that owners of properties within the floodplain understand their obligations. The City will launch a consumer education campaign to convey this information. Communication channels may include MTA advertisements, radio spots, news blasts, and social media, among other options.

2. Encourage owners of properties to purchase flood insurance and improve policyholder awareness at time of sale or renewal (O)

   Issues of consumer awareness and education should be addressed at the points of sale and renewal, and throughout the life of an insurance contract.

3. Inform property owners who have paid off their mortgage that flood insurance is still necessary (S)

   Property owners and homeowners should be aware that their standard homeowners' policies generally do not provide flood coverage.

4. Identify programs and grants that assist citizens in purchasing flood insurance and making flood proofing changes (M)

   Efforts to update and remap Baltimore's floodplain will likely result in significant changes in flood insurance premiums, which many residents, especially the City's most vulnerable populations, will not be able to afford. Methods which will help individuals afford risk-based premiums under the NFIP should be explored. Flexible pricing options, such as a higher deductible, can encourage more residents to purchase flood insurance. (See the Summary of the NFIP October 2013 Premium Rate and Rule Changes).

5. Develop an annual newsletter to inform and remind owners of property in the floodplain about flood insurance and flood proofing activities they should undertake (S, O)

   An annual newsletter that informs and reminds owners of property within the floodplain about flood insurance and flood proofing measures will ensure that property owners aware and informed about the hazards they may face and how they can take action to prevent damage.

6. Provide information on how to file for reimbursement for impacts of hazards (S, O)

   Citizens impacted by a flood event need assistance navigating the formal process of reimbursement. Assist members of the public in understanding what is available to them and how to file — when individual assistance is made available by FEMA, a disaster recovery center (DRC) is established that provides this help.

7. Require a flood disclosure form, and educational information as part of lease agreements for commercial and residential properties (S)

   It is important to proactively communicate with property owners and renters about the risks associated with flooding, which can decrease impacts from flooding and the loss of property during hazardous events.

8. Develop floodplain awareness information for rental tenants and ensure distribution as tenants change

   Since rental tenants are generally more transient than property owners, it is important that the City increase awareness programs regarding floodplain conditions to this population. Changing tenants should be provided with resources and information regarding their property and risks associated with flooding.

IMPLEMENTATION GUIDELINES	
Lead Agency	FEMA/MEMA
Stakeholders	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM
Alignment with Goals	Goals 1, 5, and 6
Connection with Existing Efforts	CAP; CRS
Timeframe	∞

FOOD SYSTEM

PS-10 Increase Baltimore's Food Security

To grow the capacity of the food system to withstand direct and indirect risks associated with climate change and natural hazards, Baltimore will work with local and regional partners to study the local food system for potential vulnerabilities and produce a long-term plan for protecting the resiliency of the regional food system. In collaboration with partners, the City will identify what our current food system looks like, where our food comes from, and our food needs. This will lead to identifying vulnerabilities and utilization of scenario modeling to increase food system resiliency.

This process will involve data collection and analysis, proactive planning, and transportation system considerations all of which are necessary to increase the adaptive capacity of the Baltimore food system.

1. Develop a food security plan for Baltimore

   Climate change, extreme weather and economic volatility threaten and increase the vulnerability of the global food system. Changes in rainfall patterns and increases in more extreme weather are expected to affect food production and distribution. These changes are also expected to increase the number of pests and diseases that both crops and livestock are susceptible to. This could destabilize our current farming and food systems. A food security plan helps increase production of, access to, and consistency of, healthy food options for Baltimore's residents. It also evaluates food storage, food distribution, location of food banks and pantries, accessibility, and backup energy considerations for stores, among other issues.

2. Increase land under cultivation for commercial urban agriculture

   Increased local food cultivation has many benefits beyond increasing the amount of food available. Increasing the amount of land used for commercial agriculture would also reduce stormwater runoff, reduce the impervious surface area within the City, reduce the urban heat island effect, and would boost the City's self-sufficiency and capacity to support residents in a hazard event. Although the amount and type of food currently grown in the Baltimore region is insufficient to wholly support residents in a food crisis, increasing opportunities for urban agriculture would help offset food needs and demand during and after a hazard event.

3. Link Jessup and regional/local food producers to local distributors

   Building adaptive capacity of our food system and surrounding agricultural community is essential to becoming more resilient to climate change. This requires identifying where our food comes from, how that source may be impacted by climate change, how that food gets to the city, and the current capacity and abilities of Jessup. Once these elements are identified, it is essential to determine vulnerabilities in the food system, identify additional aggregator needs, and develop strategies for reducing vulnerability. It also requires evaluating new technology and developing a "climate-smart" food system which could include creation of additional regional or local aggregator (if necessary). Linking assets such as food producers, food banks, and retailers to local residents can help reduce food availability issues and can connect local communities with one another, building social capital.

4. Incorporate Baltimore's food policy initiative into planning efforts

   Baltimore's food policy initiative focuses on integrating food issues into all planning processes. This includes consideration of food deserts, food access and opportunities to expand local food options.

5. Double the size and number of food producing community gardens by 2025

   The current food policy goal is to increase access to fresh foods and grow more food locally so as to increase self-sufficiency. This requires consideration of all land being utilized for food production as well as the number of people with the skills to grow food. Baltimore City will work with local and regional partners to collect relevant land use data and increase the amount of land being utilized for food production within the City.

IMPLEMENTATION GUIDELINES	
Lead Agency	DOP
Stakeholders	BOS, DOP, MDA, Urban Farms and Community Gardens (P&P and CGRN)
Alignment with Goals	Goal 1
Connection with Existing Efforts	MD DNR
Timeframe	

Chapter 6

Implementation Maintenance and Evaluation

The City of Baltimore is committed to reaching the goals of the DP3 Plan, and completing, to the maximum degree possible, the strategies and actions presented in Chapter 5. To start this process, steps to implement the strategies are outlined in this chapter, and include information on adoption, maintenance, and revision of the plan. As the strategies and actions were developed, members of the Advisory Committee also considered how each action would be implemented, monitored, and evaluated. Agencies and organizations responsible for implementation, as well as possible funding or financing sources have been identified for each strategy. The DP3 Plan is the product of a collaborative effort including City agencies and stakeholders from all sectors, and collaboration moving the plan forward is a vital priority in order to achieve success.

Plan Adoption

The City of Baltimore DP3 Plan was officially endorsed by the DP3 Advisory Committee on August 19, 2013. The Plan was then presented and adopted by Sustainability Commission on ___, 2013. On October __, 2013, the Baltimore City Planning Commission also adopted the Plan.

Following formal adoption of this plan by both The City of Baltimore Planning Commission and Sustainability Commission, this Plan will be presented to the Federal Emergency Management Agency (FEMA), the Maryland Emergency Management Agency (MEMA), and the Maryland Department of Natural Resources (MDNR) for approval. Once approved, this Plan will act as a guide to making hazard mitigation and climate adaptation management decisions and will allow city agencies to integrate the strategies and actions into ongoing and new projects and assist in guiding policy decisions.

Accomplishing the strategies and actions proposed in this plan will require cooperation from City officials and staff and an ongoing long-term commitment to the Plan's vision and goals. It will also require collaboration with the FEMA, MEMA, and MDNR. Lead agencies, stakeholders, and timelines are identified in the spreadsheet within this chapter.

Implementation Guidance

The City of Baltimore must act now and prepare for the future by proactively mitigating natural hazards and adapting to climate change. Recognizing that the City is already exposed to natural hazards and that many of those hazards are difficult to predict, it is crucial that the strategies outlined within this plan are implemented swiftly and efficiently. The DP3 Plan provides a series of guidelines to ensure the successful implementation of the proposed actions.

DP3 is a living document which has proposed a series of actions that shall persist well into the future. As Baltimore grows and develops, or as conditions change and new information becomes available, some adjustments may need to be made to the plan. The implementation framework will guide the processes through which DP3 may be applied, monitored, evaluated, updated, and sustained so as to ensure that the plan remains both effective and relevant.

Implementation

The Baltimore Office of Sustainability is responsible for general oversight , maintenance and progress reporting of the DP3 plan.. The execution of each strategy and action, however, will primarily lie within the responsibilities of lead agencies that were identified for their capacity for overseeing implementation of individual actions.

A key to creating a viable mitigation and adaptation plan is identifying and capitalizing upon existing efforts and programs. Therefore, additional guidance is provided in this chapter that will assist other agencies with implementing DP3 strategies and actions. It urges for a process by which government agencies may incorporate DP3 requirements into planning tools, such as comprehensive or capital improvement plans, where appropriate.

The implementation guidance segment below calls attention to key details which will guide and manage the implementation of the strategies and actions recommended in this plan. It identifies the relationship each strategy may share with existing efforts, policies, and plans so as to highlight the potential to coordinate ongoing efforts. These existing initiatives may include other plans, such as the Climate Action Plan (CAP); the Baltimore Sustainability Plan; Emergency Support Functions (ESF); and the Community Rating System (CRS) among others, or may generally refer to entire agencies or organizations.

Just as the list of strategies in Chapter 5 had noted key stakeholders, the list below identifies lead agencies that are likely to oversee the progress of that individual strategy (for a glossary of acronyms, please refer to the list in Appendix __). An estimated timeframe is also noted for each strategy. The period of implementation may be ongoing, short, medium, or long. Again, varying timeframes may be indicated for individual actions by the letters O, S, M, and L. Financial support for the implementation of these strategies had also been considered, and possible sources are suggested for each. Some metrics and performance measures have been identified, but this is not an exhaustive list, and additional indicators will be added as the implementation process begins.

DP3 is an ongoing process, and continued public involvement is critical. A number of strategies and their actions rely heavily on the establishment and use of comprehensive education and outreach efforts. In addition to creating a process for public input and community involvement, outreach efforts ensure that residents are provided with adequate information and resources for responding to hazard warnings.

DP3 Monitoring and Evaluation, Maintenance and Revision

In order to evaluate the successes and limits of DP3, there must be a process for monitoring the implementation of strategies and actions. Monitoring is best conducted through an organized and routine process that will measure and assess the progress of strategy implementation, evaluating the effectiveness of those recommendations. The Baltimore Office of Sustainability in collaboration with the Sustainability Commission's Climate Committee will be in charge of maintenance, monitoring, and reporting of the DP3 Plan. If necessary, these monitoring bodies may call a meeting of the DP3 Advisory Committee or its subcommittees to propose, consider, and adopt revisions as formal amendments to the plan.

The monitoring body, in its review process, will examine DP3's implementation efforts and continued viability with respect to changing circumstances or strategies, implementation progress, plan modification, the need for any additional information or elements. Should the implementation of any one strategy or action prove exceedingly difficult, the Climate Committee will investigate possible restrictions (e.g. outside circumstances) and consider various solutions for overcoming those barriers—either by removing a particular constraint or reconsidering the action

Steps taken to monitor progress may include:

- Determine how strategies and actions will be monitored; establishing a collection of indicators to measure success.
- Coordinate, compile, and disseminate hazard mitigation funding information.
- Review of annual reports produced by lead agencies tasked with the implementation of adaptation and mitigation projects or activities as identified in Chapter 5 of this Plan.
- Review progress and completion of strategies.
- Maintain and revise the strategy and action list as needed.
- Research and identify changing or new natural hazards which may affect Baltimore City.

The plan monitoring and refinement strategy should include a post-disaster component to identify a framework for reviewing the plan after a future major hazard event. This component will facilitate revisions, as needed, based on new experiences or circumstances. This process will require continued coordination with Baltimore's Mayor's Office of Emergency Management (MOEM) and the Baltimore City Health Department (BCHD). Should this process indicate a need for any revisions, they will be incorporated into the routine plan update noted above. Additionally, following a hazard event, this plan should also be reviewed in order to assess its continued applicability or any needs for revisions.

Following an evaluation and revision schedule, DP3 will be continuously updated as new information becomes available. In compliance with FEMA requirements, the Plan will also be updated every five years and presented to FEMA to reflect any new findings.

Portions of the DP3 Plan will be routinely reviewed. Comments and recommendations offered by lead agencies in charge of implementation, DP3 Advisory committee members, City and State Hazard Mitigation Officers, and public comment will be considered and incorporated into plan updates. Reevaluation, updating, and revision will be ongoing. For each major FEMA update, the climate science will be reviewed and strategies updated to reflect new concerns or vulnerabilities. The public will also be given an opportunity to provide feedback about implementation to date and updates to the plan.

DP3 progress and activities will continue to engage diverse audiences across Baltimore, including the general public. When appropriate, news and information will be shared on the Baltimore Office of Sustainability website and the City's natural hazards site.

Funding Sources

A number of financing options are available for the development, operation, and maintenance of hazard mitigation and climate adaptation measures. Identification of these potential funding resources is an essential element to achieving the City's resilience goals. Funding opportunities and sources are constantly changing. For instance, the City of Baltimore currently remains eligible for Hazard Mitigation Grant Program (HMGP) funding as a result of Hurricane Sandy. HMGP provides funding to implement long-term hazard mitigation measures after a major disaster declaration in order to reduce the loss of life and property due to natural disasters. Since Hurricane Sandy occurred in late 2012, this funding for numerous projects, such as generators, draining/flooding reduction efforts, acquisition and demolition, and wind retrofitting is currently available, but for a limited time. The list below is a quick look at potential funding sources at the time this plan was developed. Often, opportunities for funding will need to be explored in greater detail by the lead agency and stakeholders.

The Federal Emergency Management Agency | The Federal Emergency Management Agency (FEMA) funds several programs, coordinated through the Maryland Emergency Management Agency (see below), which assist with preparedness, mitigation, and response efforts.

Hazard Mitigation Grant Program | FEMA's Hazard Mitigation Grant Program (HMGP) provides grants to States, local governments, and Indian tribes for long-term hazard mitigation projects following a major disaster declaration. The purpose of the program is to reduce the loss of life and property in future disasters by funding mitigation measures during the recovery phase of a natural disaster. In the case of flood mitigation, projects can include the flood proofing or acquisition and relocation of flood prone properties, the elevation of structures in compliance with National Flood Insurance Program (NFIP) standards, and other flood control measures, including structural projects, where identified as cost-effective. FEMA conducts a final eligibility review to ensure compliance with Federal regulations. HMGP projects must comply with Federal environmental laws and regulations, be cost-effective, and be technically feasible. Although State and local units of government are eligible applicants, HMGP funds can be used on private property for eligible projects. The HMGP gives priority to properties identified by FEMA as repetitive-loss properties.

Flood Mitigation Assistance Program | The Flood Mitigation Assistance (FMA) program can provide funds to assist States and communities implement measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under NFIP. Three types of FEMA grants are available to States and communities: (1) Planning, (2) Project, and (3) Management Cost. The funds are coordinated through Maryland's Hazard Mitigation Officer. In addition to participating in the NFIP, eligible program applicants must meet cost-benefit criteria established by FEMA. Mitigation of repetitive-loss properties is given a high priority under this program. Increased cost of compliance (ICC) coverage under the NFIP may provide a funding source for bringing noncompliant structures into compliance after a flood loss.

Public Assistance Program | FEMA's Public Assistance Program provides supplemental financial assistance to State, local governments and certain private, non-profit organizations for response and recovery activities as a result of a Presidentially-declared disaster. The Public Assistance Program provides Federal grant assistance for the repair, replacement or restoration of disaster-damaged, publicly owned and uninsured facilities. This grant funding is provided at a 75% Federal/25% applicant grant share formula. The Public Assistance Program may pay for mitigation measures under Section 406 of the Stafford Act.

Pre-Disaster Mitigation Program | FEMA's Pre-Disaster Mitigation (PDM) program provides funds to states, territories, Indian tribal governments, communities, and universities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event. Funding these plans and projects reduces overall risks to the population and structures, while also reducing reliance on funding from actual disaster declarations. PDM grants are to be awarded on a competitive basis and without reference to state allocations, quotas, or other formula-based allocation of funds. Examples of eligible projects include property acquisition, structure acquisition and demolition or relocation, structure elevation, safe room construction, dry flood proofing of nonresidential structures and historic residential structures, and minor localized flood reduction projects. Individual homeowners and businesses may not apply directly to the program; however an eligible Applicant or Sub-applicant may apply on their behalf.

Repetitive Flood Claims Grants | FEMA's Repetitive Flood Claims Program (RFC) provides funds on an annual basis to reduce the risk of flood damage to individual properties insured under the NFIP that have had one or more claim payments for flood damages. The Repetitive Flood Claims (RFC) grant program was authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004, which amended the National Flood Insurance Act of 1968. RFC provides funding to reduce or eliminate the long-term risk of flood damage to structures insured under the National Flood Insurance Program (NFIP) that have had one or more claim payments for flood damages.

Severe Repetitive Loss Grants | FEMA's Severe Repetitive Loss (SRL) grant program was authorized by the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004, which amended the National Flood Insurance Act of 1968 to provide funding to reduce or eliminate the long-term risk of flood damage to severe repetitive loss structures insured under the National Flood Insurance Program. An SRL property is defined as a residential property that is covered under an NFIP flood insurance policy and:

- That has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or
- For which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.
- For both (a) and (b) above, at least two of the referenced claims must have occurred within any ten-year period, and must be greater than 10 days apart.
- Examples of eligible projects include property acquisition, structure removal or relocations, structure elevation, dry flood proofing of residential structures, mitigation reconstruction, and minor localized flood reduction projects.

National Training and Education Division | In addition to financial resources, FEMA offers a National Training Program. At the time of print, the National Training and Education Division had been offering more than 125 courses to help build critical skills that responders need to function effectively in mass consequence events.

U.S. Department of Housing and Urban Development (HUD) **Community Development Block Grant Program** | Community Development Block Grant (CDBG) programs, funded by the U.S. Department of Housing and Urban Development (HUD), provide communities with resources to address a wide range of unique community development needs, including disaster recovery and neighborhood stabilization. Over a one-, two-, or three-year period, as selected by the grantee, not less than 70 percent of CDBG funds must be used for activities that benefit low- and moderate-income persons. In addition, each activity must meet one of the following national objectives for the program: benefit low- and moderate-income persons, prevention or elimination of slums or blight, or address community development needs having a particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community for which other funding is not available. Depending on the nature of the hazard event, possible use of this assistance may support repair to damaged housing; acquisition and demolition of significantly damaged dwellings; construction of new housing; or repairs to publicly-owned utility systems, streets, sidewalks, or other infrastructure.

U.S. Small Business Administration Loan Programs | The U.S. Small Business Administration (SBA) provides low-interest disaster loans to homeowners, renters, businesses of all sizes, and most private nonprofit organizations. SBA disaster loans can be used to repair or replace the following items damaged or destroyed in a declared disaster: real estate, personal property, machinery and equipment, and inventory and business assets. Types of disaster loans include Home and Personal Property Loans, Business Physical Disaster Loans, and Military Reservists Economic Injury Loans. Additionally, Drought Disaster Assistance may be available through Economic Injury Disaster Loans.

U.S. Army Corps of Engineers | The U.S. Army Corps of Engineers programs are potential sources of funding, particularly for implementing flood adaptation and mitigation recommendations of this plan.

U.S. Fire Administration | The mission of the U.S. Fire Administration (USFA), an entity of FEMA, is to provide national leadership to foster a solid foundation for our fire and emergency services stakeholders in prevention, preparedness, and response. USFA's National Fire Academy provides tuition-free training in firefighting, fire prevention, emergency medical services, and related areas to persons with substantial involvement in the fire control and prevention, emergency medical services, fire-related emergency management activities, and related professions.

Additionally, USFA administers several grant programs that are designed to assist local fire departments and other organizations in protecting citizens and firefighters against the effects of fire and fire-related incidents. These programs include the Assistance to Firefighters Grant program, the Fire Prevention and Safety Grant programs, and the Staffing for Adequate Fire and Emergency Response (SAFER) Grant program.

Chemical Emergency Preparedness and Prevention (CEPP) Technical Assistance Grants Program | CEPP programs provide financial assistance for chemical accident prevention, for chemical emergency planning, and for community right-to-know programs which are established to prevent or eliminate unreasonable risk to the health and environment of communities within the State. The Innovative Technical Assistance Grants are offered to improve the ability to protect public health and safety and involve the development of technical assistance or similar materials that could be used directly or adapted by other States/Tribes or Local Emergency Planning Committees (LEPCs). Projects which address implementing the Risk Management Program under the Clean Air Act Section 112(r) are especially of interest.

National Institute of Environmental Health Sciences (NIEHS) Hazardous Waste Worker Health and Safety Training | The Hazardous Waste Worker Education and Training Program (WTEP) is sponsored by the National Institutes of Health, Department of Health and Human Services to provide assistance for Superfund Site worker training. The program has compiled a number of resources related to emergency preparedness and response, offering these resources to address issues in government preparedness and public preparedness. Sample resources offered include Emergency Responders Health Monitoring and Surveillance (ERHMS) Document and Guide for Key Decision Makers, the Guidance for Managing Worker Fatigue During Disaster Operations , a report on DISASTER PREPAREDNESS: Better Planning Would Improve OSHA , and Talking About Disasters: Guide for Standard Messages - 2004 Edition.

Maryland Emergency Management Agency | The Maryland Emergency Management Agency (MEMA) was created by the Maryland legislature to ensure that our state is prepared to deal with large-scale emergencies. MEMA is responsible for coordinating the state's response in any major emergency or disaster. This includes supporting local governments as needed or requested, and coordinating assistance with the Federal Emergency Management Agency (FEMA) and other federal partners. MEMA provides resources to communities through various grant programs, including the Public Assistance Program and the Hazard Mitigation Grant Program (both are described above).

Maryland Department of Natural Resources | The Maryland Department of Natural Resources (MDNR) states its mission in securing a sustainable future for our environment, society, and economy by preserving, protecting, restoring, and enhancing the State's natural resources. Through a number of programs, MDNR offers tools, resources, and financial assistance to other state agencies, businesses, and communities pursuing efforts that further this mission. This includes initiatives to build community resilience through strengthening key natural systems. Many of the financial programs will be valuable for actions that address the health and resiliency of the urban forest, goals for habitat restoration and conservation, as well as for actions that intend to strengthen coastal and other hydrological systems. The list below is only a sample of the programs MDNR has to offer.

Coastal Zone Management Program | The Chesapeake and Coastal Service program is an umbrella program for other coastal and watershed initiatives. It includes funding resources such as the Chesapeake & Atlantic Coastal Bays Trust Fund, to address pollution and water quality, the CoastSmart Communities initiative, which aims to assist businesses, communities and local governments with access to available products and services that address the current risks associated with coastal hazards and the potential increased impacts of those hazards in the future due to climate change.

It also establishes the Watershed Assistance Collaborative, a partnership that provides services and technical assistance to communities to advance restoration activities and projects. By leveraging resources of existing programs, the Watershed Assistance Collaborative exists to provide coordinated capacity building opportunities to local implementers. Communities interested in undertaking comprehensive watershed protection and restoration activities are encouraged to take advantage of the services offered through this partnership. The Collaborative offers the tools, resources and outreach needed to work toward large nonpoint source pollution implementation and restoration efforts.

Additional MDNR Programs | Additional programs, support restoration efforts through the development of new technologies, can benefit private landowners with major projects, and even offer financial assistance to actions that can provide resources and education to the public about natural resources and efforts to strengthen and restore these features. An extensive list of MDNR's financial resources may be found online, at their Grants and Loans Center webpage.

Maryland Energy Administration | The Maryland Energy Administration (MEA) offers a number of State and Local Government Incentives for energy improvements, including programs that support fuel efficiency.

Together with the resources noted above, supplementary funding should be explored through local or regional resources, or may be available for more targeted or specific projects. In the Implementation Guidance segment below, potential financing programs have been identified for each strategy. These sources have not been secured, nor are they guaranteed. Furthermore, the limited size of each list does not suggest that additional funding opportunities don't exist. Again, new funding sources may later develop, or the availability of currently known resources may change in the future.

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
IN-1	(MOEM)	Protect and enhance the resiliency and redundancy of electricity system					
Work with the Maryland Public Service Commission (PSC) to minimize power outages from the local electric utility during extreme weather events by identifying and protecting critical energy facilities and located within the City	MOEM MEMA	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant	• Evaluation or development of an alternative energy plan • Percentage of electricity generated within the 500-year floodplain able to remain online after a 500-year flood event • Percentage of assets at or above their loading limits during peak demand periods (e.g., during heat waves) • Resiliency investment in the power supply system • Successful creation and employment of a maintenance and training program	Yes	ESF-12
Evaluate the City of Baltimore utility distribution system, and identify "underground utility districts" using BGE's May 2013 short term reliability improvement plan	PSC DPW- city	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant	To Be Determined with Future Data	Yes	ESF-12
Support BGE's collaboration with the Maryland Public Service Commission to implement various smart grid solutions that will provide the City with real-time access to data during events	DPW	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant	To Be Determined with Future Data	Yes	ESF-12
Identify, harden, and water seal critical infrastructure relative to electrical, heating, and ventilation hardware within the flood plain	MOEM	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short-Medium	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant	To Be Determined with Future Data	Yes	ESF-12: COOP
Increase resiliency in our energy generation system by encouraging the development of decentralized power generation and developing fuel flexibility capabilities	MOEM	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short-Medium	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant	To Be Determined with Future Data	Yes	COOP
Develop a comprehensive maintenance and training program for City employees at facilities with backup generators to ensure proper placement, hook-up and function during hazard events.	MOEM	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short-Medium	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant			
Install external generator hookups for critical City facilities that depend on mobile generators for backup power	MOEM	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short-Medium	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant	To Be Determined with Future Data		COOP
Partner with utility to evaluate protecting power and utility lines from all hazards.	MOEM	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short-Medium	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant	To Be Determined with Future Data	Yes	
Determine low-laying substation vulnerability and outline options for adaptation and mitigation.	PSC DPW- city	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short	• Baltimore City CIP • Federal Sources • BGE's existing funds allocated through the Smart Grid Investment Grant		Yes	ESF-12
Evaluate and protect low laying infrastructure - switching vaults, conduit and transformers	MOEM PSC	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator	Short-Medium	• BGE • Federal Funds • Local Funds		Yes	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
IN-2	(BoS)	Increase energy conservation efforts					
Increase energy efficiency across all sectors through education, efficiency retrofits, and building management systems	BoS	BGE, Building owners, City Delegates, DOP, DPW, Energy Office, PSC	Medium	• MEA	• Overall energy consumption and use • Number of permits for energy efficiency retrofits or upgrades • Number of critical facilities connected to cogeneration systems • Use of the City's electricity demand-response program	Yes	
Encourage critical facilities and institutions to connect to existing cogeneration systems, or develop new cogeneration systems	Energy Office (MEO)	BOS,BGE, Building owners, DOP, DPW, Energy Office, PSC	Short- Long	• Federal Emergency Grant Funds • Local Funds		Yes	ESF-12
Continue the City's electricity demand-response program during peak usage or pre-blackout periods	BGE	BGE, Building owners, City Delegates, DOP, DPW, Energy Office, PSC	Medium	• BGE • Federal Funds	To Be Determined with Future Data	Yes	
IN-3	(MEO)	Ensure backup power generation for critical facilities and identified key infrastructure during power outages					
Investigate off-grid, on-site renewable energy systems, generators, and technologies for critical facilities to ensure redundancy of energy systems	DGS	BGE, DGS, DHMH, DOP, DOT, DPW, MOEM	Medium	• Baltimore City CIP • Federal Programs	• Number of critical facilities with backup power generation sources • Percentage of hospital and healthcare facility patient capacity (e.g. hospital beds) in flood-prone areas meeting resiliency requirements • City buildings with backup generators • Number of critical facilities connected to CHP cogeneration systems	Yes	ESF-8,12
Seek funding to purchase and install generators for all city building designated as critical to agency functions	DGS	DGS, DOP, DOT, DPW, MOEM	Short	• Federal Grants • State Grants	To Be Determined with Future Data	No	ESF-12, 7
Develop Combined Heat and Power (CHP) co-generation plants at identified critical facilities	MEO	DGS, DOP, DOT, DPW, MOEM	Medium	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	Yes	
Evaluate and ensure backup power generation is available to healthcare facilities (nursing homes, critical care facilities, hospitals, etc.)	MDH2E	DGS, DOP, DOT, DPW, MOEM	Medium	• Hospital Budgets • Federal Emergency Funds	To Be Determined with Future Data		
IN-4	(MOEM)	Protect and manage compressed liquefied natural gas sites and (city) fueling stations before and during hazard events					
Work with BGE to ensure existing preparedness plans for Spring Gardens liquefied natural gas site incorporate its vulnerability to present and predicted flooding, storm surge and sea level rise	BGE	BGE, DGS, DOP, DOT, DPW, Veolia	Medium	BGE	• Completion of a Spring Gardens study and evaluation • Percentage of liquid fuel assets in the floodplain hardened against flood events • Revisions to building codes to address hazard resilience • Liquid fuel facilities with anchored storage tanks that are 50 gallons or larger		ESF-3, 10
Adopt building code that requires anchoring of 50 gallon storage tanks or larger	MOEM/HCD	MDE,BGE, DGS, DOP, DOT, DPW, Veolia	Medium		To Be Determined with Future Data		
Support the Maryland Public Service Commission's effort to accelerate replacement of aging natural gas infrastructure which will harden the system against flooding	BGE	BGE, DGS, DOP, DOT, DPW, Veolia	Medium	BGE			

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
IN-5	(MOEM)	Evaluate and improve resiliency of liquid fuels infrastructure					
Design and implement a generator program that assists private gas stations in securing backup generators, especially those stations along major evacuation routes	MOEM	BCFD, BCPD, DES, DOT, DPW, MOE	Medium	• Fuel Up Maryland • Federal Sources	• Percentage of gas stations with quick-connects for generators • Percentage of liquid fuel assets in the floodplain hardened against a flood event • Development and implementation of a generator program • Program or plan for allocating fuel supplies to emergency responders first		
Increase and ensure fuel availability during distribution disruptions	MOEM	BCFD, BCPD, DES, DOT, DPW, MOE	Medium		To Be Determined with Future Data		
Ensure fuel for generators and delivery priority is given to critical facilities and emergency responders.	MOEM	BCFD, BCPD, DES, DOT, DPW, MOE	Medium		To Be Determined with Future Data		
IN-6	(MOEM)	Evaluate and improve resiliency of communication systems that are in place for sudden extreme weather events					
Utilize new technologies such as fiber optics, external hook-ups, and mobile generators to improve resiliency	MOEM	BGE, DOT, Energy Office, FCC, MOIT, Private Entities, PSC	Medium	• Federal Grant Programs • State Grant Programs • Baltimore City CIP	• Percentage of communication system transitioned to fiber optics and/or other alternative technologies	No	ESF-2
Build redundancy into all public and inter-agency warning and communication systems	MOEM	BGE, DOT, Energy Office, FCC, MOIT, Private Entities, PSC	Short	• Federal Grant Programs • State Grant Programs • Baltimore City CIP	• Number or percentage of critical telecommunication facilities implementing hazard resiliency measures into planning and operations	No	ESF-2
Identify best practices for the installation and management of flood proofing of all communications infrastructure at risk of water damage	DGS + DOP	BGE, DOT, MOE, MOEM, FCC, MOIT, Private Entities, PSC	Short	• Federal Grant Programs • State Grant Programs • Baltimore City CIP	• Number of buildings transitioned per year	No	ESF-2, 3
Implement additional nurse triage phone lines and community health centers to reduce medical surge on hospitals	MDH2E	BGE, MOEM, DOT, Energy Office, FCC, MOIT, Private Entities, PSC	Short	• Private Funding	• Percentage of hospitals where triage phone lines are added	No	ESF-8,12
Evaluate and improve early warning systems for hazard events	MOEM	BCPD, BCFD, BGE, DHMH, DOP, DOT, Energy Office, FCC, JIS, MOIT, Private Entities, PSC	Short	• Baltimore City CIP	• Percentage of people reached • System improvements	Yes	
Ensure continued operation of city governments various computer mainframes for email, control systems, and internet service by having stand-by batteries for each with a capacity sufficient for backup generation to operate	MOIT	BGE, DOT, Energy Office, FCC, MOEM, Private Entities, PSC	Short	• Baltimore City CIP	• Systems functioning in an emergency		COOP
Identify shared communication technology for emergency responders and government agencies to ensure continued and coordinated communication during emergency events	MOEM	BGE, DOT, Energy Office, FCC, MOIT, Private Entities, PSC	Short	• Baltimore City CIP	To Be Determined with Future Data		
IN-7	(DOT)	Integrate climate change into transportation design, building and maintenance					
Determine the coastal storm vulnerability and complete an exposure assessment of City transportation assets	DOT	CSX, DOT, DPW, MTA, Private Contractors	Short	• Federal Grant Programs	• Number of lane-miles reconstructed, repaved, or resurfaced • Percentage of Baltimore's transportation assets adapted for climate change resiliency • Reference to climate adaptation and hazard mitigation in transportation planning documents • New project compliance with the alternative rating systems	No	ESF-1
Improve stormwater management, operations and maintenance for stream flooding that erodes away bridge supports	DOT	CSX, DOT, DPW, MTA, Private Contractors	Ongoing	• Incorporate into existing Capitol Projects	To Be Determined with Future Data	No	ESF-1,3
Incorporate compliance with earthquake standards to withstand a magnitude eight earthquake for all new, improved and rebuilt bridges	DOT	CSX, DOT, DPW, MTA, Private Contractors	Medium	• Federal Funds • City Capitol Funds	To Be Determined with Future Data	No	ESF-1
Design bridges expansion joints for longer periods of high heat and develop a more robust inspection and maintenance process	DOT	CSX, DOT, DPW, MTA, Private Contractors	Short	• Incorporate into existing Capitol Projects	To Be Determined with Future Data	No	ESF-1

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
Research utilizing existing and new rating systems for all new infrastructure and road projects	DOT	CSX, DOT, DPW, MTA, Private Contractors	Medium		To Be Determined with Future Data		
Identify, investigate, and incorporate Best Management Practices as they relate to transportation design, construction and maintenance	DOT	CSX, DOT, DPW, MTA, Private Contractors	Medium		To Be Determined with Future Data		
Require that backup solar powered street lights and signals be integrated along evacuation routes and high traffic areas	DOT	CSX, DOT, DPW, MTA, Private Contractors	Medium	Emergency Grant Programs	To Be Determined with Future Data	Yes	
IN-8	(MOEM)	Identify additional alternative routes and modes for effective transport and evacuation efforts during emergency situations					
Evaluate existing systems and develop a comprehensive evacuation plan	MOEM	BCFD, BCHD, DOP, DOT, MOEM	Short	• Consider looking to MEMA or FEMA for planning assistance through the hazard mitigation grant program	• Inventory and database of transportation routes and vulnerability to current and future flood • Altered evacuation route procedures where necessary	No	ESF-1, 11
Coordinate evacuation plans with regional partners	MOEM	BCFD, BCHD, DOP, DOT, MOEM	Short-Medium	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	
Develop and prioritize clearance of specified transportation routes for delivery of emergency response supplies	DOT MOEM	BCFD, BCHD, DOP, DOT, MOEM	Short	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	
Educate the public on the dangers of driving through flooded roads	DOT MOEM	BCFD, BCHD, DOP, DOT, MOEM	Short	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	
Make available a network of dedicated pedestrian and bicycle transportation routes leading into and throughout the City	DOT	BCFD, BCHD, DOP, DOT, MOEM	Ongoing	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	Yes	
Identify and collaborate with bicycle groups and repair shops to assist in emergency response and accommodate alternate transportation needs	DOT	BCFD, BCHD, DOP, DOT, MOEM	Short	• Private Funds		No	
IN-9	(DOT)	Alter transportation systems in flood-prone areas in order to effectively manage stormwater					
Prioritize infrastructure upgrades for roads identified at risk of flooding through the use of elevation data and Sea, Lake and Overland Surges from Hurricanes (SLOSH) model results	DOT	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Long	• The City's existing capital plan	• Number of lane-miles of reconstructed, repaved, or resurfaced roadways in flood-prone areas • Percentage of Baltimore's transportation assets adapted for climate change resiliency • Stormwater management technologies implemented with transportation projects within flood-prone areas	No	ESF-1
Raise streets in identified flood prone areas as they are redeveloped	DOT	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Long	• Federal Emergency Mangement Funding programs • Baltimore City Capitol Budget	To Be Determined with Future Data	No	
Encourage development of Green Streets in flood prone areas and throughout the City	Planning/ DOT	DOT, DPW, MON, Public, NGO's, Property Owners	Short-Ongoing		To Be Determined with Future Data	Yes	ESF-1
Encourage use of permeable pavement in non-critical areas – low-use roadways, sidewalks, parking lots and alleys where soils permit proper drainage	DPW	DOT, DPW, MON, Public, NGO's, Property Owners, Rec & Parks	Medium		To Be Determined with Future Data	No	ESF-1
Add pumps or other mitigation alternatives to streets as they are redeveloped (if needed)	DPW	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Long	• Federal Emergency Mangement Funding programs • Baltimore City Capitol Budget	To Be Determined with Future Data	Yes	ESF-1, 3
Assess need for new culvert capacity and identify where upgrades are needed	DPW	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Long	• Emergency Grant Programs	To Be Determined with Future Data	No	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
Conduct an in-depth analysis of the impacts of drain fields that feed the harbor	DPW	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Medium-Long	• Emergency Grant Programs	To Be Determined with Future Data	No	ESF-3
Expand and reinforce existing stormwater education programs	DPW	MTA, Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Long		To Be Determined with Future Data	No	ESF-11
Design and implement floodgates and barriers in transportation tunnels	MOEM	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MON, NGOs, MTA	Long	• Funding options dependent on ownership of tunnel.	To Be Determined with Future Data	No	
Encourage Federal and State Government to design and install floodgates and barriers at vulnerable transportation tunnels	FHWA	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MON, NGOs,MTA	Long		To Be Determined with Future Data	No	ESF-1
Upgrade existing floodgate hardware and mechanisms to control rise rate of water into all city tunnels	MOEM, CSX, Amtrak, MTA FHWA	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MON, NGOs, MTA	Long		To Be Determined with Future Data	No	ESF-3
IN-10	(CSX, Amtrack, MTA)	Ensure structural stability of all transportation tunnels to reduce impact from seismic activity					
Repair cracks and leaks in all tunnels to reduce impact of seismic activity	CSX, Amtrak, MTA	Amtrak, CSX, DOT, DPW, FHWA, MDTA, MOEM, MTA	Medium	Funding options dependent on ownership of tunnel.	• Database of all transportation tunnels and their vulnerability to seismic activity • Construction and maintenance projects addressing vulnerability of tunnels to seismic activity	No	ESF-1
Follow Federal, State and Local criteria for the stabilization of Historic transportation tunnels (e.g. Howard Street)	CSX, Amtrak, MTA	Amtrak, CSX, DOT, DPW, FHWA, MOEM, MTA	Long	Funding options dependent on ownership of tunnel.	To Be Determined with Future Data	No	
Install a seismically resistant fire standpipe, air monitoring, and automatic valve system in all tunnels to provide a fully automated and monitored fire suppression system	CSX, Amtrak, MTA	Amtrak, CSX, DOT, DPW, FHWA, MDTA, MOEM	Long		To Be Determined with Future Data	No	ESF-1, 4, 10
IN-11	(DOT)	Evaluate changes to road maintenance and construction materials based on anticipated changes in climate					
Implement a repaving strategy that reduces heat-related damage to asphalt and incorporates maintenance and operations that extend the life of the road surface	DOT	DOT, SHA	Long	• The analysis of City infrastructure is an ongoing priority and could be completed as part of this ongoing process. • The City's existing capital plan	• Development of a repaving strategy • Number of lane-miles reconstructed, repaved, or resurfaced • Percentage of Baltimore's transportation assets adapted for climate change resiliency • Reference to climate change and scientific projections in road maintenance and construction project materials.	Yes	ESF-1
Develop a reconstruction and repair strategy that reduces damage to concrete and incorporates better maintenance and operations	DOT	DOT, SHA	Long	• The analysis of City infrastructure is an ongoing priority and could be completed as part of this ongoing process. • The City's existing capital plan	To Be Determined with Future Data	No	
Develop deicing strategies and materials that are effective in extreme cold temperatures and prolonged events to stabilize roadway and bridge surfaces	DOT	DOT, SHA	Long		To Be Determined with Future Data	No	
Design pavement sections and materials that withstand longer periods of extreme heat events	DOT	DOT, SHA	Long	• The analysis of City infrastructure is an ongoing priority and could be completed as part of this ongoing process. • The City's existing capital plan	To Be Determined with Future Data	No	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
IN-12	(DOT)	Enhance the resiliency of the city's waterfront to better adapt to impacts from hazard events and climate change					
Raise bulkhead height along shoreline areas most at risk	DOT	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, MOEM	Long	• Federal Funding Sources	• Federal dollars secured for coastal protection projects • Linear miles of coastal edge restored • Number or percentage of buildings with reduced coastal risk due to coastal protection projects • Map and database of waterfront edges • Revisions to coastal area design guidelines that incorporate climate change	No	
Utilize vegetation and stone to stabilize and armor unprotected shorelines	DOT	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, MOEM	Short		To Be Determined with Future Data	No	
Encourage the development of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures	USACE DOT MOEM DGS	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, MOEM	Long	• Federal Emergency Management Funds • Wetland and Wildlife funds • City Capitol Budget	To Be Determined with Future Data	No	
Review and enhance coastal area design guidelines to better mitigate the impacts of flooding	MDNR/ Planning	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, MOEM	Long	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	
Enhance and strengthen waterfront zoning and permitting	Planning MDNR	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, MOEM	Long	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	
IN-13	(DPW)	Increase the resilience of all wastewater systems and protect them from current and projected extreme weather events					
Ensure all water and wastewater pumping stations have off-grid, on-site energy sources and/or reliable backup power sources by increasing the number of backups and pulling electricity from different grids	DPW/MEO	DPW, Energy Office, MOEM	Long	• Utility CIP	• Number or percentage of wastewater facilities protected or raised above flood protection levels • Map and database of wastewater systems • Reference to climate change and scientific projections in wastewater project documentation	Yes	ESF-3, 12
Evaluate the sewer system to identify and develop key areas for prevention of raw sewage overflows	DPW	DPW, MOEM	Long	• Federal Funds • State Funds • Local Funds		No	
Develop and adopt increased level of protection for construction, redevelopment, and design of all water and wastewater facilities that incorporate future climate projections	DPW	DPW, Energy Office, MOEM	Long	• Federal Funds • State Funds • Local Funds		No	
Retrofit and harden low-laying pumping stations and treatment plants in flood hazard areas	DPW	DPW, Energy Office, MOEM	Long	• Utility CIP	To Be Determined with Future Data	No	
Ensure effective operations and security for wastewater treatment plants if facilities are overwhelmed by hazard event	DPW	DPW, Energy Office, MOEM	Long		To Be Determined with Future Data	No	ESF-3; COOP
Establish the capability of wastewater treatment plants to function during large storm events and establish protocols for storms that overwhelm the system	DPW	DPW, Energy Office, MOEM	Long	Federal, State and Local funds	To Be Determined with Future Data	No	ESF-3
Increase stormwater recharge areas and quantity management to prevent flooding from overflows	DPW	DPW, MOEM	Long	• Utility CIP	To Be Determined with Future Data	No	
Conduct an assessment of the City's current water system to identify age, condition of infrastructure, capacity, weaknesses and areas for priority upgrades	DPW	DPW, MOEM	Long		To Be Determined with Future Data	No	ESF-3
Conduct and utilize a detailed risk assessment to determine vulnerability of the sewage treatment plant to prevent overflows from extreme storm events	DPW	DPW, Energy Office, MOEM	Long	• Federal Funds • State Funds • Local Funds		No	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
Determine the elevation of sewage treatment buildings, tank construction details, and if the plant is at risk of back flow, for improvements to withstand coastal storm events	DPW	DPW, Planning, MOEM	Long	• Utility CIP	To Be Determined with Future Data	No	
Retrofit wastewater treatment facility and methane gas storage system to withstand seismic activity to protect against earthquakes. Design facility to exceed current building codes	DPW	DPW, DGS, MOEM	Long	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	ESF-3
IN-14	(DPW)	Integrate resiliency, redundancy, and structural stability into the City's drinking and water system to ensure safe and reliable water storage and distribution					
Repair leaks and improve connection from all City reservoirs and the Susquehanna River	DPW	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Short-Long	• The City's existing capital plan • Federal Funding Sources	• Number and percentage of facilities that have integrated security and preparedness into budgeting, training, and manpower responsibilities • Percentage of utilities that can meet minimum daily demand with their primary production/treatment plant non-functional	No	
Provide water conservation education, and continue to protect our watersheds to assist in maintaining water quality	DPW MDNR	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Short	• Grant Progams • Educational Budget of Stormwater Utility	To Be Determined with Future Data	Yes	
Ensure dam emergency plans account for impacts of climate change	DPW MOEM	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Medium		To Be Determined with Future Data	No	
Identify and document post damage responsibilities in memorandums of understanding as addendums to Reservoir Watershed Management Agreement	DPW	MOEM, Planning,	Short			No	ESF-3 ESF-5
Review dam capacity, load and failure points and review them against 1,000 year and 10,000 year precipitation events	DPW MOEM	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Medium	Federal Emergency Grants	To Be Determined with Future Data	No	
Conduct a study to determine seismic design standards and seismic resiliency of drinking water distribution system (tunnels, piping, clean water pump stations, dams, shafts, and tanks)	DPW	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Medium	Federal Emergency Grants	To Be Determined with Future Data	No	ESF-3
Increase stormwater recharge areas and quantity management	DPW	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Short			Yes	ESF-3
Evaluate the impacts of sediment loading on reservoir capacity	DPW	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Short	Utility CIP funds	To Be Determined with Future Data	No	
Manage watershed forests to provide maximum benefits for water quality and to maintain resiliency during extreme weather events	MDNR	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Short		To Be Determined with Future Data	Yes	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
Adopt new policies on salt application to prevent high salinization on drinking water supplies	DOT	DPW, MDE, SHA, Balto Co Govt, Regional watershed groups, NGO's	Medium	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	ESF-3, 10, 8
Establish a structured Firming Program to maintain adequate storage and water quality in the source-water reservoirs during drought conditions	DPW MOEM	BCHD, BCRP, DHCD, DHMH, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Medium		To Be Determined with Future Data		
Maintain appropriate agreements with Susquehanna River Basin Commission (SRBC) and the Exelon Power Company to ensure adequate water withdraws from the Susquehanna River during drought emergency	DPW	BCHD, BCRP, DHCD, DHMH, DOP, DOT, MOEM, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Medium		To Be Determined with Future Data		
IN-15	(DPW)	Conduct an assessment that evaluates and improves all pipes' ability to withstand extreme heat and cold					
Replace old and malfunctioning pipes with new pipes or retrofit existing pipes with new lining	DPW	DOT	Short to Medium; Ongoing	• The analysis of City infrastructure is an ongoing priority and could be completed as part of this ongoing process. • The City's existing capital plan	• Map and database of water pipes highlighting key vulnerabilities • Ongoing maintenance and construction of pipe systems with increased resiliency for natural hazards	Yes	ESF-3
Evaluate and utilize new technology that allows for greater flexibility in pipes as they are replaced	DPW	DOT	Short to Medium; Ongoing	Federal Grant Programs, City Utility CIP	To Be Determined with Future Data		ESF-4
IN-16	(DPW)	Enhance and expand stormwater infrastructure and systems					
Implement the requirements of Baltimore's MS4 (separate stormwater and sewer system) permit	DPW	Community Groups, DOT, DPW, MOEM, MDNR, NGOs, Private Developers, Stormwater Utility	Short	• The Stromwater Utility existing capital plan	• Storm drain upgrades in areas with reoccurring floods • Installation and utilization of flood mitigation devices and strategies • Revisions to storm drain design guidelines	No	
Prioritize storm drain upgrades and replacement in areas with reoccurring flooding	DPW	DOT, Community Groups	Short	Stormwater Utility		No	
Install backflow-prevention devices or other appropriate technology along waterfront to reduce flood risk	DPW	Community Groups, DOT, MOEM,	Medium-Long	• Federal Funds • State Funds • Local Funds		No	
Preserve and protect natural drainage corridors	DPW	Community Groups, DOT, DPW, MOEM, MDNR, NGOs, Private Developers, Stormwater Utility	Short	Ongoing as part of environmental enforcement efforts and stream restoration projects.	To Be Determined with Future Data	No	
Review and revise storm drain design on a continuous basis, to accommodate projected changes in intense rainfall	DPW	Community Groups, DOT, DPW, MOEM, MDNR, NGOs, Private Developers, Stormwater Utility, USACE	Long, Ongoing	• The analysis of City infrastructure is an ongoing priority and could be completed as part of this ongoing process. • The City's existing capital plan	To Be Determined with Future Data	No	
IN-17	(DOP)	Modify urban landscaping requirements and increase permeable surfaces to reduce stormwater runoff					
Support existing stormwater requirements and continue to evaluate and improve Best Management Practices	Planning	BCRP, BDW, BDC, Citizens, DHCD, DOP, DOT, DPW, NGOs, Private Developers	Medium		• Revisions of urban landscape requirement guidelines • Percentage of land covered by impervious surfaces • Number of vegetative roofs or other water conservation elements	No	ESF-3
Encourage urban landscaping requirements and permeable surfaces into community managed open spaces	Planning	BCRP, BDW, BDC, Citizens, DHCD, DOP, DOT, DPW, NGOs, Private Developers	Short	Small grants programs at Parks and People, Other Foundation Grants	To Be Determined with Future Data	No	ESF-3
Utilize water conservation elements such as green roofs, rain gardens, cisterns, and bioswales on residential, commercial, industrial, and City-owned properties to capture stormwater	HCD, Planning, DPW	BDC, BCRP, BDW, Citizens, DHCD, DOP, DOT, DPW, NGOs, Private Developers	Short-Medium		To Be Determined with Future Data	Yes	ESF-3
Encourage permeable paving on low-use pathways	Planning	BCRP, BDC, Citizens, DHCD, DOP, DOT, DPW, NGOs, Developers	Medium			No	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
IN-18	(DPW)	Evaluate and support DPW's stream maintenance program.					
Review and improve status of standing maintenance requirements	DPW	DOT, DOP, MDE, MDNR, MOEM, USACE	Ongoing	• The analysis of City infrastructure is an ongoing priority and could be completed as part of this ongoing process. • The City's existing capital plan	• Number and scale of stream restoration projects • Revisions to maintenance requirements that exceed standard minimums to account for projected changes in climate	No	
Ensure adequate funding is in place to support stream maintenance	DPW	DOT, DOP, MDE, USACE	Ongoing	Stormwater Utility CIP	To Be Determined with Future Data	No	
Identify opportunities where stream restoration efforts will off-set maintenance costs	DPW	DOT, DNR, MDE, MDNR, MOEM, USACE	Ongoing		To Be Determined with Future Data	No	
Identify interdependencies and benefits of stream maintenance with other transportation programs	DOT	DPW, MDE, MDNR	Ongoing		To Be Determined with Future Data	No	
Clear streams on a regular basis, prioritize dredging the stream beds, and increase inspection and cleaning of culverts and storm drains to prevent flooding	DPW	DOT, MDE, MOEM, USACE	Ongoing	Stormwater and DOT ongoing maintenance programs	To Be Determined with Future Data	No	ESF-3
IN-19	(DPW)	Support and increase coordination and information sharing across jurisdictions to better enable mitigation of cross-border impacts on the regions watersheds (e.g., understanding flood conditions upstream in the County)					
Partner with local counties to evaluate major tributaries in all watersheds to determine best management practices for capturing run-off and slowly releasing it (stormwater quantity management)	DPW	BCRP, County Governments, DOP, DPW, MCC, MDNR, NGOs, Stormwater Utility	Ongoing		• Discussion of cross-jurisdictional concerns within comprehensive watershed plans • Coordinated evaluation of regional conditions affecting watersheds	No	
Encourage information sharing within the Chesapeake Bay community to assist in developing best management practices	DPW	County Governments, DOP, MDNR, NGOs	Ongoing		To Be Determined with Future Data	No	
IN-20	(DPW)	Reevaluate and support a comprehensive debris management plan for hazard events					
Investigate best practices for managing and disposing of downed trees, yard waste, building debris, as well as additional household garbage	DPW	Planning, MOEM, R&P, MOEM, BGE, NGOs	Short		• Development of a comprehensive debris management plan • Reference to climate change and hazard resiliency in debris management program documentation	No	ESF-3
Expand and integrate existing programs to reduce or intercept debris before it gets into the streams and harbor	DPW	DPW, DOT, NGOs	Medium	Stormwater Utility Operating Progams and CIP	To Be Determined with Future Data	No	
Develop and promote solid waste management actions for citizens to implement before a hazard event	DPW	DPW, MOEM, NGOs	Short	Existing trash management education budgets.	To Be Determined with Future Data	Yes	
IN-21	(DOP)	Encourage the integration of climate change and natural hazards into private and State planning documents, systems, operations, and maintenance					
Incorporate consideration of hazards and climate adaptation efforts into all plans, systems, operations, and maintenance.	DOP	DPW, DOT, DGS, SHA, MTA, MEMA, MOEM	Medium		• Percentage of hospitals and healthcare facilities incorporating resiliency into programs and planning • Reference to hazard mitigation and climate adaptation actions in new and updated planning documents statewide • Coordination between jurisdictions for improved resiliency efforts	Yes	ESF-1
Ensure Red Line planning incorporates adaptation strategies.	MTA	DOT, DOP	Short		To Be Determined with Future Data	Yes	ESF-1
Ensure hazard scenarios, utilized in vulnerability assessments, are at a minimum 25% greater in intensity and impact than historical record events to date.	DOP	MOEM, DOT, Health Care Community, Hospitals, MD2HE, MEMA, MTA, MOEM, SHA	Ongoing		To Be Determined with Future Data	No	
Develop guidelines for hospital, health care facilities and other institutional entities (e.g. Universities).	MOEM	DOT, Health Care Community, Hospitals, MD2HE, MEMA, MTA, MOEM, SHA	Ongoing	Utilize Hazard Mitigation Grant Programs	To Be Determined with Future Data	No	
Partner with regional air quality institutions to integrate air quality measures and messaging into City climate change policy efforts	BCHD	Health Care Community, Hospitals, MD2HE, MEMA, MTA, MOEM, SHA	Ongoing			Yes	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
IN-22	(DOP)	Develop City policy which requires new city government capital improvement projects to incorporate hazard mitigation principles					
Discourage new public projects in hazard-prone areas such as floodplains or the coastal high hazard areas	DOP	BCHD, BCRP, DGS, DOP, DOT, DPW, MOEM	Short to Medium; Ongoing	• The City's existing capital plan	• Percent of capital improvement projects which incorporate hazard mitigation principles • Projects initiated in hazard-prone areas • Establishment of above-code design requirements for use by critical facilities	No	ESF-3, 5
Utilize hazard mitigation design requirements that exceed minimum standards for critical facilities	DOP	BCHD, BCRP, DGS, DOP, DOT, DPW, Energy Office, MOEM	Short to Medium; Ongoing		To Be Determined with Future Data	No	
Use comprehensive infrastructure assessments to identify infrastructure in need of replacement and prioritize funding for those projects	DGS	BCHD, BCRP, DOP, DOP, DOT, DPW, Energy Office, MOEM	Short to Medium; Ongoing		To Be Determined with Future Data	No	
BL-1	(MOEM)	Develop and implement hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.					
Conduct educational outreach for city-owned, residential, commercial, and industrial buildings about proper storage and disposal of hazardous materials and heating oil	MOEM	BGE, DGS, DOP, DPW, Hospitals, Material Storage Sites	Short	Utilize Hazard Mitigation Grant Programs	• Number and percentage of Critical facilities with hazard protection plans that incorporate natural hazard resilience efforts • Number and percent of utilities with physical and/or procedural controls in place to safeguard hazardous chemicals.	No	
Require hazardous materials stored in city-owned, residential, commercial, and industrial buildings within the floodplain to be elevated a minimum of three feet above the freeboard	MOEM	BGE, DGS, DOP, Hospitals, Material Storage Sites	Medium		To Be Determined with Future Data	No	ESF-5, 10
Require new critical facilities to be designed with redundant operating systems	Planning MOEM	BGE, DGS, DOP, Hospitals, Material Storage Sites	Long	Existing Capitol Budgets	To Be Determined with Future Data	No	ESF-3, 5
Require pre-wiring for generators at all facilities designated critical to agency operations and hazard response	DGS	BGE, DGS, DOP, Hospitals, Material Storage Sites	Medium	Existing Capitol Budgets	To Be Determined with Future Data	No	ESF-3, 5, 12
Develop stricter flood regulations for critical facilities	DOP	BGE, DGS, MOEM, Hospitals, Material Storage Sites	Medium		To Be Determined with Future Data	No	ESF-3, 5
Develop partnership with private fueling stations to provide backup generators in exchange for a commitment to fueling emergency response vehicles during a hazard event	MOEM	BGE, DGS, DOP, Hospitals, Material Storage Sites	Medium		To Be Determined with Future Data	No	
Ensure storage of and access to fuel for generators in critical facilities	MOEM	BGE, DGS, DOP, Hospitals, Material Storage Sites	Medium		To Be Determined with Future Data	No	
BL-2	(DOP)	Enhance City building codes that regulate building within a floodplain or near the waterfront					
Design new projects to be resilient to a mid-century sea level rise projection and adaptable to longer-term impacts	DOP, HCD, MOEM	Baltimore County, BDC, DPW, MDE, Utilities		Existing Capitol Budgets	• Federal dollars secured for coastal protection projects • Number or square footage of buildings implementing flood resiliency measures • Number and percentage of buildings with reduced coastal risk due to coastal protection projects • Revisions to building codes that exceed minimum standards for addressing building resilience within a floodplain and near the waterfront	No	ESF-3, 5
Incorporate climate change and coastal hazard considerations into building codes by increasing freeboard requirements to two feet as buildings are redeveloped and renovated	DOP	Baltimore County, BDW, DHCD, DOP, DPW, MDE, Utilities	Short		To Be Determined with Future Data	No	ESF-3, 5
Continue to regulate to the existing tidal floodplain delineation as adopted 2 February, 2012	DOP	Baltimore County, BDC, DHCD, DOP, DPW, MDE, Utilities	Short		To Be Determined with Future Data	No	ESF-3, 5, 12

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
Incorporate outfall elevation regulations	DPW, DOP	Baltimore County, BDW, DHCD, DOP, MDE	Short-Medium		To Be Determined with Future Data	No	
Develop Construction Best Practices for development within floodplains	DOP	Baltimore County, BDC, DHCD, DOP, DPW, MDE, Utilities	Short		To Be Determined with Future Data	Yes	ESF-3
Train all code enforcement and building inspectors about flood proofing techniques and the local floodplain ordinance	MDE, DOP	Baltimore County, BDW, DHCD, DPW, MDE, Utilities	Medium		To Be Determined with Future Data	No	
Encourage green roof installations to include vegetative and reflective technologies for all new commercial, industrial, multifamily, and city-owned development	HCD	BDC, DHCD, DOP, DPW, MDE, Utilities	Medium		To Be Determined with Future Data	Yes	ESF-5
BL-3	(DOP)	Strengthen City zoning, floodplain and construction codes to integrate anticipated changes in climate					
Review zoning and strengthen language (where necessary) in order to better protect citizens and increase resiliency in buildings	DOP	BDC, City Government, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners	Medium	Local Funding	• Revisions of city codes to incorporate scientific climate projections • Reference to climate change in current and updated zoning, floodplain, and construction code documents • The inclusion of standards that exceed NFIP minimums in zoning and building code documents	No	ESF-3, 5
Review and amend existing building and floodplain regulations to require more flood resistant new and existing structures when located in the floodplain	DOP	BDC, City Government, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners	Medium, Ongoing	Local Funding	To Be Determined with Future Data	No	ESF-3, 5
Utilize open space category in zoning code to protect sensitive areas (e.g. stormwater sites, steep slopes, floodways, etc.)	DOP	BDW, City Government, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners	Medium		To Be Determined with Future Data	No	ESF-5
Review and increase Flood Protection Elevation (Base Flood Elevation + Freeboard) standards to the highest available State, Federal or local elevation level	DOP	BDW, City Government, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners	Short	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	ESF-5
Evaluate and update stormwater management regulations to avoid increases in downstream flooding	DOP	BDC, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners	Short	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	ESF-3
Adopt design requirements that include wet and dry flood proofing techniques	DOP	BDC, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners	Short	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	ESF-3, 5
Review and consider adoption of the International Green Construction code	HCD	BDC, DOP, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners	Short Ongoing	Local Funding		Yes	ESF-5
BL-4	(DOP)	Update a list of flood prone and repetitive loss buildings to consider for acquisition					
Continue to acquire property (including repetitive loss properties) in the special flood hazard areas where feasible and appropriate	DOP	DHCD, MEMA, MDE, Office of Real Estate	Ongoing	• Additional funds may be needed for print publications and web-based materials • Explore funding opportunities from MEMA, FEMA, MOEM, and other agencies	• Inventory and database of flood-prone and repetitive loss properties • Acquisition of flood-prone and repetitive loss properties	No	ESF-3, 5
Prioritize Hazard Mitigation Assistance funding for mitigation of repetitive loss properties and severe repetitive loss properties	MOEM	DHCD, DOP, MEMA, MDE, Office of Real Estate	Ongoing	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	ESF-5
Develop a creative financing program for flood resiliency in industrial buildings	BDC	DHCD, DOP, MEMA, MDE, Office of Real Estate	Ongoing	• Federal Funds • State Funds • Local Funds	To Be Determined with Future Data	No	

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BL-5	(DHCD)	Improve wind resiliency of new and existing structures					
Review local building codes to determine if revisions are needed to improve the structures ability to withstand greater wind velocities and storm impacts	HCD	BDC, Commercial Building Owners, DGS, DOP, MDE, MOEM, Private Developers	Short	• Federal Funding Sources	• New construction and renovation projects utilizing increased wind resiliency standards • Revision of local codes (if necessary) to raise wind resiliency requirements • Renovations for improved wind resiliency at emergency shelters	No	ESF-3
Retrofit emergency shelter windows to withstand winds associated with coastal storm events	DGS	Commercial Building Owners, DCHD, DGS, DOP, MDE, MOEM, Private Developers	Long	• Federal Emergency Management Funding	To Be Determined with Future Data	No	ESF-3,6
BL-6	(DGS)	Evaluate various seismic design enhancements using prototypical Baltimore City building types					
Determine engineering effectiveness and cost-benefit of various earthquake mitigation measures using computer modeling	DGS	DCHD, MOEM, USGS	Short	• The analysis of City infrastructure is an ongoing priority and could be completed as part of this ongoing process. • The City's existing capital plan	• Completion of a study to evaluate potential effectiveness and feasibility of engineering measures.	No	ESF-3
BL-7	(DOP)	Retrofit existing buildings in the designated Flood Area to increase resiliency					
Target and encourage flood resiliency retrofits for buildings in the designated Flood Area	DOP	BDC, DHCD, DPW, Federal and State Partners, MCC, MON, NGOs, MOEM	Long	• Federal Funding Sources • Housing Recovery Funding • NFIP • Commercial Insurance Policies • FEMA Public Assistance Program	• Number or square footage of buildings implementing flood resiliency measures • Inventory of existing buildings within the 100-year floodplain and database of resiliency measures taken • Renovation of existing buildings in the 100-year floodplain • Creation of a mandate for flood resiliency retrofits within flood-prone areas • Modifications to exposed public housing facilities	No	
Prioritize retrofitting and increasing resiliency of Public Housing units in the designated Flood Area and other high risk areas	DHCD, DOP	BDC, DPW, Federal and State Partners, MON, MOEM	Long			No	
Educate building owners within the floodplain to ensure that all electrical, mechanical, and key building systems are above the base flood elevation and meet existing codes	DOP	BDC, DHCD, DPW, Federal and State Partners, MCC, MON, NGOs, MOEM	Long			No	
BL-8	(DGS)	Improve resource conservation practices in all city owned buildings					
Install energy-efficient and low-water-use equipment during renovations in all City-owned buildings	DGS	MOE, BCPSS, DCHD, DGS, DOP	Medium	• MEA's Jane E. Lawton Conservation Loan Program • MEA's State Agency Loan Program (SALP)	• Resource conservation measures used in city-owned buildings • Mandate requiring resource conservation measures in city-owned buildings • Energy efficiency and weatherization upgrades at Baltimore City Schools/Reference of efficiency and weatherization upgrades within BCPSS Ten-Year plan	Yes	
Support energy efficiency and weatherization as part of Baltimore City schools ten-year plan	DOP	MOE, BCPSS, DCHD, DGS, DOP	Short	BCPSS CIP	To Be Determined with Future Data	Yes	
Update Baltimore green building standards by offering multiple compliance paths for new and substantially renovated construction	DHCD, DOP	BCPSS, DCHD, DGS, DOP	Medium			Yes	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
BL-9	(DOP)	Conduct educational outreach to increase resource conservation practices in private buildings					
Conduct educational outreach and provide information about savings related to reduced water use	DPW	BCPSS, BGE, BOS, DOP, Exelon, MON, NGOs, MOEM	Short	• Housing Recovery Funding • MEA's Jane E. Lawton Conservation Loan Program	• Directory of print and web-based educational materials created and delivered to City stakeholders, residents, and property owners • Inventory of agency publications made available to residents and property owners • Creation and use of training courses, workshops and seminars presented to residents, property owners, and City officials • The number of CRS credits achieved through education and outreach activities.	Yes	ESF-5
Educate and provide resources and information about utility rebate programs	BGE	BCPSS, DOP, DPW, Exelon, MON, NGOs, MOEM	Short		To Be Determined with Future Data	Yes	ESF-11
Provide energy efficiency education to include information on conserving electrical power. Emphasize reductions during summer peak demand hours	DOP	BCPSS, BGE, DPW, Exelon, MON, NGOs, MOEM	Short	State, Local and Foundation Funding	To Be Determined with Future Data	Yes	
BL-10	(DOP)	Use HAZUS-MH computer modeling to determine losses generated by coastal storms					
Utilize engineering studies and cost-benefit analyses to identify additional mitigation needs and actions	DOP	FEMA, MEMA, MOEM, NOAA	Short	Emergency Management Grant Programs	To Be Determined with Future Data	No	
Evaluate various building design enhancements to reduce losses generated by earthquakes, floods, and storm surge	DOP	DHCD,FEMA, MEMA, MOEM, NOAA	Short		To Be Determined with Future Data	No	ESF-3
NS-1	(BCRP)	Utilize green corridors and parks to help protect surrounding communities from the impacts of hazard events					
Evaluate green corridors and parks for possible improvements for floodplain management	Rec & Parks	DOP, Community Groups, DPW, NGO's	Medium		• Reference of a connected green corridor system in City and community planning documents • Increase of green spaces and vegetative cover in the city • Resiliency renovations to park facilities and buildings	Yes	
Increase the resiliency of park facilities and buildings	R&P	DOP, MOEM, Community Groups, NGOs	Medium	Ongoing R&P Capitol Budget	To Be Determined with Future Data	Yes	
NS-2	(BCRP Forestry)	Increase and enhance the resilience and health of Baltimore's urban forest					
Anticipate the impacts of future changes in temperature and weather on the urban forest by developing a comprehensive list of plant and tree species known to have a broad range of environmental tolerances	Rec & Parks	BGE, Community Groups, DOP, DOT, DPW, MDNR, NGOs	Short	Local and Foundation Funding	• Size and growth of Baltimore's Urban Forest • Percentage of facilities in flood-prone zones being upgraded for greater resiliency • Number of trees inspected, pruned, and maintained • Completion of a comprehensive tree inventory • Formation of a comprehensive tree maintenance program	Yes	
Establish and routinely update a comprehensive tree inventory to anticipate insect and forest structural impacts of climate change	Rec & Parks	BGE, Community Groups, DOP, DOT, DPW, MDNR, NGOs	Short	State, Local and Foundation Funding	To Be Determined with Future Data	Yes	
Establish a comprehensive maintenance program that includes pruning for sound structure and the removal of hazardous limbs and trees. First focus on areas where vulnerable infrastructure is nearby such as energy supply and roads	Rec & Parks	USFS, BGE, Community Groups, DOP, DOT, DPW, MDNR, NGOs	Medium	R&P Operating Budget Federal, State, Local and Foundation Funding	To Be Determined with Future Data	No	
Continually adjust and modify planting details and specifications to assure the health and longevity of trees	Rec & Parks	USFS, BGE, Community Groups, DOP, DOT, DPW, MDNR, NGOs	Short	Federal, State, Local and Foundation Funding	To Be Determined with Future Data	Yes	
Increase the urban tree canopy and target areas with urban heat island impacts	Rec & Parks	USFS, BGE, Community Groups, DOP, DOT, DPW, MDNR, NGOs	Ongoing	Baltimore City Capitol Budget, Mitigation Funds, Forest Conservation Program	To Be Determined with Future Data	Yes	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
NS-3	(DOP)	Create an interconnected network of green spaces to support biodiversity and watershed based water quality management					
Utilize the Growing Green Initiative to increase green spaces in areas where there is available vacant land in order to reduce the heat island effect	Planning	HCD, DPW, Rec & Parks, BDC, State Agencies, Federal Agencies, NGO's, Community Groups	Ongoing	• Federal Grants • State Grants • Foundation Grants	• Reference of a connected green network in City and community planning documents • Percentage of facilities in flood-prone zones being upgraded for greater resiliency • Number of trees inspected, pruned, and maintained • Identification of a benchmark biodiversity index and continued evaluation • Percentage of green spaces within the watershed areas • Utilization of natural stormwater management technologies	Yes	
Convert vacant land and row houses into meaningful and connected open space	HCD	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies	Ongoing	• Baltimore City Bond Funds	To Be Determined with Future Data	Yes	
Complete a habitat analysis and plan for the City	DOP	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Create a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation	DOP	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Certify Baltimore as a Community Wildlife Habitat through the National Wildlife Foundation (NWF)	NWF Planning	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
NS-4	(DOP)	Expand, protect and restore riparian areas in the city					
Conduct regular maintenance of stream restoration projects and stormwater quality facilities	DPW	BCRP, DOP, DPW	Ongoing	• Federal Grants • State Grants • Local Grants • Foundation Grants	• Number and scale of stream restoration projects • Use of riparian buffers in all new development and capital projects • Revisions (if appropriate) to floodplain and stream buffer regulations	No	
Evaluate current regulations regarding stream buffers and floodplains and modify them (if appropriate) to assure they adequately protect perennial stream corridors	Planning	BCRP, DOP, DPW	Ongoing	• Federal Grants • State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data		
NS-5	(DOP)	Preserve and create new coastal buffer efforts and support creating more wetlands and soft shoreline along coastal areas					
Integrate natural buffer requirements, such as wetlands and soft shorelines, into new development or redevelopment	Planning	BCRP, BDC, DOP, DPW, NGOs, State Agencies, Waterfront Partnership	Short	• Federal Grants • State Grants • Local Grants • Foundation Grants	• Linear miles of coastal edge restoration • Federal dollars secured for coastal protection projects • Number and percentage of buildings with reduced coastal risk due to coastal protection projects • Number and scale of stream and coastline restoration projects • Use of natural buffer requirements in all new waterfront development and capital projects • Completion of an evaluation of property in the Critical Area	No	
Complete stream restoration projects in Baltimore City and County stream valleys that lead into the coastal wetlands so as to increase habitat and reduce sedimentation	DPW	BCRP, BDC, DOP, DPW, NGOs, State Agencies, Waterfront Partnership	Long	• Federal Grants • State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	No	
Identify and evaluate areas in the Critical Area buffer to prioritize ecological buffer restoration efforts	Planning	BCRP, BDC, DOP, DPW, NGOs, State Agencies, Waterfront Partnership	Medium	• Critical Area Buffer Offset Fees • Private Funds	To Be Determined with Future Data	No	

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NS-6	(DPW)	Require the City's drought management plan to account for changes in climate					
Map drought risks and water availability via climate change scenarios	DPW	BCHD, Water Utility	Short	• Federal Grants • State Grants • Foundation Grants	• Reference of climate change in drought management plans • Modification of drought management plans to exceed current standards	No	
Update drought management plans to recognize changing conditions	DPW	BCHD, Water Utility	Short		To Be Determined with Future Data	Yes	
NS-7	(DOP)	Integrate climate change and natural hazards planning into small watershed action plans (SWAPs)					
Review existing watershed management plans and identify future actions to address climate impacts		DOP, DPW, NGO's	Ongoing		• Reference of hazard mitigation and climate change in new and updated SWAP planning documents • Integration of standards that exceed current minimums for watershed planning		
NS-8	(DOP)	Conduct detailed ongoing analysis of climate information, trends in storm events and hydrology to support policy changes responding to climate change					
Expand the use of climate information (e.g. seasonal forecasts) in water resources planning and management.	Planning	BDC, FEMA, MDE, MDNR, MEMA, NGOs, State Agencies, Waterfront Partnership	Short	State, Local and Foundation Funding	• Reference of sea level rise in new and updated flood regulations and planning documents • Integration of standards that exceed current minimum design and development restrictions to account for sea level rise	No	
Research and actively monitor trends in storm events, stream flow and other conditions affecting hydrology and water		BDC, FEMA, MDE, MDNR, MEMA, NGOs, State Agencies, Waterfront Partnership	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
Update flood maps to reflect changing risk associated with climate change.	Planning	BDC, FEMA, MDE, MDNR, MEMA, NGOs, State Agencies, Waterfront Partnership	Short	• Federal Grants • State Grants • Local Grants	To Be Determined with Future Data	No	
Continuously improve and enhance flood vulnerability data.	Planning	BDC, FEMA, MDE, MDNR, MEMA, NGOs, State Agencies, Waterfront Partnership	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
PS-1	(MOEM)	Strengthen emergency preparedness coordination between local government, NGOs, and private entities by updates to the City Emergency Operations Plan (EOP) and related Emergency Support Functions (ESF)					
Identify and develop a common database that all city government agencies and departments should utilize for hazard information, preparedness and response	MOEM	BCHD, County Governments, DOP, DHMH, Humane Society, MOIT, PSC	Short	• Federal Grants • State Grants • Foundation Grants	• Formation of a database for hazard information, preparedness, and response procedures • Inclusion of outreach efforts that are integrated between agencies • Number and percentage of animal rescue facilities that incorporate natural hazard emergency procedure strategies	Yes	
Ensure consistency and integration with existing and future response plans within and between agencies	MOEM	BCHD, County Governments, DOP, DHMH, Humane Society, MOIT, PSC	Ongoing		To Be Determined with Future Data	Yes	
Continue to identify and improve coordination with Key Partners including private sector, State partners, Federal partners, community, universities and industry leaders through Local Emergency Planning Committee	MOEM	BCHD, City Agencies, County Governments, DOP, DHMH, FEMA, General Public, Humane Society, MDE, MDNR, MEMA, MOIT, PSC	Ongoing	• Foundation Grants	To Be Determined with Future Data	Yes	
Coordinate outreach efforts of the Mayor's Office of Emergency Management, Mayor's Office of Neighborhood and Constituent Services and Baltimore City Health Department to leverage messages related to all-hazards emergency preparedness	MOEM DHMH	BCFD, BCHD, BCPD, Community Groups, County Governments, DOP, DHMH, Humane Society, MOEM, MOIT, MON, PSC	Medium	• State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	No	
Develop strong working relationships with local experts to provide technical assistance to refine and improve city government emergency preparation	MOEM	BCHD, County Governments, DOP, DHMH, Humane Society, MOIT, PSC	Ongoing	• State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	No	
Review and improve specific response plans contained in the EOP and related ESFs that relate to extreme weather events (snow, heat, flood, wind, electrical outages, and other hazard events)	MOEM	BCHD, County Governments, DOP, DHMH, Humane Society, MOIT, PSC	Ongoing	• State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	No	EOP

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
Ensure equipment purchases and communication systems are compatible across agencies and jurisdictions	PSC MOEM	BCHD, County Governments, DOP, DHMH, Humane Society, MOEM, MOIT, PSC	Ongoing	• Federal Funding • State Funding • Local Funding	To Be Determined with Future Data	Yes	
Encourage all animal rescue and care shelters to further develop their internal plans for animal's health and safety during and after a hazard event	Humane Society	BCHD, County Governments, DOP, DHMH, Humane Society, MOIT, PSC	Ongoing	• Federal Funding • State Funding • Local Funding	To Be Determined with Future Data	No	
Ensure all animal rescue and care shelters located within the floodplain are provided the support to apply for and obtain funds to relocate	Humane Society	BCHD, County Governments, DOP, DHMH, Humane Society, MOIT, PSC	Ongoing	• State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	No	
Develop and implement a case study of hospital-based practices that foster community resilience to climate change		BCHD, County Governments, DOP, DHMH, Humane Society, MOIT, PSC	Ongoing	• Private funding	To Be Determined with Future Data	Yes	
PS-2	(MOEM)	Develop a Hazard Awareness Program					
Create a standardized early warning system for members of the public	MOEM	BCHD, DHMH, DOP, MDH2E, MEMA, MOEM	Short	• Local Funding	• Creation of a hazard awareness program • Number and extent of ongoing educational programs, including workshops, seminars, and other outreach events	Yes	
Evaluate and improve community health center strategies for communicating with patients during an emergency	MOEM	BCHD, MDH2E, MEMA, MOEM	Ongoing	• Private funding	To Be Determined with Future Data	No	
Educate citizens about the existing early warning systems and actions they should take when alarms sound	MOEM	BCHD, MDH2E, MEMA, MOEM	Ongoing	• Foundation Grants	To Be Determined with Future Data	No	ESF-11
Prepare and integrate occupational health and safety messages and instructions for first responders	DHMH	BCHD, DHMH, MDH2E, MEMA, MOEM	Ongoing	• Foundation Grants	To Be Determined with Future Data	Yes	
Hold climate specific seminars, in partnership with MDH2E and MHA, for hospital emergency and sustainability managers	Local Hospitals	BCHD, MDH2E, MEMA, MOEM	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
PS-3	(MOEM)	Designate community leaders and organizations that can assist and provide support during hazard events					
Prior to a hazard event, identify lead contacts serving vulnerable populations and coordinate actions to maximize safety and information sharing	MOEM DOP	BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, MOEM, MON	Ongoing	• Community Development Block Grant Program (CDBG)	• Creation of a directory of community hazard mitigation leaders • Formation of a hazard response procedure plan for community leaders.	Yes	
Develop a community group coordination plan and implementation guide	MOEM	BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, MOEM, MON	Medium			No	
Identify and evaluate plans already in place and work to improve utilization of community based leaders to assist in preparedness and response	MOEM	BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, MOEM, MON	Long	• State Grants • Local Grants • Foundation Grants		No	
PS-4	(MOEM)	Integrate climate change and natural hazards planning into all City and community plans					
Develop guidelines to include proactive resilience planning into plan development process	DOP, DHCD	BCHD, MOEM, State and Federal Agencies	Ongoing, Medium	• Community Development Block Grant Program (CDBG)	• Inclusion of hazard mitigation and climate adaptation actions in new and updated planning documents • Development and employment of an institutional checklist for resiliency at health care facilities	Yes	
Incorporate language that strengthens the ability of city government officials to enforce rules and restrictions that support public health, safety and welfare related to hazard events and conditions	MOEM	BCFD, BCHD, BCPD, DHCD, DOP, MOEM, State and Federal Agencies	Medium	• State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Partner with Maryland Department of Health and Mental Hygiene or other pertinent entity to develop institutional checklist and materials for health care specific resilience plans	Local Hospitals	BCHD, DOP, MOEM, State and Federal Agencies	Ongoing, Medium	• Private funding	To Be Determined with Future Data	No	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
PS-5	(MOEM)	Better equip emergency workers for natural hazards					
Research and identify personal protective equipment (PPE) needs based on specific hazards	MOEM	BCFD, BCPD, MOEM	Ongoing	• State Grants • Local Grants • Foundation Grants	• Number of training programs for educating emergency workers about natural hazard risks and response procedures. • Number of emergency workers undergoing hazards training • Evaluation of personal protective equipment (PPE) needs	Yes	
PS-6	(BCHD)	Anticipate and address potential disease outbreaks caused by extreme weather events and changing climatic conditions					
Support studies of heat and flood related vector borne diseases in the Baltimore the region based on changing temperature and moisture	BCHD	BCHD, CDC, DHMH, MDNR, MEMA, MH2E, MOEM, State Agencies	Ongoing	• Federal Grants • State Grants • Foundation Grants	• Identification of potential disease outbreaks and incorporation of prevention measures into ongoing health programs • Revisions of existing programs to better detect and respond to disease outbreaks	Yes	
Evaluate existing programs that detect disease outbreaks to determine their flexibility to respond to new conditions	BCHD	BCHD, CDC, State Agencies	Ongoing		To Be Determined with Future Data	Yes	
PS-7	(MOEM)	Protect Baltimore residents from the effects of hazard events and plan for more frequent hazard instances					
Re-evaluate and update existing heat alerts, advisories, and updates to healthcare and emergency service providers	MOEM, BCHD	BCFD, BCHD, BCPD, BCRP, DHMH, Licenses and Permitting, MDE, MOEM, Healthcare providers	Short	• State Grants • Local Grants • Foundation Grants	• Revisions to existing hazard advisory programs • Inventory and evaluation of existing cooling centers, as well as their hours and accessibility, to determine necessary program modifications • Inclusion of code red information in event permitting documentation • Total number of poor air quality days	No	
Ensure that residents and visitors have access and transportation to cooling centers during extreme heat events	MOEM, BCHD	BCHD, BCRP, Community Groups, DHMH, Licenses and Permitting, MDE, MOEM, Transportation partners	Ongoing	• State Grants • Local Grants • Foundation Grants			
Evaluate code red plans to ensure all agencies adequately protect their own workers	MOEM, BCHD	BCFD, BCHD, BCPD, BCRP, DHMH, Licenses and Permitting, MDE, MOEM, Agencies with outdoor workers	Short	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Consider extending hours for public wading pools during extreme heat events	MOEM, BCHD	BCHD, BCRP, Community Groups, DHMH, Licenses and Permitting, MDE	Medium	• State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Include information about Code Red in the event permitting process, and incorporate language that allows BCHD to cancel outdoor events	MOEM, BCHD	BCHD, BCRP, Licenses and Permitting, MDE	Medium, Ongoing	• State Grants • Local Grants • Foundation Grants	To Be Determined with Future Data	No	
Work with Regional, State and Local partners to improve air quality and reduce respiratory illnesses	MDE	BCHD, BCRP, Licenses and Permitting, MDE	Medium, Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Create and implement programs to manage combined health impacts of heat and air pollution	BCHD	BCHD, BCRP, DHMH, Licenses and Permitting, MDE	Medium, Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
PS-8	(MOEM)	Conduct climate, resiliency, and emergency planning education and outreach					
Incorporate environmental health and climate change into curriculum at schools, universities and health care facilities	BCPSS	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals	Ongoing	• Community Development Block Grant Program (CDBG) • Federal Funding Sources	• Directory of print and web-based educational materials created and delivered to City stakeholders, residents, and property owners • Inventory of outside agency publications made available to residents and property owners • A list of training courses, workshops and seminars presented to residents, property owners, and City officials, etc. • Number of CRS credits achieved through education and outreach activities.	Yes	
Educate communities on how city agencies respond to hazard events, their role in an event, and how agencies work together	MOEM	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Educate and train community groups to participate in responding to hazards	MOEM	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Generate a comprehensive community-specific all hazards outreach campaign	MOEM DOP	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals	Short	• State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Develop and communicate a simplified process for Baltimore residents to follow after a hazard event	MOEM	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals	Short	• State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Create curriculum for hospitals to teach communities about climate change as part of hospital community benefits programs	MOEM	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals	Medium	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Utilize existing preparedness messaging to include information on universal precautions to insect-borne and other infectious diseases	MOEM, BCHD	BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals	Short	• State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
PS-9	(FEMA/ MEMA)	Improve awareness and education about the importance of flood insurance and preparation for Baltimore citizens					
Create an educational program centered on flood hazards, coastal construction practices and evacuation procedures	MOEM DOP	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Short	• Housing Recovery Funding • NFIP	• Educational and informative communication with property owners in flood-prone areas • Percentage of property owners in 100-year floodplain purchasing flood insurance • Average premium paid for NFIP policies • Inventory of flood-prone properties and use of an outreach program to monitor property sales • Development of a newsletter about floodplains and flood insurance • Financial assistance provided to property owners in flood-prone areas • Use of a flood disclosure form and education information sheets alongside lease agreements	Yes	
Encourage owners of properties to purchase flood insurance and improve policyholder awareness at time of sale or renewal	FEMA, NFIP DOP	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Ongoing	• Housing Recovery Funding • NFIP	To Be Determined with Future Data	Yes	
Inform property owners who have paid off their mortgage that flood insurance is still necessary	FEMA, NFIP DOP	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Short	• State and Foundation Grants	To Be Determined with Future Data	Yes	
Identify programs and grants that assist citizens in purchasing flood insurance and making flood proofing changes	FEMA, NFIP DOP	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Medium	• Housing Recovery Funding • NFIP	To Be Determined with Future Data	Yes	

ACTION	LEAD AGENCY	STAKEHOLDERS	ESTIMATED TIMEFRAME (short 1-2yrs, med 3-5yrs, long 6+)	FINANCING OPTIONS	PERFORMANCE METRICS	OVERLAP WITH CAP	EOP, ESF, COOP
Develop an annual newsletter to inform and remind owners of property in the floodplain about flood insurance and flood proofing activities they should undertake	FEMA, NFIP DOP	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Short, Ongoing	• State Grants • Foundation Grants	To Be Determined with Future Data	Yes	
Provide information on how to file for reimbursement for impacts of hazards	MOEM	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Short, Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
Require a flood disclosure form, and educational information as part of lease agreements for commercial and residential properties	DOP	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Short	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
Develop floodplain awareness information for rental tenants and ensure distribution as tenants change	HCD MOEM Planning	Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM	Ongoing	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
PS-10	(DOP)	Increase Baltimore's Food Security					
Develop a food security plan for Baltimore	DOP	BOS, DOP, MDA, Urban Farms and Community Gardens (P&P and CGRN)	Ongoing, Long	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
Increase land under cultivation for commercial urban agriculture	DOP	BOS, DOP, MDA, Urban Farms and Community Gardens (P&P and CGRN)	Ongoing, Long	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
Link Jessup, Maryland Food Hub, and regional/local food producers to local distributors	MD Department of Agriculture	BOS, DOP, MDA, Urban Farms and Community Gardens (P&P and CGRN)	Ongoing, Long	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
Incorporate Baltimore's food policy initiative into planning efforts	DOP	BOS, DOP, MDA, Urban Farms and Community Gardens (P&P and CGRN)	Ongoing, Long	• Federal Grants • State Grants • Foundation Grants	To Be Determined with Future Data	No	
Double the size and number of food producing community gardens by 2025	DOP	BOS, DOP, MDA, Urban Farms and Community Gardens (P&P and CGRN)	Ongoing, Long	• Community Development Block Grant Program (CDBG)	• Number of grocery stores with backup power supplies, including generators or quick connects for generators • Number of communities with community gardens • Total number of community gardens • Percent of urban agriculture land uses • Reference of Baltimore's food policy in new and revised planning documents • Development of a comprehensive food security plan for use during emergency events		

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Appendix

Appendix A: Adoption

Placeholder

Documentation of Adoption of the DP3 Plan by the Baltimore City Sustainability Commission

Documentation of Adoption of the DP3 Plan by the Baltimore City Planning Commission

Appendix B: Glossary and Acronyms

Glossary

100-year floodplain- The geographical area with a 1 percent or greater chance of flooding in any given year.

500-year floodplain- The geographical area with a 0.2 percent chance of flooding in any given year.

Adaptive Capacity- The ability of a system to adjust to changes in the environment — including climate variability and extreme shifts in weather — in order to moderate potential damages or cope with the consequences of those changes.

Asset- Any manmade or natural feature that has value, including, but not limited to people; buildings; infrastructure like bridges, roads, and sewer and water systems; lifelines like electricity and communication resources; or environmental, cultural, or recreational features like parks, dunes, wetlands, or landmarks.

Base Flood- A flood that has a 1% probability of being equaled or exceeded in any given year. Also known as the 100-year flood.

Base Flood Elevation (BFE) Elevation of the base flood in relation to a specified datum, such as the National Geodetic Vertical Datum of 1929. The Base Flood Elevation is used as the standard for the National Flood Insurance Program.

Building- A structure that is walled and roofed, principally above ground, and permanently affixed to a site.

Community Rating System (CRS)- An NFIP program that provides incentives for NFIP communities to complete activities that reduce flood hazard risk. When the community completes specified activities, the insurance premiums of policyholders in these communities are reduced.

Climate- Describes the long-term trends of atmospheric conditions in particular regions.

Climate Adaptation- A process that intends to reduce long-term risks from hazards associated with climate variability and climate change. More specifically, adaptation refers to changes that are made to better respond to new climate conditions, thereby reducing harm and taking advantage of present opportunities.

Climate Change- Any significant change in the measures of climate lasting for an extended period of time.

Climate Normals-

Climate Projection- Consolidates weather patterns over a period, typically 30 years, to determine expected changes in averages, called "climate normals."

Community Asset-

Critical Facilities- Facilities that are critical to the health and welfare of the population and that are especially important following hazard events. Critical facilities include, but are not limited to, shelters, police and fire stations, and hospitals.

Critical Infrastructure-

Debris- The scattered remains of assets broken or destroyed in a hazard event. Debris caused by a wind or water hazard event can cause additional damage to other assets.

Duration- How long a hazard event lasts.

Earthquake- A sudden motion or trembling that is caused by a release of strain accumulated within or along the edge of earth's tectonic plates.

Erosion- The wearing away of the land surface by detachment and movement of soil and rock fragments, during a flood or storm or over a period of years through the action of wind, water, or other geologic processes.

Extent- The size of an area affected by a hazard or hazard event.

Exposure-

Fault- A fracture in the continuity of a rock formation caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are differentially displaced parallel to the plane of fracture.

Flash Flood- A flood event occurring with little or no warning where water levels rise at an extremely fast rate.

Flood- A general and temporary condition of partial or complete inundation of normally dry land areas from (1) the overflow of inland or tidal waters, (2) the unusual and rapid accumulation or runoff of surface waters from any source, or (3) mudflows or the sudden collapse of shoreline land.

Flood Depth- Height of the floodwater surface above the ground surface.

Flood Elevation- Elevation of the water surface above an established datum, e.g. National Geodetic Vertical Datum of 1929, North American Vertical Datum of 1988, or Mean Sea Level.

Flood Hazard Area- The area shown to be inundated by a flood of a given magnitude on a map.

Flood Insurance Rate Map (FIRM)- Map of a community, prepared by FEMA that shows both the special flood hazard areas and the risk premium zones applicable to the community.

Flood Zone- A geographic area shown on a Flood Insurance Rate Map (FIRM) that reflects the severity or type of flooding in the area.

Floodplain- Any land area, including watercourse, susceptible to partial or complete inundation by water from any source.

Floodway- The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the 1-percent-annual-chance flood without cumulatively increasing the water surface elevation by more than a designated height.

Frequency- A measure of how often events of a particular magnitude are expected to occur. Frequency describes how often a hazard of a specific magnitude, duration, and/or extent typically occurs, on average. The reliability of this information varies depending on the kind of hazard being considered.

Fujita Scale of Tornado Intensity Rates- tornados with numeric values from F0 to F5 based on tornado wind speed and damage sustained. An F0 indicates light damage such as broken tree limbs or signs, while an F5 indicates incredible damage was sustained.

Geographic Information Systems (GIS)- A computer software application that relates physical features on the earth to a database to be used for mapping and analysis.

Global Warming- The recent ongoing rise in global average temperature near Earth's surface caused mostly by increasing concentrations of greenhouse gases in the atmosphere.

Hazard- A source of potential danger or adverse condition. Hazards in this plan are both natural and technological in origin and include: floods/flash floods, droughts, wind, thunderstorms/lightning, winter storms, tornados, hurricanes, extreme heat, landslides, earthquakes, wildfires/fires, land subsidence, mining hazards, dam failures, hazardous materials, and nuclear accidents. These events are hazards when they have the potential to harm people or property.

Hazard Event- A specific occurrence of a particular type of hazard.

Hazard Identification- The process of identifying hazards that threaten an area.

Hazard Mitigation- Any sustained action taken to reduce or eliminate long-term risks to people and their property from hazards and their effects.

Hazard Profile- A description of the physical characteristics of hazards and a determination of various descriptors including magnitude, duration, frequency, probability, and extent. In most cases, a community can most easily use these descriptors when they are recorded and displayed as maps.

HAZUS- A GIS-based, nationally standardized hazard loss estimation tool developed by FEMA.

Hurricane- An intense tropical cyclone, formed in the atmosphere over warm ocean areas, in which wind speeds reach 74-miles-per-hour or more and blow in a large spiral around a relatively calm center or "eye." Hurricanes develop over the North Atlantic Ocean, northeast Pacific Ocean, or the South Pacific Ocean east of 160° longitude. Hurricane circulation is counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Hydrology- The science of dealing with the waters of the earth. A flood discharge is developed by a hydrologic study.

Infrastructure- Refers to the public services of a community that have a direct impact on the quality of life. Infrastructure includes communication technology such as phone lines or internet access, vital services such as public water supplies and sewer treatment facilities, and includes an area's transportation system such as airports, heliports; highways, bridges, tunnels, roadbeds,

Glossary Continued...

overpasses, railways, rail yards, depots; and waterways, canals, locks, seaports, ferries, harbors, dry-docks, piers and regional dams.

Intensity- A measure of the effects of a hazard event at a particular place.

Impact-

Impact Assessment- Identifies the degree to which, and in what manner, hazards will impact people, places, and the economy. The impact assessment identifies what stands to be damaged due to a hazard event, and the cost of such a loss

Landslide- Downward movement of a slope and materials under the force of gravity. Lateral Spreads Develop on gentle slopes and entail the sidelong movement of large masses of soil as an underlying layer liquefies in a seismic event.

Magnitude- A measure of the strength of a hazard event. The magnitude (also referred to as severity) of a given hazard event is usually determined using technical measures specific to the hazard.

Mitigation Plan- A systematic evaluation of the nature and extent of vulnerability to effects of natural hazards typically present in the state and includes a description of actions to minimize future vulnerability to hazards.

National Flood Insurance Program (NFIP)- Federal program created by Congress in 1968 that makes flood insurance available in communities that enact minimum floodplain management regulations in 44 CFR §60.3.

National Weather Service (NWS)- Prepares and issues flood, severe weather, and coastal storm warnings and can provide technical assistance to federal and state entities in preparing weather and flood plans.

National Emergency Management Information System (NEMIS)- An evolving agency-wide system of hardware, software, telecommunications and applications software that provides a new technology base to FEMA and its partners to perform the emergency management mission.

No-notice- A no-notice incident is one that occurs unexpectedly or with minimal warning. Incidents with typically predictable patterns can also become no-notice incidents when their behaviors or patterns differ from what had been predicted or expected. Due to the nature of no-notice events, the ability of emergency responders to react in a timely manner may be challenged

No-regrets Actions-

Nor'easter- An extra-tropical cyclone producing gale-force winds and precipitation in the form of heavy snow or rain.

Planning- The act or process of making or carrying out plans; the establishment of goals, policies and procedures for a social or economic unit.

Pre-Disaster Mitigation Program (PDM)- The Pre-Disaster Mitigation (PDM) Program was authorized by §203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 USC, as amended by §102 of the Disaster Mitigation Act of 2000. Funding for the program is provided through the National Pre-Disaster Mitigation Fund to assist states and local governments (to include Indian Tribal governments) in implementing cost-effective hazard mitigation activities that complement a comprehensive mitigation program.

Probability- A statistical measure of the likelihood that a hazard event will occur.

Recurrence Interval- The time between hazard events of similar size in a given location. It is based on the probability that the given event will be equaled or exceeded in any given year.

Repetitive Loss Property- A property that is currently insured for which two or more National Flood Insurance Program losses (occurring more than ten days apart) of at least $1000 each have been paid within any 10- year period since 1978.

Replacement Value- The cost of rebuilding a structure. This is usually expressed in terms of cost per square foot, and reflects the present-day cost of labor and materials to construct a building of a particular size, type and quality. In this plan, replacement values are largely based on insurance estimates.

Richter Scale- A numerical scale of earthquake magnitude devised by seismologist C.F. Richter in 1935.

Risk- The estimated impact that a hazard would have on people, services, facilities, and structures in a community; the likelihood of a hazard event resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to a specific type of hazard event. It also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk Assessment- identifies the nature, location, intensity and probability of a threat, and then determines vulnerabilities and exposure to those threats while considering the capacities and resources available for to address or manage threats. A risk assessment is a multi-faceted, 'stepped' process. It includes three stages: (1) Hazard identification, (2) vulnerability assessment, and (3) impacts assessment.

Riverine- Of or produced by a river.

Scale- A proportion used in determining a dimensional relationship; the ratio of the distance between two points on a map and the actual distance between the two points on the earth's surface.

Sensitivity-

Severity-

Stafford Act- The Robert T. Stafford Disaster Relief and Emergency Assistance Act, PL 100-107 was signed into law November 23, 1988 and amended the Disaster Relief Act of 1974, PL 93-288. The Stafford Act is the statutory authority for most federal disaster response activities, especially as they pertain to FEMA and its programs.

State Hazard Mitigation Officer (SHMO)- The representative of state government who is the primary point of contact with FEMA, other state and federal agencies, and local units of government in the planning and implementation of pre- and post- disaster mitigation activities.

Structure- Something constructed. (See also Building)

Topographic- Characterizes maps that show natural features and indicate the physical shape of the land using contour lines. These maps may also include manmade features.

Tornado- A violently rotating column of air extending ground-ward.

Tropical Cyclone- A cyclonic, low-pressure system over tropical or sub-tropical waters.

Tropical Storm- A tropical cyclone with maximum sustained winds greater than 39 mph and less than 74 mph.

Tsunami- Great sea wave produced by submarine earth movement or volcanic eruption.

Urban Heat Island- A metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

Urban Karst- Urban land with sinkholes, springs, and streams that sink into subsurface caverns. These sinkholes may develop progressively as subtle, bowl-shaped depressions, or they may collapse suddenly into steeply sided, water-filled craters.

Vulnerability- Describes how exposed or susceptible to damage an asset is. Vulnerability depends on an asset's construction, contents, and the economic value of its functions. Like indirect damages, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power – if an electric substation is flooded, it will affect not only the substation itself, but a number of businesses as well. Often, indirect effects can be much more widespread and damaging than direct ones.

Vulnerability Assessment- A process that further develops the risk assessment by examining current exposure (measure(s) of defense), sensitivity (degree to which something is affected), and adaptive capacity (ability to recover). This assessment determines the extent of injury and damage that may result from a hazard event of given intensity in a given area.

Weather - Refers to what changes we experience on a day-to-day basis or over a short period of time. Weather may describe current temperature, humidity, precipitation, wind, or other similar conditions; and a weather forecast may predict conditions in the near future

A/C	Air conditioning
BCFD	Baltimore City Fire Department

Acronyms

BCHD	Baltimore City Health Department
BCPD	Baltimore City Police Department
BCPSS	Baltimore City Public School System
BCRP	Baltimore City Department of Recreation and Parks
BDC	Baltimore Development Corporation
BDW	Baltimore Development Workgroup
BFE	Base Flood Elevation
BFPI	Baltimore Food Policy Initiative
BGE	Baltimore Gas and Electric
BOS	Baltimore Office of Sustainability
CAI	Community Asset Inventory
CAP	Climate Action Plan
CDBG	Community Development Block Grant
CERT	Community Emergency Response Teams
CHAP	Commission for Historic and Architectural Preservation
COOP	Continuity of Operations Plan
CoS	Commission on Sustainability
CRS	Community Rating System
CSC	NOAA's Coastal Services Center
CSX	CSX Corporation
CVAT	Community Vulnerability Assessment Tool
DES	Department of Environmental Services
DFIRM	Digital Flood Insurance Map
DGS	Baltimore City Department of General Services
DHCD	Department of Housing and Community Development
DHMH	Maryland Department of Health and Mental Hygiene
DOIT	Department of Information Technology
DOP	Baltimore City Department of Planning
DOT	Baltimore City Department of Transportation
DP3	Disaster Preparedness and Planning Project
DPH	Department of Public Health
DPW	Baltimore City Department of Public Works
EAP	Emergency Action Plan
EHR	Electronic health records
EOP	Emergency Operation Plan
EFP	
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FTA	Federal Transit Administration
GGi	Growing Green Initiative
GHG	Greenhouse Gas
GIS	Geographic Information Systems
HAZUS-MH	Hazards U.S.–Multi-Hazard, software
HVAC	Heating, ventilation, and air conditioning
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate
LiDAR	Light Detection and Ranging
LiMWA	Limit of Moderate Wave Action
LPC	Landmarks Preservation Commission
MCC	Maryland Conservation Corps
MDE	Maryland Department of the Environment
MDH2E	Maryland Hospitals for a Healthy Environment
MDNR	Maryland Department of Natural Resources
MDTA	Maryland Transportation Authority
MEMA	Maryland Emergency Management Agency
MOEM	Mayor's Office of Emergency Management
MON	Mayor's Office of Neighborhoods
MOIT	Mayor's Office of Information Technology
MPH	Miles per hour
MTA	Maryland Transit Administration
NACCS	North Atlantic Coast Comprehensive Study
NAHB	National Association of Home Builders
NAS	National Academy of Sciences
NAVD88	North American Vertical Datum 1988
NCA	National Climate Assessment
NCDC	National Climate Data Center
NFIP	National Flood Insurance Program
NGO	Non-governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PSC	Public Service Commission
RVAT	Risk and Vulnerability Assessment Tool
SHA	Maryland State Highway Administration
SLOSH	Sea, Lake, and Overland Surge from Hurricanes
SLR	Sea level rise
SNAP	Supplemental Nutrition Assistance Program
UHI	Urban Heat Island
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
UTC	Urban Tree Canopy

Appendix C: Acknowledgements

Project Management
Kristin Baja, Project Manager
Megan Griffith, Project Intern

Baltimore Office of Sustainability Staff
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Kristin Baja, Climate and Resilience Planner
Ken Hranicky, Floodplain Manager

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Robert Maloney, Co-chair
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Meghan Butasek
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Rich Foot
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Local Emegency Planning Committee (LEPC)
Homeland Security Planning Committee (HSPC)
Baltimore Community Groups
Georgetown Climate Center

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Moffat and Nicol, Inc.

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Federal Emergency Management Agency
Maryland Emergency Management Agency
National Oceanic and Atmospheric Administration
Maryland Department of Natural Resources

Appendix D: Advisory Committee

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Mayor's Office of Emergency Management

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Not voting Advisory Committee members:
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Baltimore Sustainability Commission Climate Committee

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Cindy Parker
Joan Plisko
Inez Robb
John Skinner
Betty Bland Thomas (a)
Joe Wade
Kristin Baja (Lead)

(a)- advisory role, not a voting member of the committee

Full Advisory Committee Meeting Dates

Advisory Committee Meeting #1

Date: February 13, 2013
Location: Baltimore City Department of Planning
Attendees: 33
Materials: Agenda
Project Timeline
Definitions List
Concensus Document
Google Drive Instructions
Reporting Document
Presentation

Advisory Committee Meeting #2

Date: March 5, 2013
Location: Baltimore City Department of Planning
Attendees: 26
Materials: Agenda
Subcommittees List
Presentation

Advisory Committee Meeting #3

Date: April 9, 2013
Location: Baltimore City Department of Planning
Attendees: 24
Materials: Agenda
Draft Recommendations List
Framing Document
Vulnerability Assessment Exercise
Presentation

Advisory Committee Meeting #4

Date: June 28, 2013
Location: Baltimore City Department of Planning
Attendees: 30
Materials: Agenda
Draft Recommendations List
Vulnerability Assessment Results
Presentation

Advisory Committee Meeting #5

Date: April 9, 2013
Location: CitiStat Room, City Hall
Attendees: 26
Materials: Agenda
Draft Document
Presentation

Sub-Committee Meeting Dates

Meeting Dates:

INFRASTRUCTURE
Dates: March 25, 2013
March 27, 2013
Location: Department of Planning

BUILDINGS
Dates: February 27, 2013
March 11, 2013
March 27, 2013
Location: Department of Planning

NATURAL SYSTEMS
Dates: March 22, 2013
March 25, 2013
Location: Department of Planning

PUBLIC SERVICES
Dates: March 11, 2013
March 26, 2013
Location Department of Planning

Internal Working Group Meeting Dates

Meeting Dates:

January 16, 2013	Project Review and Roles
February 4, 2013	Historic Hazards Research
March 1, 2013	Profiling Hazards
March 25, 2013	Final Hazards List
March 26, 2013	Critical Facilities
April 10, 2013	Critical Facilities
May 23, 2013	Review Strategies
July 12, 2013	Review Actions
July 16, 2013	HAZUS Review
July 31, 2013	HIA

Additional Presentations and Input Ses-

Baltimore City Homeland Security Planning Committee (HSPC)	Nov., 2012
Pakrs and People Foundation	March 7, 2013
American Institute for Architects (AIA)	April 15, 2013
	June 10, 2013
DC Climate Action Group	May 18, 2013
Northwest Public Safety Day	June 23, 2013
Baltimore City Forestry Board	July 16, 2013
Blue Water Baltimore	July 25, 2013
Baltimore City Local Emergency Planning Committee (LEPC)	July 1, 2013
Johns Hopkins Public Health	Sept. 10, 2013

Advisory Commitee Meeting February 13, 2013

Agenda

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Advisory Committee Meeting

February 13, 2013

Committee Purpose:

- To bring together stakeholders from key agencies, institutions, businesses, and neighborhoods to identify actions and recommendations for the City of Baltimore's Disaster Preparedness and Planning Project.

Meeting Objective:

- Review project process
- Review existing hazards and implications of climate change and come to consensus on vision statement, hazards, and definitions of climate change and adaptation
- Present examples of actions and recommendations for sub-committee review

Materials Provided:

- List of committee members with contact information
- List of key dates and deadlines
- Draft list of example actions and recommendations for sub-committee review

Agenda:

3:00pm-3:15pm: Tom Stosur, Director, Department of Planning

- Welcome and brief introductions

3:15pm-3:30pm: Tom Stosur, Director, Department of Planning

- Why you are here and review meeting goals

3:30pm-3:40pm: Beth Strommen, Director, Office of Sustainability

- Integration of the All Hazards Mitigation Plan and the Climate Adaptation Plan
- Importance of this project

3:40pm-4:20pm: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Natural hazards in Baltimore City
- Overview of hazard mitigation and climate adaptation
- Review example actions and recommendations list and reporting document
- Vision statement for the project
- Project timeline
- Consensus on hazards, definitions of climate change and adaptation, and vision statement

4:20pm-4:40pm: Beth Strommen, Director, Office of Sustainability

- Subcommittee expectations
- Subcommittee assignments and reporting criteria
- Subcommittee meeting scheduling and deadlines

4:40pm-5:00pm: Tom Stosur, Director, Department of Planning

- Next steps

Project Timeline

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Project Timeline

February 5	Advisory Committee Meeting (full group)
February 5-25	Advisory Committee Sub-Committee meetings
	HAZUS analysis complete
March 5	Advisory Committee Meeting (full group)
March 5-29	Advisory Committee Sub-Committee Meetings
March 27	Town Hall Meeting I
April 9	Advisory Committee Meeting (full group)
April 9-30	Advisory Committee Sub-Committee Meetings
	Community Meeting - Fells Point (Sea Level Rise)
May	Advisory Committee Meeting (full group) – if needed
	Advisory Committee Sub-Committee Meetings– if needed
	Community Meeting – Urban Heat Islands
June 25	Town Hall Meeting II
July	Final Document (word)
August	Approval from Sustainability Commission
September	Final Document (In Design)
	Approval from Planning Commission

Definitions List

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Definitions

What is the Disaster Preparedness and Planning Project (DP3)?

The DP3 is comprised of three different elements that will all be integrated into one final plan. Every five years the Federal Emergency Management Agency (FEMA) requires local governments to update their All Hazards Mitigation Plan (AHMP). In an effort to plan for existing hazard and prepare for predicted hazards due to climate change, we propose to develop and implement an integrated AHMP, floodplain mapping, and Climate Adaptation Plan that will provide the City with a comprehensive system for addressing existing and future impacts. This project assures that adaptation recommendations are included in capital and operation budget decision making and prioritized in planning processes.

Hazards Mitigation and All Hazards Mitigation Plan

According to FEMA, hazard mitigation is sustained action taken to reduce or eliminate long-term risk to people and their property from hazards. The purpose of mitigation planning is to identify policies and actions that can be implemented over the long term to reduce risk and future losses. In 2000, the President signed into law the Disaster Mitigation Act of 2000 (DMA 2000). Part of this act requires local governments to develop and submit a hazard mitigation plan as a condition of receiving mitigation project grants. Hazard mitigation plans are required to be updated every five years. The City's AHMP will act as the foundation for Baltimore's long-term strategy to reduce disaster losses, damage, and expenses. The DP3 project will follow all requirements and procedures required for local mitigation plans by FEMA.

Climate Change

Climate Change refers to any significant change in the measures of climate lasting for an extended period of time. This includes major changes in temperature, precipitation, wind patterns, or other effects, that occur over several decades or longer. Over the past century, Maryland's average temperatures have risen by 1.8°F and are projected to continue rising. These rising temperatures have already led to changes in weather and climate including more extreme weather events, longer and more frequent heat waves, and a rise in sea level to name a few.

Climate Adaptation

Climate-related impacts are already affecting Baltimoreans. Adaptation refers to changes made to better respond to new climate conditions, thereby reducing harm and taking advantage of opportunities. Heat waves, sea level rise, and flooding due to more extreme precipitation events will all impact the City's environmental, social, and economic systems. Building adaptation into this plan will allow Baltimore City to reduce risk and increase resiliency

Why Combine the AHMP and Climate Adaptation Plan?

Integrating hazard mitigation planning which focuses on past events with climate adaptation planning and its focus on what will likely happen in the future is a win-win situation for Baltimore City. Both plans require a detailed inventory of natural hazards, a risk assessment, and a vulnerability analysis. These processes will then inform both actions to mitigate hazards and adapt to predicted climate impacts. This process provides clear guidance and a unified strategy that supports Baltimore's sustainability and resilience. Essentially, the goals for hazard mitigation and climate adaptation are the same.

Our Process:

The DP3 project will utilize the following process for plan development:

1. Identify and profile existing hazards.
2. Conduct an inventory that identifies all assets such as hospitals, schools, etc.
3. Utilize modeling to identify risk from existing hazards and predicted climate impacts.
4. Complete a vulnerability analysis of identified assets and critical facilities. Identify exposure, sensitivity and adaptive capacity.
5. Identify actions and recommendations to deal with existing hazards and predicted impacts.
6. Develop implementation plans for these actions, as well as recommendations for stakeholder involvement and funding strategies.

Vision Statement:

Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Concensus Document

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Topics for Consensus

It is important to gain consensus from the Advisory Committee regarding the following topics in order to move forward with this project. Please feel free to submit any changes to the DP3 Project Director.

Natural Hazards:

Coastal Storms, Drought, Earthquakes, Extreme Heat, Flooding, Hail, Hurricane, Ice Storms, Lightning, Severe Winter Storms, Tornado, Windstorm (Derechos)

Climate-Related Changes:

Flooding

- The frequency and severity of major storms is increasing leading to more intense rainfall and peak flooding events

Tropical Storms and Sea Level Rise

- Rising sea surface temperatures and sea level
- Sea level in this region is projected to rise more than the global average
- Sea level could rise between 2 to 3 feet (conservative estimates) by the end of this century
- The rate of sea level rise is faster now than at any time in the past 2000 years

Heat

- Temperatures are projected to rise an additional 2.5 to 4°F in winter and 1.5 to 3.5°F in summer
- More frequent days with temperatures above 100°F
- Heat waves are projected to become much more commonplace in the near future
- Hot summer conditions arriving earlier in the spring and lasting longer into the fall
- Vector

Extreme Storms and Precipitation

- Increased heavy precipitation events
- Less winter precipitation falling as snow and more as rain
- More irregular extreme events are predicted

Air Quality

- Hot summer days can worsen air pollution, especially in urban areas
- This region is likely to experience some of the highest number of heat-related illnesses and deaths compared with the rest of the nation

Infectious Diseases

- Higher temperatures, humidity and changes in precipitation will provide more ideal environments for reproduction, survival and longevity of insects and arachnids which carry diseases

Sub-Committees

I. Infrastructure
II. Buildings
III. Public Health and Human Services
IV. Natural Systems

Vision Statement:

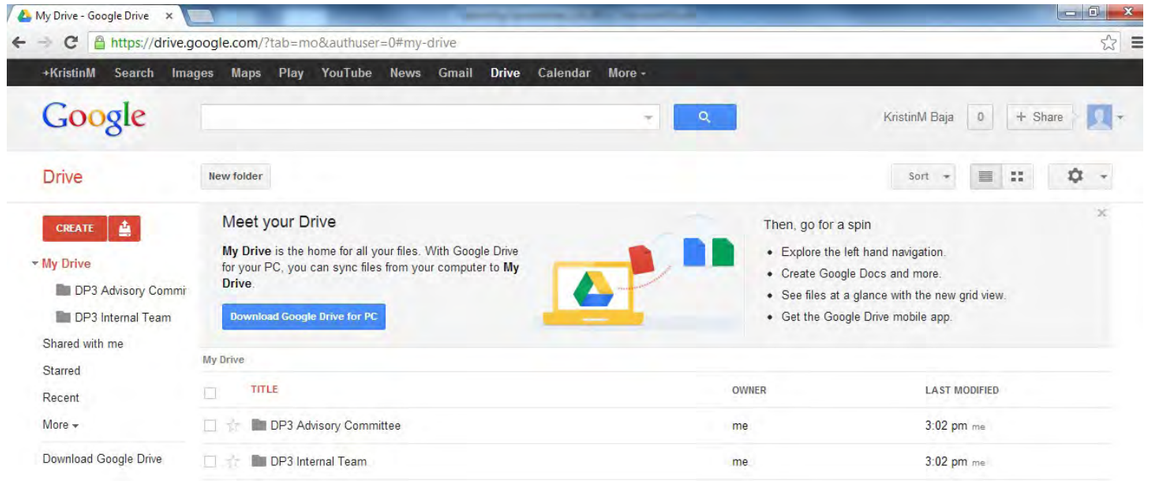
Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Project Name:

Throughout this process we have found that people have a difficult time understanding the difference between hazard mitigation, climate mitigation, and climate adaptation. For this reason we decided to rename this project for ease of understanding. The City of Baltimore Office of Sustainability appreciates your input on this decision. Do you feel Disaster Preparedness and Planning Project is a good title for this process?

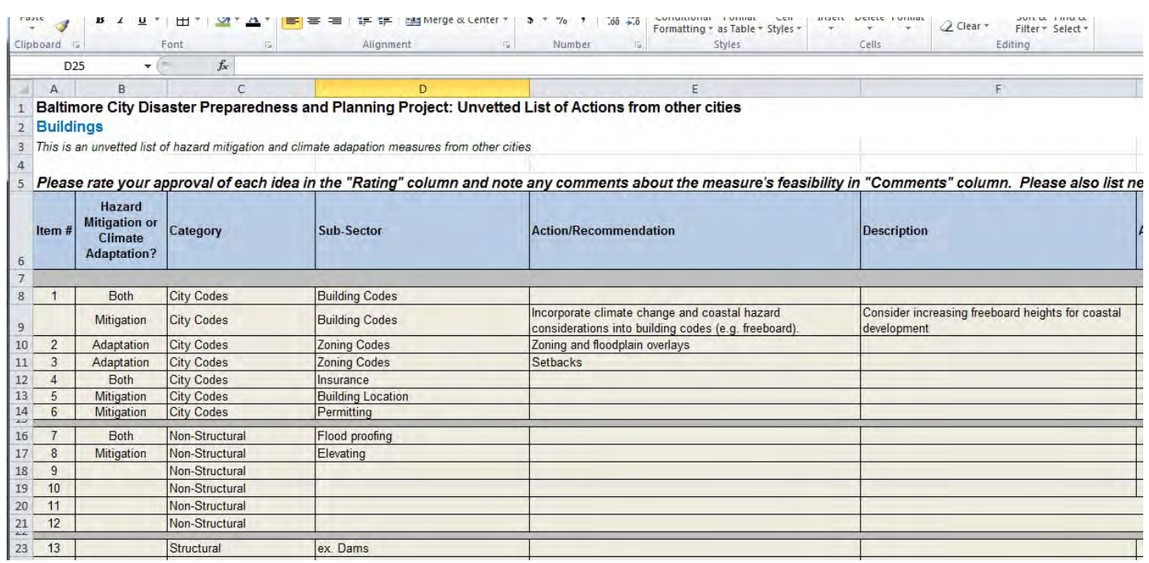
Google Drive and Documents

Google drive was utilized through this project as a place to store files, research and information for the entire Advisory Committee to access. Documents were also posted on the google drive site so all committee members could make edits and communicate with each other via chat when not in a advisory committee meeting.



Reporting Document

Draft strategies and actions were brainstormed and collected in an online reporting document. The document was used by city staff and the sub-committees to determine timelines, stakeholders, lead agencies, benefits, and concerns related to each draft strategy and action.



Baltimore City Disaster Preparedness and Planning Project: Unvetted List of Actions from other cities

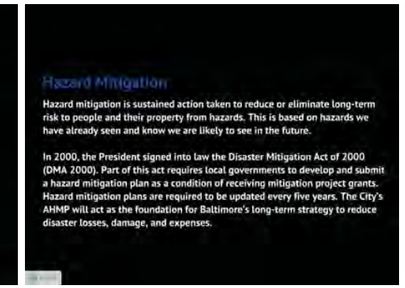
Buildings

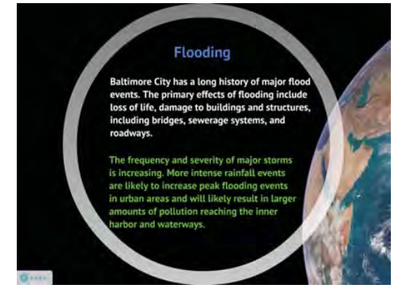
This is an unvetted list of hazard mitigation and climate adapation measures from other cities

Please rate your approval of each idea in the "Rating" column and note any comments about the measure's feasibility in "Comments" column. Please also list ne

Item #	Hazard Mitigation or Climate Adaptation?	Category	Sub-Sector	Action/Recommendation	Description
1	Both	City Codes	Building Codes		
	Mitigation	City Codes	Building Codes	Incorporate climate change and coastal hazard considerations into building codes (e.g. freeboard).	Consider increasing freeboard heights for coastal development
2	Adaptation	City Codes	Zoning Codes	Zoning and floodplain overlays	
3	Adaptation	City Codes	Zoning Codes	Setbacks	
4	Both	City Codes	Insurance		
5	Mitigation	City Codes	Building Location		
6	Mitigation	City Codes	Permitting		
7	Both	Non-Structural	Flood proofing		
8	Mitigation	Non-Structural	Elevating		
9		Non-Structural			
10		Non-Structural			
11		Non-Structural			
12		Non-Structural			
13		Structural	ex. Dams		

Presentation





Tropical Storms

Tropical cyclones are circulating weather systems over tropical waters. They bring powerful winds, rain, flooding and tornadoes. Types of tropical cyclones include tropical storms and hurricanes.

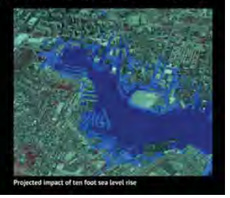
There has been a substantial increase in hurricane activity in the Atlantic since the 1970s.

Recent Tropical Storms/Hurricanes in Baltimore:
2011 Tropical Storm Lee
2011 Hurricane Irene
2006 Tropical Storm Ernesto
2003 Hurricane Isabel

Sea Level Rise

The rate of sea-level rise is increasing. After at least two thousand years of little change, sea level rose by roughly 8 inches over the last century, and satellite data provide evidence that the rate of rise over the past 20 years has roughly doubled

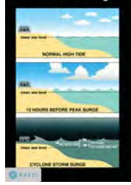
Sea level is rising because ocean water expands as it heats up and because water is added to the oceans from melting glaciers and ice sheets. Sea level is projected to rise an additional 1 to 4 feet this century.



Projected impact of ten foot sea level rise

Storm Surge

Refers to the rise of water associated with the storm, plus tide, wave run-up, and freshwater flooding.



Winter Storms

The biggest rainstorms and snowstorms are getting bigger. The amount of precipitation released by the largest annual storms in Maryland increased by 14 percent from 1948 to 2011.

Warmer air holds more moisture, and that moisture is fuel for storms. It won't necessarily rain/snow more often. But when it does, it's more likely to be intense and significant.

Baltimore's snowiest month ever was February, 2010 with 50.9" of snow

Because of warm waters of the Gulf Stream off our eastern shore, it is typical for the rain-snow line to cut right across Baltimore City. Ice storms are likely to happen more often in the future due to sub-freezing air being trapped.

Lightning and Hail

Other dangers associated with increased storms are lightning and hail. Lightning occurs in all thunderstorms. A typical thunderstorm has three or more strikes per minute at its peak.

With increased number of extreme storm events will come increased risk from lightning strikes.

Lightning events may induce secondary hazards such as infrastructure deterioration or failure, utility failures, power outages, and fires.

Hail is possible within most thunderstorms. It can cause serious damage to automobiles, aircraft, structures, livestock, and crops.

Extreme Heat

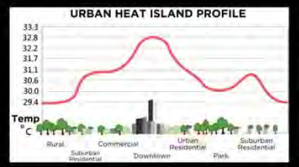
Extreme heat can be lethal, especially for our most vulnerable citizens. Temperatures in the contiguous United States last year were the hottest in more than a century of record-keeping

Average air temperatures are projected to increase by about 3°F by mid-century. Average summer temperatures could increase by as much as 9°F leading to extended heat waves.

The number of days with air temperatures exceeding 90°F is projected to double (and could even triple) by the end of the century. Under the higher emissions scenario, each year could average more than 24 days of air temperatures exceeding 100°F.

Urban Heat Islands

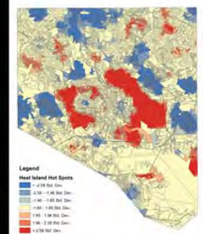
A metropolitan area, which is consistently hotter than the surrounding area due to human activities. The main cause of the urban heat island is modification of the land surface by urban development which uses materials which effectively retain heat.



"Over the past ten years, heat has been the number one weather-related killer in the United States, resulting in hundreds of fatalities each year.

In fact, on average, excessive heat claims more lives each year than floods, lightning, tornadoes and hurricanes combined." - NOAA

Baltimore Urban Heat Island Map



High Wind Events

The Baltimore region has a long history of powerful storms with damaging winds. High winds can lead to power outages due to tree branches disrupting the flow of energy through power lines, structural damage, and damage to infrastructure such as bridges.

Research suggests increases in intensity of extreme storm events which increases the likelihood of damaging winds. This will lead to more severe damage to city infrastructure and housing.

Extreme Wind Storms and Derechos

The June 2012 derecho was one of the most destructive and deadly fast-moving severe thunderstorm complexes in North American history.

Tornadoes

Tornadoes are dangerous atmospheric disturbances that can be spawned by thunderstorms or hurricanes. They appear as funnel-shaped clouds and are very destructive

The City of Baltimore has experienced six tornadoes within the city limits over the last 23 years.

Drought

Drought is not a major issue directly facing the City of Baltimore, however residents of Baltimore will be severely impacted by the drought conditions being felt throughout the rest of the country

Droughts may have economic, social or environmental impacts.

Baltimore residents are likely to see impacts in the form of increased food prices and diminished food availability.

Increased weed and pest pressure associated with longer growing seasons and warmer winters will also have human health implications

Extreme Storms and Precipitation

A 2012 report from The Environment Maryland Research & Policy Center 2012 report confirmed that extreme rainstorms and snowstorms are happening 55 percent more frequently in the Mid-Atlantic region than in 1948. Bigger storms are continuing to hit Maryland more often. Heavy downpours or snowstorms that used to happen once every 12 months on average in the Mid-Atlantic region now happen every 7.7 months on average.

Precipitation is projected to increase during the spring and winter months, but become more episodic. During the summer months, extended droughts are projected to be more

Increase Precipitation

The increase in extreme precipitation events are occurring primarily during the spring and fall.

The map shows percent increases in the amount falling in very heavy precipitation events (defined as the heaviest 1 percent of all daily events) from 1958 to 2012 for each region

Rainfall in Maryland is projected to increase by 5-12% by 2100

Other Important Hazards

Air Quality

Earthquakes

Infectious Diseases

Air Quality

Changing weather patterns have lead to an increase in the number of extreme heat days.

Sunlight and heat combined with air pollution from vehicles, industrial factories, pesticide applications and volatile organic compounds (VOCs) has generated higher ozone concentrations.

A= best/cleanest B C D F=worst/dirtiest in the U.S.

Higher ozone concentrations can lead to asthma, chronic obstructive lung disease, emphysema, lung cancer, and cardiovascular disease.

Airsheds

Much of our air originates in areas of the Midwest dominated by polluted emissions from powerplants and motor vehicles.

Baltimore generates plenty of air pollution from the same sources within the region, but the amount from outside sources essentially doubles it. This heavy air pollution load causes human health problems.

Earthquakes

Earthquakes are a sudden release of energy in the Earth's crust that creates seismic waves. On August 23, 2011 a 5.8 magnitude earthquake occurred in the Central Virginia Seismic Zone. Earthquakes in the eastern US, although less frequent, are typically felt over a much broader region.

In Baltimore, two buildings partially collapsed due to the quake blocking off the area of Highland Ave and Conkling Street.

"After the blizzard of the century and the tornado and the floods, I don't think we should be surprised."

Mayor Stephanie Rawlings-Blake referring to the 2011 earthquake

Infectious Diseases

"Vector-borne disease" is the term commonly used to describe an illness caused by an infectious microbe that is transmitted to people by blood-sucking insects or arachnids such as mosquitoes, fleas, lice, mites and ticks.

Weather affects vector disease transmission. Higher temperatures, humidity, and changes in precipitation all factor into biting behavior, survival, reproduction rates, and longevity for insects.

This can lead to formerly prevalent diseases such as malaria and dengue fever to re-emerge, or the introduction of new disease agents, such as West Nile virus.

- Help gather and verify historical hazard data
- Provide information regarding cost and impacts of previous hazard events
- Assist with gathering more recent and relevant climate science
- Work in sub-committees to develop both mitigation and adaptation recommendations
- Assist with outreach, education and development of implementation and monitoring plan

Sub-Committees

I. Infrastructure

II. Buildings

III. Public Health and Human Services

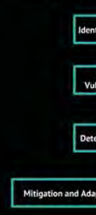
IV. Natural Systems

Sub-Committee Tasks

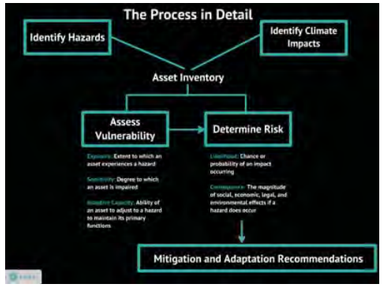
1. Consider the hazards and climate impacts we discussed
2. Determine how these hazards impact your topic area
3. Work with sub-committee to draft recommendations
4. Fill in reporting document

Implications

The DP3 Process Simplified



The Process in Detail



Google Documents

- You will be sent an invitation to join
- You will need to create a User Name
- You will need to create a Password

Timeline

February 11	Advisory Committee Meeting (full group)
February 11-27	Advisory Committee Sub-Committee meetings
March 5	Advisory Committee Meeting (full group)
March 5-29	Advisory Committee Sub-Committee Meetings
March 27	Town Hall Meeting I
April 9	Advisory Committee Meeting (full group)
April 9-30	Advisory Committee Sub-Committee Meetings Community Meeting
May	Advisory Committee Meeting (full group) – if needed Advisory Committee Sub-Committee Meetings Community Meeting
June 25	Town Hall Meeting II
August	Approval from Sustainability Commission
September	Approval from Planning Commission

Vision Statement

Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards

Mitigation and Adaptation Recommendations

Generate a list of hazard mitigation and adaptation recommendations
- Identify advantages and disadvantages
- Identify stakeholders
- Identify interdependencies with other systems

Evaluate recommendations
- Cost-benefit analysis
- Determine overlap

Prioritize recommendations
- Ranking
- Consensus

Implementation strategies

Incorporating adaptation best practices into city planning strategies is essential and can have positive effects on community resilience, human health, air quality, energy demand and economic prosperity

Baltimore needs to develop and apply proactive approaches to increase community resilience by planning for and adapting to emerging climate change impacts

For every $1 spent on hazard mitigation, society saves an average of $4

Your Role

Consensus on the following:

- Hazards we are facing
- Climate related changes
- Vision Statement
- Sub-Committees
- Project Name

Questions?

Comments?

Advisory Commitee Meeting March 5th, 2013

Agenda

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Advisory Committee Meeting

March 5, 2013

Committee Purpose:

- To bring together stakeholders from key agencies, institutions, businesses, and neighborhoods to identify actions and recommendations for the City of Baltimore's Disaster Preparedness and Planning Project.

Meeting Objectives:

- Report out on sub-committees and get everyone on the same page
- Discussion and consensus on goals and objectives for the project
- Enhance the understanding of adaptation and what we are adapting to
- Better understand how Baltimore has responded to hazards in the past

Materials Provided:

- Agenda
- List of sectors, categories, and subcategories

Agenda:

9:30am-9:35am: Tom Stosur, Director, Department of Planning

- Welcome and brief introductions

9:35am-10:00am: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Report out on sub-committees
- Vision, goals, objectives, actions

10:00am-10:15am: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Increased frequency and intensity of hazards (Rich Foot)
- Adaptation and the ICLEI process

10:15am-10:35am: CP Hsia, Office of Emergency Management

- Understanding past hazards and the City's response
- Future hazard response when considering climate change

10:35am-10:50am: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Subcommittee meetings and next steps
- Subcommittee deadlines

10:50am-11:00am: Gather with subcommittees

Subcommittees

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Subcommittees

March 5, 2013

Subcommittee Progress:

- Each subcommittee met at least once between February 13th and February 27th. Subcommittee members determined the categories and subcategories for structuring recommendations and actions within their sectors; they evaluated best practices from other city's all hazards plans and climate adaptation plans; and they drafted new actions based on the hazards identified in the previous meeting.

Categories by Sector:

Infrastructure:

- Energy Systems
- Transportation Systems
- Communication Systems
- Water and Wastewater Systems
- Stormwater Systems
- Solid Waste Systems

Buildings:

- City Codes
- Non-Structural
- Structural
- Design

Natural Systems:

- Land Use
- Greening
- Maintenance and Operations
- Water Supply
- Stormwater Management

Public Health and Human Services:

- Organized by Hazard instead of Category- all hazards, flooding, extreme storms, air quality, sea level rise
- Identified actions as mitigation measures, preparedness measures, response, recovery, and/or policy
- Began process of identifying education/outreach measures and communication measures associated with each action/recommendation

Advisory Committee Feedback:

- Are there any categories missing that you feel are important to incorporate into a specific sector?
- Do you feel the sectors adequately cover the main elements at risk to hazards and climate change?

Advisory Committee Meeting Presentation — March 5, 2013

City of Baltimore
Department of Planning

Disaster Preparedness and Planning Project (DP3)

Advisory Committee Meeting #2

March 5, 2013

Tom Stosur,
Director
Department of Planning

Robert Maloney,
Deputy Chief of Emergency Management and Public Safety

Agenda

- Review Subcommittee Progress
- Vision Statement and Goals
- Rich Foot- Climate Science
- Review Adaptation and the ICLEI process
- CP Hsia- Understanding the City's response to hazards
- Next Steps

Subcommittees

- Infrastructure
- Buildings
- Natural Systems
- Public Health and Human Services

Objectives and Actions

Objectives: Specific, measurable outcomes of the project.

Examples:

1. *Increase awareness of threats from natural hazards and climate change.*
2. *Enhance the understanding of Baltimore's vulnerability to climate change and natural hazards, and identify data gaps.*
3. *Develop hazard mitigation and climate adaptation actions and utilize a prioritization system to direct implementation efforts*
4. *Design a methodology that combines hazard mitigation planning and climate change adaptation, enabling the City to engage in a combined planning effort in the future.*
5. *Create a DP3 plan that Baltimore can use to implement the chosen actions.*

Actions: Activities the City of Baltimore and the community will undertake to achieve greater resiliency, mitigate hazards and adapt to the impacts of climate change.

Climate Science

Rich Foot
Data and specific changes to natural hazards in Baltimore

Coastal Storms	more severe
Floods	more extensive
Severe Thunderstorms	more severe
Wind	increase intensity
Winter Storms	less snow, more flooding
Extreme Heat/Drought	more severe and intense
Sea Level Rise	increased threat
Air Quality	lower quality and increase risk

Sea Levels

Infrastructure

- Energy Systems
  - Power supply, Substations
- Transportation Systems
  - Highways and Roads, Bridges, Tunnels, Public Transportation
- Communication Systems
  - Technology, Redundancy
- Water and Wastewater Systems
  - Drinking Water, Water Supply, Sewers, Pumping Stations
- Stormwater Systems
  - Flooding and Erosion, Maintenance
- Solid Waste System

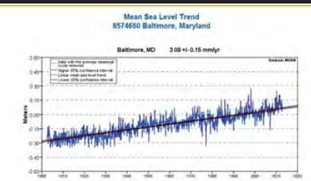
Buildings

- City Codes
  - Building Codes, Zoning Codes, Insurance
- Non-Structural
  - Improve Efficiency
- Structural
  - Retrofits and Upgrades, Flood proofing, Critical Facilities
- Design
  - Design Guidelines

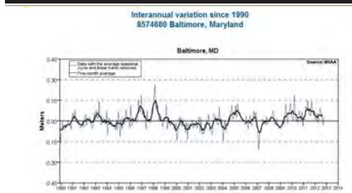
Natural Systems

- Land Use
  - Land Acquisition, Land Preservation
- Greening
  - Tree Canopy, Landscape, Policy, Vacant Lots
- Maintenance and Operations
  - Trees and Vegetation, Debris, Ecological Buffers
- Water Supply
  - Drinking Water Quality and Supply, Drought Preparedness
- Stormwater Management

Mean Sea Level Trend



Inter-decadal variation since 1990



http://www.agu.org/pubs/crossref/pip/2012GL053435.shtml

Public Health and Human Services

- Organized by Hazard instead of Category
  - All Hazards, Heat, Flooding, Extreme Storms, Sea Level, Air Quality
- Identified whether actions were Mitigation Measures, Preparedness, Response, Recovery and/or Policy
- Began process of identifying Education/Outreach Measures and Communication Measures associated with each action/recommendation.

Sample of Recommended Actions

- Incorporate climate change and coastal hazard considerations into building codes by increasing freeboard requirements to two or three feet.
- Manage urban forest and vegetation to reduce susceptibility to invasive or epidemic insects, disease, and drought.
- Become a Community Rating System (CRS) certified community.
- Use elevation data and model results to determine roads at risk of flooding and prioritize infrastructure upgrades for those at risk.

Vision and Goals

Vision Statement:
Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Goals: A broad statement of what will be achieved within a fixed timeframe

Examples:

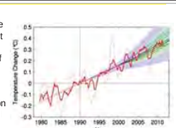
1. *Protect life and property.*
2. *Support emergency services.*
3. *Promote public awareness.*
4. *Encourage the development and implementation of long-term, cost-effective and environmentally sound mitigation and adaptation projects.*

Goals → Objectives → Actions

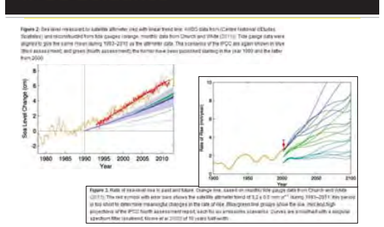
http://stateofthecoast.noaa.gov/

IPCC Guidance

The results show that global temperature continues to increase in good agreement with the best estimates of the IPCC, especially if we account for the effects of short-term variability due to the El Niño/Southern Oscillation, volcanic activity and solar variability. The rate of sea-level rise of the past few decades, on the other hand, is greater than projected by the IPCC models. This suggests that IPCC sea-level projections for the future may also be biased low.



IPCC Guidance



Adaptation

- **Why focus on adaptation?**
  - Scientific evidence indicates that even if we could halt greenhouse gas emissions today, the world would still experience a changing climate for decades to come
- **Adaptation refers to changes made to better respond to new climate conditions.**
  - Many of the impacts (changing temperature and weather patterns, drought, flooding, and sea level rise) are already being felt directly in Baltimore

ICLEI

- **International Council for Local Environmental Initiatives, ICLEI,** is an international association of local governments that have set the national standard for local climate adaptation planning
- ICLEI supports cities in their efforts to develop adaptation strategies and action plans, and to guide them through a systematic process of implementation and management.

ICLEI Process

ICLEI Process: Current Phase

Identify possible adaptation responses:

1. **Develop actions**
   Activities the City of Baltimore and the community will undertake to achieve greater resiliency, mitigate hazards and adapt to the impacts of climate change
2. **Prioritize actions**
3. **Identify implementation tools**
4. **Develop measures used to track results over time**

State Adaptation Plan

- Integrate key recommendations into our plan
- Data-sharing
- Utilize State Adaptation and Hazard Mitigation information to enhance our preparedness and planning efforts

City of Baltimore
Mayor's Office of Emergency Management

MOEM and Disaster Preparedness and Planning Project (DP3)

C.P. Hsia
March 5, 2013

Stephanie Rawlings-Blake, Mayor

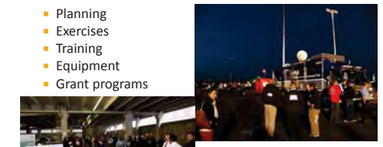
Robert Maloney, Deputy Chief of Emergency Management and Public Safety

MOEM Typical Responses

- Large fires
- Incidents affecting critical infrastructure or location of cultural importance (hospital, school, etc.)
- Weather-related, usually flooding
  - 8 flood-related MOEM responses since 2006, outside of large incidents such as Hurricane Irene and TS Lee
  - Typically involves: DPW, DOT, DHCD, BPD, MOEM, MTA, BGE

MOEM: Preparedness Programs

- Planning
- Exercises
- Training
- Equipment
- Grant programs



Continuous Improvement Cycle

- Preparedness cycle is one of constant improvement
- MOEM generates After-Action Report (AAR) for incidents
- Large incidents will also have an After-Action Conference (AAC)
- Many agencies also have an internal AAR process

Homeland Security Exercise and Evaluation Program (HSEEP)

Similar cycle for HSEEP

NEXT STEPS

Information/Data Gathering

- Agency Directors will receive a survey regarding what your agency is already doing in response to natural hazards (keep an eye out for this email)
- Specific committee members will be asked for assistance and data related to climate and modeling
- All members should review the Reporting Spreadsheets on google drive before the subcommittee meetings and add additional information

MOEM Overview

- Prepare City government
- Prepare the public
- Work with partners to mitigate disasters
- Coordinate interagency response and recovery
  - Incidents
  - Events

MOEM Partners

- City Agencies
  - Not just BCFD, BPD, BCHD, DHCD, DOT, DPW…
- Other Government Partners
  - MEMA, MTA, MDOT, etc.
- Private Sector
  - BGE, CSX
- Non-profits
  - Red Cross, Salvation Army, Business Volunteers Unlimited, etc.

MOEM: Operations Programs

- 24x7 Field response
  - Dispatched when incident overwhelms single agency or is outside normal scope of operations
- EOC operations

Subcommittees

- Important Subcommittee meetings in March
- Accomplish the following tasks:
  - Finalize all actions (mitigation and adaptation)
  - Identify stakeholders and lead agencies
  - Prioritization exercise
  - Develop a timeframe for all actions
  - Assess feasibility
  - Vulnerability Assessment exercise

Subcommittee Meeting Dates

- **Infrastructure**
  Monday, March 25th — 9:00am-11:00am
- **Buildings**
  Tuesday, March 12th — 2:30pm-4:30pm
  Wednesday, March 27th — 1:00pm-2:30pm
- **Natural Systems**
  Friday, March 22nd — 2:00pm-4:00pm
  Monday, March 25th — 11:30am-1:30pm
- **Public Health and Human Services**
  Monday, March 11th — 3:30pm-5:30pm
  Tuesday, March 26th — 11:00am-1:00pm

*Subcommittee meetings will be held at the Department of Planning Office

Reminders

- **Remaining Full Advisory Committee Meetings**
  - Tuesday, April 9th — 9:30am-11:30am
  - Tuesday, May 21st — 9:30am-11:30am
- **First DP3 Public Meeting**
  - Wednesday, March 27th — 5:00pm-8:00pm
    War Memorial Building

Advisory Commitee Meeting April 9, 2013

Agenda

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Advisory Committee Meeting

April 9, 2013

Committee Purpose:

- To bring together stakeholders from key agencies, institutions, businesses, and neighborhoods to identify actions and recommendations for the City of Baltimore's Disaster Preparedness and Planning Project.

Meeting Objectives:

- Review document framing, goals, strategies and recommendations
- Review full recommendations list and top priority recommendations
- Gain a greater understanding of new floodplain maps
- Determine perceived risk for current and future climate conditions

Materials Provided:

- Agenda
- Full list of DP3 recommendations
- Framing document
- Vulnerability assessment worksheet

Agenda:

9:30am-9:35am: Tom Stosur, Director, Department of Planning

- Welcome and brief introductions

9:35am-10:00am: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Progress to date
- Framing of document
- Goals, strategies and recommendations

10:00am-10:05am: Beth Strommen, Director, Office of Sustainability

- Connection of DP3 plan to Federal, State, Local and non-government plans

10:05am-10:15am: Ken Hranicky, Flood Manager, Department of Planning

- Updated FEMA maps and importance of regulating to old lines

10:15am-10:50am: Small Group Work Sessions

- City employees: with Ken Hranicky and Alice Kennedy
  - Vulnerability assessment exercise
  - Future scenarios exercise
- Non-city employees: with Kristin Baja and Beth Strommen
  - Vulnerability assessment exercise
  - Future scenarios exercise

10:50am-11:00am: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Town Hall meeting
- Subcommittee meetings
- Advisory Committee moving forward

Small Group Scenarios

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Small Group Session Two

April 9, 2013

Three Scenarios:

1. **One month of 95°+ days with rolling brown outs**
   High volume of people going to the hospital or clinics for heat related illnesses
   Pavement buckling and systems heavily impacted
   What else?

2. **Massive hurricane with storm surge followed by a derecho thunderstorm system**
   Considerable portion of downtown inundated with floodwaters
   Debris scattered all over the City
   Power Out
   What else?

3. **One solid week of torrential rains and flooding**
   Considerable flooding throughout the City
   Damage to infrastructure
   Many roads unusable
   What else?

Considerations:

Personal

How would this scenario impact your personal life?

How would it impact your immediate family?

How would it impact the people you work with?

What impact would it have to your home?

Economic

How would this scenario impact business in your neighborhood?

How would it impact the city at large?

Environmental

How would this scenario impact your local environment?

Systems

How would this scenario impact the systems in which you work?

How would it impact the systems you rely on daily?

Framing

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Framing: Vision, Goals and Strategies

April 9, 2013

Vision: Outlines what the project wants to be

- Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Goals: Goals are defined as a general value statement of long-range direction which identifies desired states of affairs toward which activities andresources can be directed. Goals reflect the community's needs and values.

Draft goals

- To make Baltimore more resilient to current hazard events and predicted climate conditions
- To protect the health and safety of Baltimore City residents and visitors
- To prevent damage to infrastructure, structures, and critical facilities
- To support emergency services
- To promote public awareness
- To encourage the development and implementation of long-term, cost-effective and environmentally sound mitigation and adaptation projects

Strategies: Strategies are thoughtfully constructed plans, methods, or actions that can be employed to ultimately result in positive progress towards the achievement of a given goal. Strategies are based upon identified strengths, weaknesses, and opportunities.

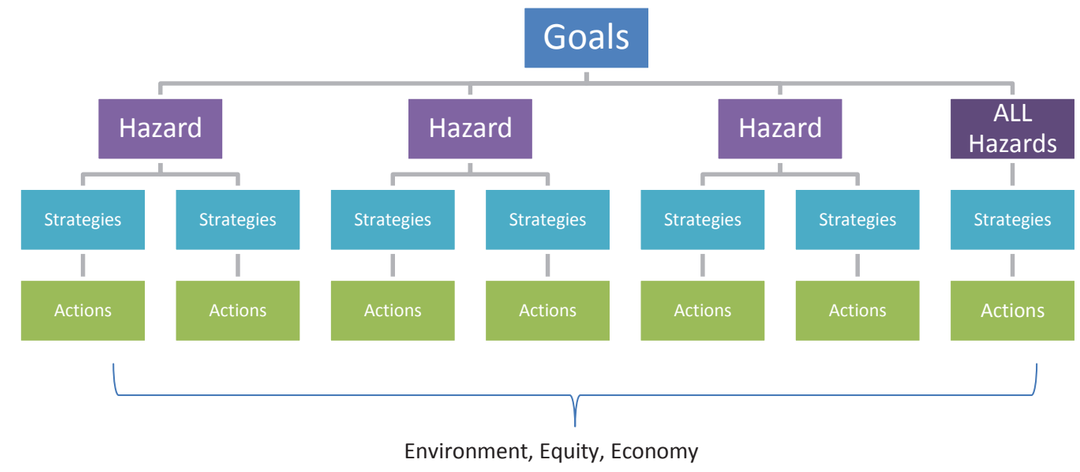
Small sample of draft strategies:

- Improve stormwater management throughout Baltimore City
- Become a Community Rating System (CRS) Community
- Increase participation in the National Flood Insurance Program (NFIP)
- Reduce vulnerability to increased heat and storm events
- Minimize damages from current and predicated extreme weather events
- Increase awareness of vulnerability to natural hazards and changes in climate through a targeted outreach and education campaign
- Incorporate climate adaptation and hazard mitigation planning and preparedness measures into all city-wide plans and planning efforts
- Continue to monitor and enhance climate data to better inform and update recommendations

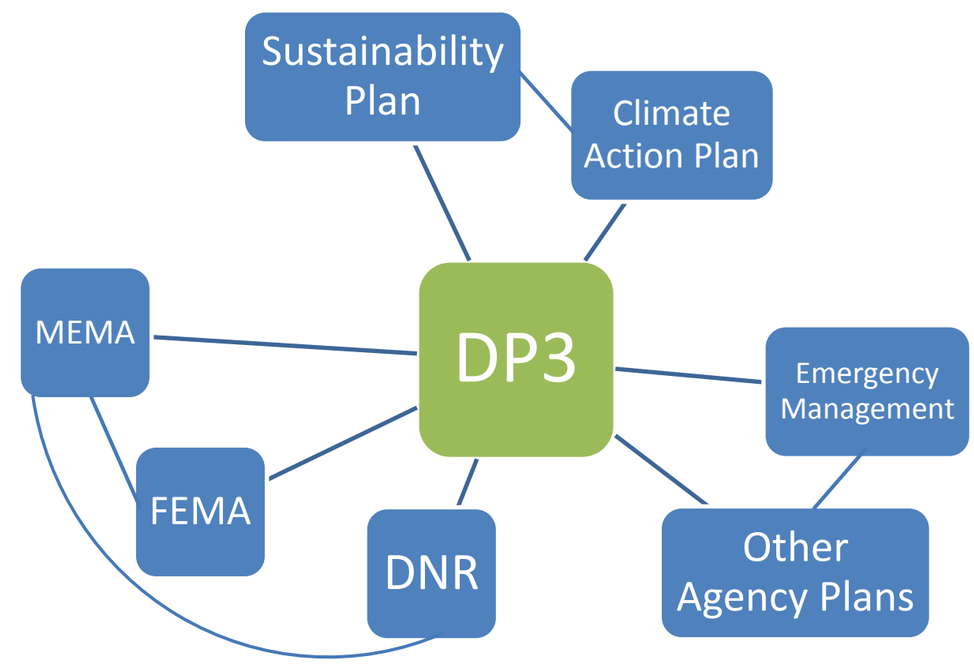
Actions: Specific actions that are endorsed to accomplish one or more strategies, and thereby make positive progress toward the achievement of goals.These are actions the City of Baltimore and the community will undertake to achieve greater resiliency, mitigate hazards and adapt to the impacts of climate change.

- See spreadsheet for a full list of draft recommendations

Framing the DP3 Plan:



Connection with other Plans:



Presentation

April 9th, 2013

DISASTER PREPAREDNESS AND PLANNING PROJECT (DP3)

Advisory Committee Meeting

Presentation Overview

1 Framing & Structure
2 FEMA Maps & strategies
3 Small Group work sessions
4 Next Steps

Progress to Date

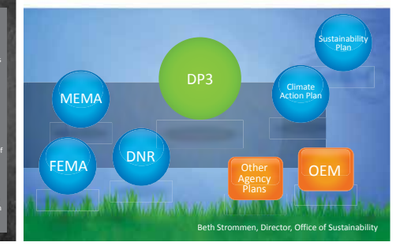
- Completed hazard identification and assessment
- Identified 150 mitigation and adaptation actions
- Generated list of lead agencies, stakeholders and co-benefits
- Identified timeframe and initial prioritization
- Conducting HAZUS analysis to identify risk and vulnerabilities
- Set up public outreach meetings- start with floods, heat next

Now onto completing data analysis and writing the plan

Top Ten DP3 Recommendations:

1. Identify how a natural disaster event will impact important energy supply systems such as the Trigen/Violia steam system, chilled water loop , and the BRESCO facility
2. Improve backup power systems by increasing the number of backups and pulling from different grids. Ensure all water and wastewater pumping stations have reliable backup power sources
3. Ensure all water and wastewater pumping stations have reliable backup power sources. Take steps to provide some level of disinfection to raw sewage for overwhelmed wastewater pumping stations.
4. Develop stricter flood regulations for critical facilities such as hospitals, fire stations, police stations, hazardous material storage sites, etc.
5. Require property owners, when completing rental registration, to identify if their property is located in the floodplain
6. Increase the urban tree canopy and target areas with urban heat island impacts
7. Develop a comprehensive list of plant and tree species or varieties known to have a broad range of environmental tolerances.
8. Ensure consistency and integration with existing response plans within and between agencies
9. Educate and train community groups to participate in responding to hazards
10. Require, through policy, that new city capital improvement projects incorporate hazard mitigation principles (e.g., prohibit new projects in hazard-prone areas such as floodplains or the coastal high hazard area; requiring above code design requirements for critical facilities).

DP3 Plan Connections



Beth Strommen, Director, Office of Sustainability

2 FEMA Flood Map Update

Ken Hranicky, City of Baltimore Flood Manager

1 Framing

Goals, Strategies, and Recommendations

Kristin Baja, Hazard Mitigation Planner

Methodology- integration of planning processes

FEMA Crosswalk Requirements

Conduct a Risk Assessment- Identify Hazards, Profile Hazards, Assess Vulnerability

Create a Hazard Mitigation Strategy- Goals, Actions, Implementation

Plan Maintenance- Monitoring, Evaluating, Updating the Plan & Public Involvement

ICELI Five Milestone Process

Milestone One: Conduct a Climate Resiliency Study

Milestone Two: Set Preparedness Goals

Milestone Three: Develop a Climate Preparedness Plan

Milestone Four: Publish & Implement Preparedness Plan

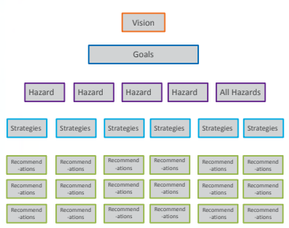
Milestone Five: Monitor & Reevaluate Resiliency

Structure of the DP3 Plan

Main Goals	Overarching goals for the plan
Hazards	Sections divided by hazard
Strategies	Strategies for each hazard
Recommendations	Actions divided into four sectors: Infrastructure, Buildings, Natural Systems, Public Health and Human Services

Example:
Hazard: Heat
Strategy: Reduce vulnerability to increased heat
Recommendations: Environment, Equity, Economy
- Infrastructure: Reduce damage to asphalt from changes in climate and determine a repaving strategy that incorporates better maintenance and operations.
- Buildings: Require reflective roof systems or vegetative roofs for all new commercial, industrial, multifamily, and city-owned development
- Natural Systems: Increase the urban tree canopy and target areas with urban heat island impacts
- Public Health: Ensure redundancy of energy systems at all city cooling centers

Structure of the Plan



Goals and Strategies

Based on the draft list of goals and strategies in front of you, do you feel we are **heading in the right direction?**

The goals and strategies may evolve as we connect DP3 to other plans

List of Recommendations

- Extensive list generated by the subcommittees- Thank you!
- DP3 Project Manager currently working to place all recommendations into the plan structure discussed
- Final list will be distributed via email for comment

Floodplain Maps

Current Maps
- Adopted on February 2, 2012
- Tidal Floodplain Delineation was based on a 1977 Virginia Institute of Maritime Science Study of the Chesapeake Bay

New Tidal Study
- Currently under consideration
- New Study- a significant increase in computing and data

FEMA Flood Maps

Significantly lower flood heights for the 1% Storm

Hurricane Isabel

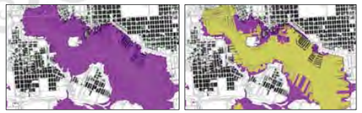
New Floodplain Maps

Land/Water Boundary

Flood Maps: Inner Harbor

Before

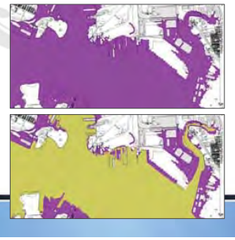
After



Flood Maps: Colgate Creek

Before

After



Flood Map Recommendations

Continue to regulate,

1. To the existing boundary
2. To the storm of record- Isabel

3 Small Group Exercises

Office of Sustainability and Department of Planning Staff

Small Group Exercise One

Perceived Vulnerability and Risk

- »Review spreadsheet as a group
- »Fill in spreadsheet
- »Return spreadsheet to city staff member

SCENARIOS

Work in your small groups on the following future climate scenarios

Small Group Exercise Two

Planning for Future Climate Changes

- »One month of 95°+ days with rolling brown outs
- »Massive hurricane with storm surge followed by a derecho thunderstorm system
- »One solid week of torrential rains and flooding

4 Next Steps

Kristin Baja, Hazard Mitigation Planner

Town Hall Meeting

- Tuesday, April 30th at the War Memorial Building
- Invitations will be sent to all people within the floodplain
- Information gathering and feedback opportunity
- Focus on new FEMA floodmaps, DP3 project, and emergency management
- Review hazard mitigation and climate adaptation actions
- 5:00pm-9:00pm

Advisory Committee Next Steps

- » **Next Advisory Committee Meeting**
  Tuesday, May 21st 9:30am-11:30am
  Focus on HAZUS outcomes and finalized actions
- » **Next Subcommittee Meeting**
  Groups can meet in person or review material online
  Focus on Implementation and Monitoring
- » **Document Review and Comment**
  Portions of the document will start to be available for review and comment in May. Advisory Committee members will be sent portions of the document for editing and review.
- » **Final Meeting to approve plan- June, 2013**

QUESTIONS?

Advisory Commitee Meeting June 28, 2013

Agenda

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Advisory Committee Meeting

June 28, 2013

Committee Purpose:

- To bring together stakeholders from key agencies, institutions, businesses, and neighborhoods to identify actions and recommendations for the City of Baltimore's Disaster Preparedness and Planning Project.

Meeting Objectives:

- Report on progress made to date
- Review and approve DP3 strategies
- Discuss DP3 actions and clarify any concerns
- Review next steps and committee members roll

Materials Provided:

- Agenda
- List of DP3 strategies
- List of DP3 strategies with draft actions

Agenda:

10:00am-10:05am: Tom Stosur, Director, Department of Planning

- Welcome and goals for the meeting

10:05am-10:20am: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Progress to date
- HAZUS and vulnerability assessment
- Flood and Heat meetings in communities

10:20am-10:35am: Beth Strommen, Director, Office of Sustainability & Kristin Baja

- Discussion of strategies by sector
- Approval of strategies

10:35am-11:10am: Beth Strommen & Kristin Baja

- Review and discuss actions of concern

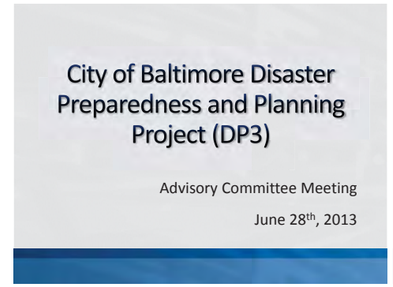
11:10am-11:15am: Kristin Baja, Hazard Mitigation Planner

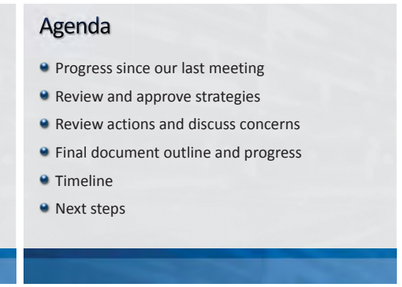
- Final document outline
- Final document timeline
- Final meeting for vote

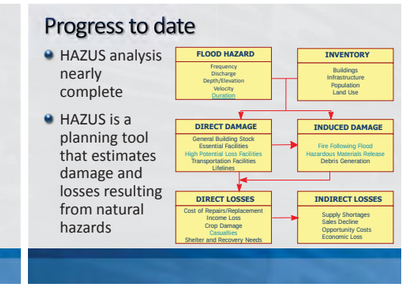
11:15am-11:30am: Beth Strommen, Director, Office of Sustainability

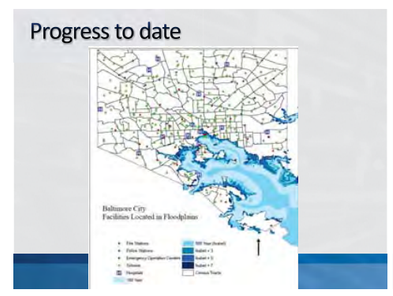
- Looking beyond this plan

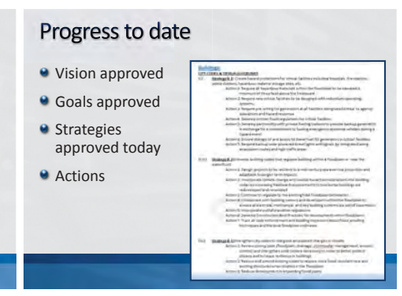
Presentation

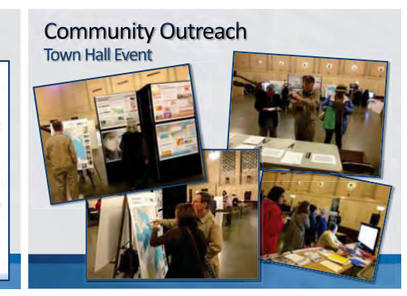


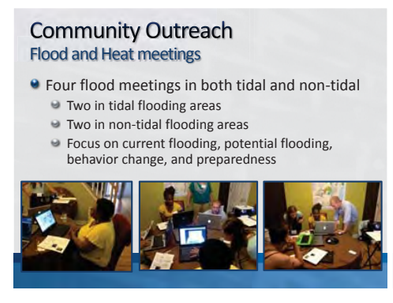


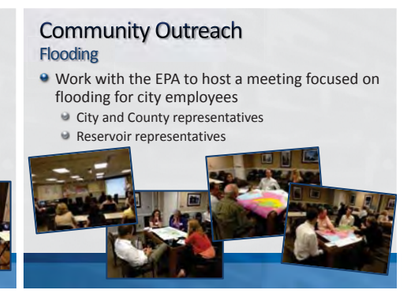












Infrastructure Strategies

ENERGY

Strategy IN-1: Protect and enhance the resiliency and redundancy of electricity system

Strategy IN-2: Increase energy conservation efforts

Strategy IN-3: Ensure backup power generation for critical facilities and identified key infrastructure during power outages

Strategy IN-4: Partner with utility to evaluate protecting power and utility lines from salt-water intrusion.

Infrastructure Strategies

LIQUID FUELS:

Strategy IN-5: Protect and manage compressed liquefied natural gas sites and (City) fueling stations before and during hazard events

Strategy IN-6: Evaluate and improve resiliency of liquid fuels infrastructure

COMMUNICATION SYSTEMS

Strategy IN-7: Evaluate and improve resiliency of communication systems that are in place for sudden extreme weather events

WATERFRONT

Strategy IN-8: Enhance the resiliency of the City's waterfront

Infrastructure Strategies

TRANSPORTATION

Strategy IN-9: Integrate climate change into transportation design, building and maintenance

Strategy IN-10: Identify additional alternative routes and modes for effective transport and evacuation efforts during emergency situations

Strategy IN-11: Alter transportation systems in flood-prone areas in order to effectively manage stormwater

Strategy IN-12: Design and implement floodgates and barriers in transportation tunnels

Strategy IN-13: Ensure structural stability of all transportation tunnels to reduce impact from seismic activity

Strategy IN-14: Explore changes to road maintenance and construction materials based on anticipated changes in climate

Buildings Strategies

NON-STRUCTURAL

Strategy B-10: Improve resource conservation opportunities in all city owned buildings

Strategy B-11: Provide education about resource conservation within buildings

Strategy B-12: Determine losses generated by a coastal storm/hurricane and engineering effectiveness and cost-benefit of various coastal storm mitigation measures using HAZUS-MH computer modeling

Natural Systems

URBAN PARKS AND FOREST

Strategy NS-1: Utilize green corridors and parks to help protect surrounding communities from the impacts of hazard events

Strategy NS-2: Increase and enhance the resilience and health of Baltimore's urban forest

Strategy NS-3: Create an interconnected network of green spaces to support biodiversity and watershed based water quality management

Strategy NS-4: Expand, protect and restore riparian areas in the city

Strategy NS-5: Preserve and create new ecological buffer efforts and support creating more (e.g. wetlands) along coastal areas

Natural Systems

FOOD SYSTEM

Strategy NS-6: Increase Baltimore's Food Security

WATER SYSTEM

Strategy NS-7: Enhance and improve the resilience of Baltimore's water supply

Strategy NS-8: Require the City's drought management plan to account for changes in climate

Strategy NS-9: Integrate climate change and natural hazards planning into small watershed action plans (SWAPs)

Strategy NS-10: Ensure that local flood damage prevention regulations account for changes in sea level rise and climate

Infrastructure Strategies

WATER AND WASTEWATER

Strategy IN-15: Increase the resilience of all wastewater pumping stations and protect them from current and projected extreme weather events

Strategy IN-16: Integrate resiliency, redundancy, and structural stability into the City's drinking and water system to ensure safe and reliable water storage and distribution

Strategy IN-17: Conduct a assessment that evaluates and improves all pipes' ability to withstand extreme heat and cold

Infrastructure Strategies

STORMWATER

Strategy IN-18: Enhance and expand stormwater and sewer infrastructure and systems

Strategy IN-19: Modify urban landscaping requirements and increase permeable surfaces to reduce stormwater runoff

Strategy IN-20: Evaluate and support DPW's stream maintenance program

Strategy IN-21: Support and increase coordination and information sharing across jurisdictions to better enable mitigation of cross-border impacts on the regions watersheds (e.g., understanding flood conditions upstream in the County)

Infrastructure Strategies

SOLID WASTE

Strategy IN-22: Reevaluate and support a comprehensive debris management plan for post hazard events

POLICY AND GOVERNMENT DECISION-MAKING

Strategy IN-23: Encourage the integration of climate change and natural hazards into private and State planning documents, systems, operations, and maintenance

Strategy IN-24: Develop City policy which requires new city government capital improvement projects incorporate hazard mitigation principles

Public Health and Human Services

EMERGENCY PREPAREDNESS

Strategy PH-1: Strengthen emergency preparedness coordination between local government, NGOs, and private entities by updates to the City Emergency Operations Plan (EOP) and related Emergency Support Functions (ESF)

Strategy PH-2: Develop a Hazard Awareness Program

Strategy PH-3: Designate community leaders and organizations who can assist and provide support during hazard events

Strategy PH-4: Integrate climate change and natural hazards planning into all City and community plans

Strategy PH-5: Anticipate and address potential disease outbreaks caused by extreme weather events and change climatic conditions

Public Health and Human Services

EMERGENCY RESPONSE

Strategy PH-6: Better equip emergency workers for natural hazards

Strategy PH-7: Protect Baltimore residents from the effects of high heat events and plan for more frequent instances of high heat days

EDUCATION AND OUTREACH

Strategy PH-8: Conduct climate, resiliency, and emergency planning education and outreach

Strategy PH-9: Improve awareness and education about the importance of flood insurance and preparation

ACTIONS

Review and discuss

Buildings Strategies

CITY CODES & DESIGN GUIDELINES

Strategy B-1: Create hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.

Strategy B-2: Enhance building codes that regulate building within a floodplain or near the waterfront

Strategy B-3: Strengthen city codes to integrate anticipated changes in climate

Strategy B-4: Increase floodplain awareness for rental tenants

Buildings Strategies

LAND USE

Strategy B-5: Update a list of flood prone and repetitive loss buildings to consider for acquisition

Strategy B-6: Prioritize retrofitting and increasing resiliency of public housing units in the 100-year floodplain and other high risk areas

Buildings Strategies

STRUCTURAL

Strategy B-7: Improve wind resiliency of new and existing structures

Strategy B-8: Evaluate various seismic design enhancements using prototypical Baltimore City building types

Strategy B-9: Retrofit existing buildings in the 100-yr floodplain to increase resiliency

Infrastructure Actions

- **Strategy IN-1:** Protect and enhance the resiliency and redundancy of electricity system

  Action 2: Evaluate the City of Baltimore utility distribution system, and identify "underground utility districts" – areas of the City where performing underground utility conversion would be feasible

- **Strategy IN-7:** Evaluate and improve resiliency of communication systems that are in place for sudden extreme weather

  Action 6: Ensure continued operation of the City's various computer mainframes for email, control systems, and internet service by having stand-by batteries for each with a capacity sufficient for backup generation to operate

Infrastructure Actions

Strategy IN-24: Develop City policy which requires new city government capital improvement projects incorporate hazard mitigation principles

Action 1: Prohibit new projects in hazard-prone areas such as floodplains or the coastal high hazard area

Action 2: Require above code design requirements for critical facilities

Strategy IN-9: Integrate climate change into transportation design, building and maintenance

Action 3: Incorporate compliance with earthquake standards to withstand a magnitude eight earthquake for all new, improved and rebuilt bridges

Action 4: Design bridges expansion joints for longer periods of high heat and develop a more robust inspection and maintenance process

Buildings Actions

Strategy B-1: Create hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.

Action 1: Require all hazardous materials within the floodplain to be elevated a minimum of three feet above the freeboard

Action 2: Require new critical facilities to be designed with redundant operating systems.

Strategy B-7: Improve wind resiliency of new and existing structures

Action 1: Review local building codes to determine if revisions are needed to improve the structures ability to withstand greater wind velocities and storm impacts

Action 2: Retrofit emergency shelter windows to withstand winds associated with coastal storm events

Buildings Actions

Strategy B-9: Retrofit existing buildings in the 100-yr floodplain to increase resiliency

- Action 1: Develop a creative financing program for residential and commercial properties
- Action 2: Mandate flood resiliency retrofits for large buildings in the 100-yr floodplain
- Action 3: Study engineering alternatives where retreat and accommodation are not possible

Public Health and HS Actions

Strategy PH-1: Strengthen emergency preparedness coordination between local government, NGOs, and private entities by updates to the City Emergency Operations Plan (EOP) and related Emergency Support Functions (ESF)

- Action 8 : Encourage Baltimore Animal Rescue and Care Shelter Inc. (BARCS) to further develop their internal plan for relocating animals from the shelter if needed during an emergency
- Action 9: Assist Baltimore Animal Rescue and Care Shelter Inc. (BARCS) in obtaining funding to move their facility out of the floodplain
- Action 10 : Partner with MD H2E, two Baltimore hospitals, and other stakeholders to develop and implement a case study of hospital-based practices that foster community resilience to climate change

Public Health and HS Actions

Strategy PH-7: Protect Baltimore residents from the effects of high heat events and plan for more frequent instances of high heat days

- Action 6: Work with Regional, State and Local partners to improve air quality and reduce respiratory illnesses
- Action 7: Develop plans to give BCHD authority to temporarily close down specific, pre-identified, high-polluting entities when specific heat and weather conditions occur

DOCUMENT

Progress

Document outline

- Chapter 1: Introduction
- Chapter 2: Mitigation and Adaptation
- Chapter 3: Hazard Identification
- Chapter 4: Risk and Vulnerability Assessment
- Chapter 5: Strategies and Actions
- Chapter 6: Adaptive Capacity
- Chapter 7: Implementation Guidance

Timeline

- June 28th — Committee approve Strategies
- July 10th — Final list of Actions distributed
- July 30th — Town Hall Meeting
- July 31st — Draft document to committee
- August 10th — Draft document posted online
- August 20th — Document approved by committee
- August 27th — Sustainability Commission approval
- September — Planning Commission approval

WHAT'S NEXT?

Beth Strommen

Advisory Commitee Meeting August 19, 2013

Agenda

City of Baltimore - Disaster Preparedness and Planning Project (DP3)

Advisory Committee Meeting

August 19, 2013

Committee Purpose:

- To bring together stakeholders from key agencies, institutions, businesses, and neighborhoods to identify actions and recommendations for the City of Baltimore's Disaster Preparedness and Planning Project (DP3).

Meeting Objectives:

- Discuss DP3 Plan chapters (generally)
- Review and endorse chapters of the DP3 Plan

Materials Provided:

- Agenda
- DP3 Plan outline
- Copy of Chapter 5
- List of comments and proposed changes

Agenda:

3:00pm-3:05pm: Tom Stosur, Director, Department of Planning and Bob Maloney, Deputy Chief of Emergency Management and Public Safety

- Welcome and goals for the meeting

3:05pm-3:30pm: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Progress to date
- Plan outline and review
- Anticipated additions

3:30pm-4:15pm: Beth Strommen, Director, Office of Sustainability & Kristin Baja

- Strategies and actions grouped/changed
- Discuss edits and concerns

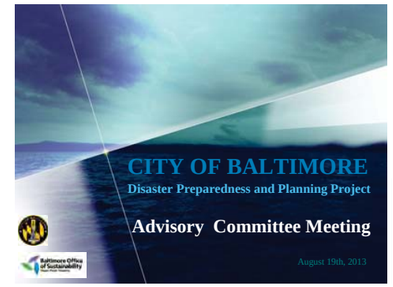
4:15pm-4:30pm: Kristin Baja & Beth Strommen

- Final discussion and endorsement of DP3 Plan

4:20pm-4:30pm: Kristin Baja, Hazard Mitigation Planner, Office of Sustainability

- Final timeline
- Looking beyond this plan

Presentation



Progress to Date

- Second DP3 Town Hall Event, July 30th
- Community Meetings
- Writing of the Plan
- HAZUS Analysis

Chapter 1

Introduction

- Overview of Project
- Overview of the City of Baltimore
- Methodology
- Plan Contents and Scope
- Climate Change

Chapter 2

Importance of Planning to Mitigate Natural Hazards and Adapt to Climate Change

- Hazard Mitigation
- Climate Change
- Climate Adaptation
- Connection between Hazard Mitigation and Climate Adaptation

Chapter 3

Natural Hazards in Baltimore City

- Identification and Profile of Current Natural Hazards
- Each Hazard explained individually accompanied with historical impacts

Chapter 4

Vulnerability Assessment

- Self-Assessment
- Impact Analysis
- Community Asset Inventory
- Inventory of Critical Facilities
- Estimated Losses

Chapter 5

Strategies and Actions for Addressing Hazards and Climate Change

- Vision
- Goals
- Current City Initiatives
- No Regrets Actions
- Strategies and Actions listed by Sector

Chapter 6

Implementation Guidance

Implementation, Monitoring and Evaluation

- Current City Initiatives
- Alignment with Goals
- Connection with existing plans/efforts
- Lead Agencies and stakeholders
- Timeframe
- Financing
- Metrics

Appendices

- Glossary
- Engineering Study of Fells Point
- Health Impact Assessment (Urban Heat)
- Community Meetings (Town Hall, Heat, Flood) feedback sheets and surveys
- Self Assessment Documents
- Maps, Supporting Charts and HAZUS data
- Ranking exercise and prioritization
- Presentations and supporting documents
- References

Additions

- Executive Summary
- THIRA/COOP Integration
- Hyperlinking to plans
- Design and use of symbols
- Historical Considerations
- Any missing data
- Appendices

STRATEGIES & ACTIONS

Changes and Concerns

Beth Strommen, Director, Office of Sustainability

Document Title

Preparedness
(Hazard Mitigation)

+

Planning
(Climate Adaptation)

= **Resilience**

Baltimore Resilience Plan

Resilience allows us to integrate hazard mitigation, climate mitigation, climate adaptation and emergency preparedness under one umbrella for education, outreach and implementation

Natural Systems

NS-2
Sara Hoverter
Yay for urban forestry, especially targeted to urban heat islands

Infrastructure Overlaps: See in Infrastructure Section
Beth Strommen
The actions are redundant

Public Services

PH-2
Sara Hoverter: Delaware is currently testing a heat health warning system that you might want to have your health department look at (hyperlink to this)

PH-6
Sara Hoverter: With the focus on vector-borne disease, etc., you might want to include an element of public health surveillance and reporting

PLAN REVIEW & ENDORSEMENT

Infrastructure

IN-4
John Quinn
Action 3: Support the Maryland Public Service Commission's effort to accelerate replacement of aging natural gas infrastructure which will harden the system against flooding
Action 4: Work with BGE to ensure existing preparedness plans for Spring Gardens compressed-liquefied natural gas site incorporate vulnerability to present and predicted flooding, storm surge and sea level rise.

IN-7
Beth Strommen
Action 5: Research utilizing the Envision™ Rating System and Greenroads Rating System for all new infrastructure and road projects
We shouldn't name specific programs or companies/vendors. This implies support of one over another, which isn't legal in terms of public procurement practices. Best to just describe what is needed and how this type of program can help.

IN-11
Sara Hoverter
I obviously like the fact that you're thinking about pavement that can withstand extreme heat – I would expand that to include pavement that will reduce heat as well.

Infrastructure

IN-13
Beth Strommen
Action 4: Retrofit and harden low-laying pumping stations and treatment plants in flood hazard areas
Language needs clarification regarding stormwater infiltrating the sewerage conveyance system.

Sara Hoverter
One of the things that DC stormwater folks are worried about is that our stormwater outfalls are not always above the water line when the river runs high, which means backups. There's talk of theoretically trying to raise some of them, but I don't know how realistic that is. Does Baltimore have the same worry with sea level rise?

IN-14
Beth Strommen
Action 7 is redundant with NS-6, Action 4
Action 9 is redundant with NS-6, Action 9

Infrastructure

IN-17
Beth Strommen
Action 1: Evaluate existing stormwater requirements and increase them to incorporate Environmental Site Design (ESD) regulations *(M)*
This should be approved by DPW Surface Water Division. Seems like they are already required to do this because of existing State regulations.

Eben Hansel
Action 4:
I don't think these actions belong in the infrastructure section, and I think they are too broad to make mandatory. It's not possible for all new buildings to have vegetative roofs, which is apparently what this requires – it just isn't feasible on some types of buildings. We discussed this in the buildings committee and (if I recall correctly) wanted to say that the city would encourage "green" roofs, meaning either vegetative or reflective.
Action 6:
The same issue applies for #6 – it's just not feasible for some buildings, and shouldn't be stated as an absolute requirement for "all" new development.

IN-21
Beth Strommen
Action 2: Ensure Red Line planning incorporates adaptation strategies. *(S)*
Modify this language to be more specific. The Red Line is in design now, and must have a specific rule for this that meets current Federal and State requirements.

Document Outline

- Chapter 1: Introduction
- Chapter 2: Mitigation and Adaptation
- Chapter 3: Hazard Identification
- Chapter 4: Risk and Vulnerability Assessment
- Chapter 5: Strategies and Actions
- Chapter 6: Implementation Guidance

NEXT STEPS

Infrastructure

Transportation
Karin Holland
One thing that you might want to make explicit in the report is how to make available more and safer transportation routes for bicycling and other alternative types of transportation (walking, etc.). This not only allows for communities to become healthier and more livable during normal day-to-day, but also allows for redundancy transportation systems in the event of an emergency or storm event. After Sandy, one of the best ways to get into cities was on bicycle (subways flooded, buses overloaded, etc.).

General Comments
Sara Hoverter
For evacuation-related strategies/actions (IN-8 and others), you might want to think about explicitly designating special assistance/outreach plans for your most vulnerable residents. Some of that shows up elsewhere, but you might want it more than one place so that multiple departments are thinking about it

Buildings

B-1
Beth Strommen
Action 7: Require that backup solar powered street lights and signals be integrated along evacuation routes and high traffic areas
Move this action to IN-7 (Integrate climate change into transportation design, building and maintenance)

B-2
Beth Strommen
Action 3: Continue to regulate to the existing tidal floodplain delineation *(M)*
This action is both redundant to NS-9 Action #5 (Develop policy to keep existing tidal floodplain boundaries for regulating development purposes) and the language is not clear. What is 'existing tidal floodplain delineation'. There is no reference to what this means. Also one is M, and one is S.

Buildings

B-1, B-7, B-9
Beth Strommen
The actions below are redundant

B-3
Eben Hansel
This had come up a few times in the full group and my understanding was that the plan would not aim to discourage development along the waterfront, but would focus on making sure any development was done correctly through building codes, etc.

Sara Hoverter
Yay to changing city codes for urban heat adaptation in B-3

Appendix E: Public Process

Town Hall Meetings

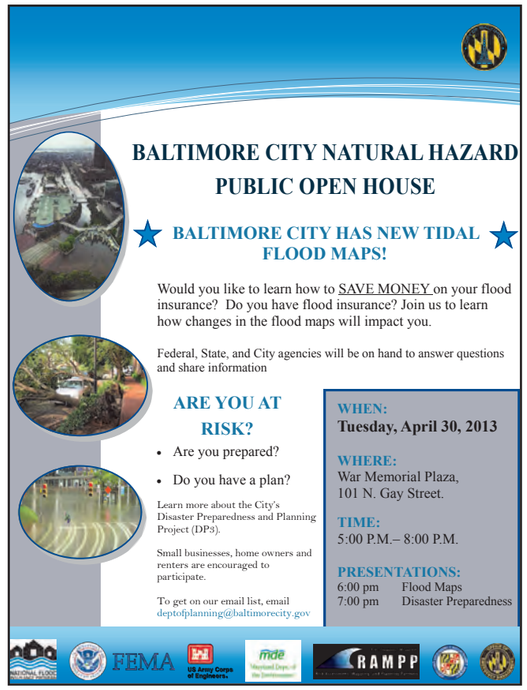
April 30, 2013

Number of Attendees:

Public Informed:
Over 8,000 mailers were sent out. 6,500 to people who live in the floodplain. 800 to the Community Association Directory. Additionally, emails were sent to the entire city planning list and to city employees

Information Tables:
Flood Manager/ Flood Maps Table (3 tables)
Maryland Emergency Management Agency (MEMA)
Maryland Department of the Environment (MDE)
Department of Natural Resources CCI
National Flood Insurance representative (NFIP)
Disaster Planning and Preparedness Project (DP3)
Office of Emergency Management (OEM)/CERT teams
Baltimore Public Health Department (BCHD)
Baltimore Energy Challenge/ Climate Action Plan

Presentations:
FEMA Flood Maps in Baltimore
FEMA Flood Maps update (RAMPP)
Disaster Planning and Preparedness Project (DP3)



Press Release

MEDIA CONTACT:

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Office 410.396.4556

FOR IMMEDIATE RELEASE

City of Baltimore to host Disaster Preparedness and Planning Project Town Hall Meeting

Office of Sustainability will provide members of the public with an opportunity to provide feedback on the draft list of goals, strategies and actions drafted by the Disaster Preparedness and Planning Project (DP3) Advisory Committee

Baltimore, MD (Tuesday July 30, 2013) – Today, the City of Baltimore is hosting a town hall event on at the War Memorial Building in downtown Baltimore. This meeting will provide members of the public with an opportunity to provide feedback on the draft list of goals, strategies and actions drafted by the Disaster Preparedness and Planning Project (DP3) Advisory Committee. There will also be presentations about the DP3 project, modeling of predicted worst case scenarios, and how to prepare for disaster events.

What:	Disaster Preparedness and Planning Project Town Hall	
Where:	War Memorial Building, 100 N. Gay Street, First Floor	
Time:	6:00pm-8:00pm	
Presentations:	Disaster Preparedness and Planning Project	6:30pm
	FEMA Worst Case Scenario Mapping	6:45pm
	Mayor's Office of Emergency Management	7:15pm

Baltimore is highly vulnerable to many natural hazards, ranging from coastal storms and flooding to extreme heat and high winds. There is strong consensus that these types of extreme events will increase, both in frequency and intensity, over the coming years. Recognizing the City's current vulnerability to the impacts of hazard events, Baltimore has undertaken a thorough, proactive approach to the hazard mitigation planning process.

Baltimore's Disaster Preparedness and Planning Project (DP3) was created by the Department of Planning as an effort to address existing hazards while simultaneously preparing for predicted hazards due to climate change. This project develops a plan and implementation guidelines that integrate hazards mitigation planning, floodplain mapping, and climate adaptation planning.

A full draft list of DP3 goals, strategies and actions can be found at:
http://baltimorehazards.wordpress.com/disaster-preparedness/goals-strategies-and-actions/full-list-of-goals-strategies-and-actions/

Town Hall Meetings

July 30, 2013

Number of Attendees:

Public Informed:
Informational emails and invites were sent to the entire city planning list, the natural hazards list, the floodplain manager list, and to city employees. A press release was also sent out before the meeting date.

Information Tables:
Flood Manager/ Flood Maps Table (3 tables)
Maryland Emergency Management Agency (MEMA)
Maryland Department of the Environment (MDE)
Department of Natural Resources CCI
National Flood Insurance representative (NFIP)
Disaster Planning and Preparedness Project (DP3)
Office of Emergency Management (OEM)/CERT teams
Baltimore Public Health Department (BCHD)
Baltimore Energy Challenge/ Climate Action Plan

Presentations:
Disaster Planning and Preparedness Project (DP3)
FEMA HAZUS Information
MOEM Emergency Preparedness

Press Release

MEDIA CONTACT:

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Office 410.396.4556

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Office of Sustainability will provide members of the public with an opportunity to provide feedback on the draft list of goals, strategies and actions drafted by the

Disaster Preparedness and Planning Project (DP3) Advisory Committee

Baltimore, MD (Tuesday July 30, 2013) – Today, the City of Baltimore is hosting a town hall event on at the War Memorial Building in downtown Baltimore. This meeting will provide members of the public with an opportunity to provide feedback on the draft list of goals, strategies and actions drafted by the Disaster Preparedness and Planning Project (DP3) Advisory Committee. There will also be presentations about the DP3 project, modeling of predicted worst case scenarios, and how to prepare for disaster events.

What:	Disaster Preparedness and Planning Project Town Hall	
Where:	War Memorial Building, 100 N. Gay Street, First Floor	
Time:	6:00pm-8:00pm	
Presentations:	Disaster Preparedness and Planning Project	6:30pm
	FEMA Worst Case Scenario Mapping	6:45pm
	Mayor's Office of Emergency Management	7:15pm

Baltimore is highly vulnerable to many natural hazards, ranging from coastal storms and flooding to extreme heat and high winds. There is strong consensus that these types of extreme events will increase, both in frequency and intensity, over the coming years. Recognizing the City's current vulnerability to the impacts of hazard events, Baltimore has undertaken a thorough, proactive approach to the hazard mitigation planning process.

Baltimore's Disaster Preparedness and Planning Project (DP3) was created by the Department of Planning as an effort to address existing hazards while simultaneously preparing for predicted hazards due to climate change. This project develops a plan and implementation guidelines that integrate hazards mitigation planning, floodplain mapping, and climate adaptation planning.

A full draft list of DP3 goals, strategies and actions can be found at:
http://baltimorehazards.wordpress.com/disaster-preparedness/goals-strategies-and-actions/full-list-of-goals-strategies-and-actions/

Community Vulnerability Survey

Baltimore City
Disaster Preparedness and Planning Survey

1. **Over the past several years, has the weather in your local area been… (Check ONE)**

   ☐ Much worse than usual
   ☐ Somewhat worse than usual
   ☐ About the same
   ☐ Somewhat better than usual
   ☐ Much better than usual
   ☐ Don't know

2. **Have the following types of extreme weather events become more or less common in your community over the past several years, or stayed about the same?**

Please circle your response	Much less common	Somewhat less common	Stayed about the same	Somewhat more common	Much more common	Don't know
Heat waves	1	2	3	4	5	0
Heavy rains	1	2	3	4	5	0
Heavy snows/ ice storms	1	2	3	4	5	0
Tropical storms/ hurricanes	1	2	3	4	5	0
High wind events	1	2	3	4	5	0
Severe Cold	1	2	3	4	5	0
Flooding events	1	2	3	4	5	0

3. **How vulnerable (exposed to the possibility of harm or damage)- if at all- are the people living in your immediate household, including yourself, to the impacts of extreme weather events?**

   ☐ Not at all vulnerable
   ☐ Only a little vulnerable
   ☐ Moderately vulnerable
   ☐ Very vulnerable
   ☐ Don't know

4. **Which of the following resources in your community do you think may be harmed by climate change in the next several years?**

   ☐ Public water supplies
   ☐ Public sewer systems
   ☐ People's health
   ☐ Transportation/roads/bridges
   ☐ Historical sites
   ☐ Coastlines
   ☐ Wetlands
   ☐ Private wells/septic systems
   ☐ Privately owned land/buildings
   ☐ There are no local risks from climate change

5. **What assets do you have in your community to assist in dealing with hazard events?** (add your own)

   ☐ Generator
   ☐ _____
   ☐ _____
   ☐ Hospital
   ☐ _____
   ☐ _____
   ☐ Strong community group
   ☐ _____
   ☐ _____

6. **Do you live in the regulated floodplain?**

   ☐ Yes ☐ No ☐ Don't know

7. **If you answered yes, are you a business owner or resident?**

   ☐ Business Owner ☐ Homeowner ☐ Renter ☐ Don't know

Name: _____

Zip code: _____

Flooding ABC's

FLOODING TO DO's

To PREPARE for a flood, you should:

Immediate:

- Build an emergency kit (http://www.ready.gov/build-a-kit) and make a family communications plan (http://www.ready.gov/make-a-plan).

Long Term:

- Elevate the furnace, water heater and electric panel in your home if you live in an area that has a high flood risk.
- Consider installing "check valves" to prevent flood water from backing up into the drains of your home.
- If feasible, construct barriers to stop floodwater from entering the building and seal walls in basements with waterproofing compounds.

In a flood, you should:

Immediate:

- Listen to the radio or television for information.
- Be aware that flash flooding can occur. If there is any possibility of a flash flood, move immediately to higher ground. Do not wait for instructions to move.
- Be aware of stream, drainage channels, and other areas known to flood suddenly. Flash floods can occur with or without typical warnings such as rain clouds or heavy rain.

Long Term: If you must prepare to evacuate or have to leave your home, you should do the following:

- Turn off utilities at the main switches or valves if instructed to do so. Disconnect electrical appliances. Do not touch electrical equipment if you are wet or standing in water.
- Do not walk through moving water. Six inches of moving water can make you fall. If you have to walk in water, walk where the water is not moving. Use a stick to check the firmness of the ground in front of you.
- Do not drive into flooded areas. If floodwaters rise around your car, abandon the car and move to higher ground safely. You and the vehicle can be swept away quickly.
- Do not camp or park your vehicle along streams, rivers, creeks, or waterfront, particularly during threatening conditions.

After a flood:

- Avoid water that is moving quickly.
- Stay away from damaged areas unless your assistance has been specifically requested by police, fire, or relief organization.
- Play it safe. Additional flooding or flash floods can occur. Listen for local warnings and information. If your car stalls in rapidly rising waters, get out immediately and climb to higher ground.
- Stay out of any building if it is surrounded by floodwaters.

Posters Developed for Public Meetings and Education

PRECIPITATION VARIABILITY

Drought

The U.S. Army Corps of Engineers' defines **drought** as "periods of time when natural or managed water systems do not provide enough water to meet established human and environmental uses because of natural shortfalls in precipitation or stream flow". In order to monitor potential drought conditions in a uniform manner across the State, Maryland uses four indicators of water sufficiency. The indicators are based on the amount of precipitation and the effect of the precipitation (or lack of precipitation) in the hydrologic system. These indicators include:

1. Precipitation levels
2. Stream flows
3. Ground water levels
4. Reservoir storage

Indicators are evaluated by comparing current conditions to natural conditions within the period of record. In this way, it can be determined if a current deficit is within a commonly experienced range, or whether it is unusually large. Maryland DNR

Drought History

From 2001-2002 the State of Maryland experienced one of the most severe droughts in the region's history. The water levels in Baltimore's three reservoirs slipped by more than 4 billion gallons – from 75 percent of capacity to 69 percent. The city even tested the pumps to evaluate moving Susquehanna water to Baltimore.

Baltimore experienced the driest February, amid the fourth-driest winter, since record-keeping began in 1871. The flow of water in Maryland streams fell below record lows set in the 1960s, and in some cases in the 1930s.

Reservoirs

Reservoirs are designed to provide adequate storage when demand exceeds reservoir inflow. As the streamflows are lowest during the summer period and demand is also greatest, the most critical time begins at the onset of summer. Baltimore has three reservoirs that are monitored for the purposes of evaluating drought conditions: Loch Raven Reservoir, Prettyboy Reservoir, and Liberty Reservoir.

Future Concerns

- Drought will significantly affected the Chesapeake Bay ecosystem and the plants and animals that live in and rely on the bay.
- Drought conditions often provide too little water to support food crops which increases food prices and reduces food availability.
- Drought sets the stage for wildfires that may cause injuries or deaths as well as extensive damage to property.

Heavy Rain Storms

Water droplets form from warm air. As the warm air rises in the sky it cools. Warm air holds quite a bit of water. When enough of these droplets collect together, we see them as clouds. If the clouds are big enough and have enough water droplets, the droplets bang together and form even bigger drops. When the drops get heavy, they fall because of gravity, and you see and feel rain.

Among the expected consequences of global warming is an increase in the heaviest rain and snow storms, fueled by increased evaporation and the ability of a warmer atmosphere to hold more moisture. **Extreme downpours are now happening 30 percent more often nationwide than in 1948.** Moreover, the largest annual storms now produce 10 percent more precipitation, on average.

The geographic area from Maryland to Maine has experienced the greatest precipitation change, with **intense rainstorms and snowstorms now happening 85 percent more often than in 1948**. Not only are extreme downpours more frequent, but they are also more intense.

History in Baltimore

Flooding is common in Baltimore and can occur during any part of the year. It is but is most common during late winter and early spring and during the hurricane season from midsummer to early fall. Baltimore has experienced many large flood events.

Source: Frank Roylance

Future Impacts in Baltimore City

According to the U.S. Global Change Research Program, "heavy downpours that are now 1-in-20 year occurrences are projected to occur about every 4 to 15 years by the end of this century," while producing 10 to 25 percent more precipitation per storm.

Increase in heavy downpours is "one of the clearest precipitation trends in the United States" and is linked to global warming.

Nor'Easters

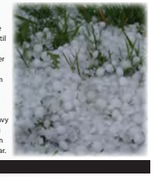
A Nor'easter is a type of storm that forms from a strong low pressure system in the Eastern United States. Cold air from the North, primarily from Canada, will often clash with the warm air masses that form over the ocean and from the Gulf Stream in the coastal areas. While most people associate Nor'easter storms with winter, these storms can actually form any time of the year. Nor'easter storms are also commonly thought to be storms that move in from the Northeast. Instead, strong Northeast winds within the storm are how the storms are named.

A Nor'easter storm forms when a low pressure system meets a high pressure system. The storms often move very slowly causing heavy amounts of precipitation. In the winter, the heavy snowfall and blizzard-like conditions cause icy road conditions, power outages, and other winter weather hazards.
Nor'easter storms are also dangerous in coastal areas due to the potential for large wind-driven storm-surge waves and heavy precipitation that can cause flooding.

Hail and Ice Storms

An **ice storm** is a type of winter storm caused by freezing rain. The U.S. National Weather Service defines an ice storm as a storm which results in the accumulation of at least 0.25-inch of ice on exposed surfaces. Ice storms form when a layer of warm air is between two layers of cold air. Frozen precipitation melts while falling into the warm air layer, and then proceeds to refreeze in the cold layer above the ground. This creates freezing rain or a glaze of ice. Warmer air in the winter months increases the possibility of a dangerous ice storms in Baltimore City.

Hail is created when small water droplets are caught in the updraft of a thunderstorm. These water droplets are lifted higher and higher into the sky until they freeze into ice. Once they become heavy, they will start to fall. If the smaller hailstones get caught in the updraft again, they will get more water on them and get lifted higher in the sky and get bigger. Once they get lifted again, they freeze and fall. This happens over and over again until the hailstone is too heavy and then falls to the ground. According to NOAA, hail causes $1 billion dollars in damage to crops and property each year.



Winter Storms

Winter storms derive their energy from the clash of two air masses of different temperatures and moisture levels. Winter storms usually form when an air mass of cold, dry, Canadian air moves south and interacts with a warm, moist air mass moving north from the Gulf of Mexico.

As the Earth gets warmer and more moisture gets absorbed into the atmosphere, we are steadily loading the dice in favor of more extreme storms in all seasons, capable of causing greater impacts on society. Large snowstorms that happened once every 12 months, on average, in the middle of the 20th century now happen every nine months. In fact, in each of the past two winters the northeastern United States has been hammered by three snowstorms that qualified as Category 3 storms or worse on the Northeast Snowfall Impact Scale.

Video Screen Grab of Blizzard of 1996

EXTREME WIND EVENTS

Definition

Wind is air in motion. It is produced by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of various land and water formations, it absorbs the sun's radiation unevenly. Two factors are necessary to specify wind: speed and direction.

As the sun warms the Earth's surface, the atmosphere warms too. Some parts of the Earth receive direct rays from the sun all year and are always warm. Other places receive indirect rays, so the climate is colder. Warm air, which weighs less than cold air, rises. Then cool air moves in and replaces the rising warm air. This movement of air is what makes the wind blow.

History in Baltimore

Maryland is at risk for high wind events. Historically, the City has seen deaths, injuries, and property damage from extreme wind events.

Notable Wind (non-hurricane) Events in Baltimore City:

June 2012	Mid-Atlantic and Mid-west Derecho
July 2011	The Cross Country Derecho
November 2010	Northeast Baltimore Tornado (EF1)
July 1996	Central Baltimore Tornado (F0)
November 1994	East Baltimore & Cadmen Yards Tornados (F1)
October 1990	Baltimore City Tornado (F1)
April 1991	The West Virginia Derecho of 1991
November 1989	Mid-Atlantic Low Dewpoint Derecho

Types of Wind Storms

A **windstorm** is a storm with high winds or violent gusts but little or no rain. Baltimore is vulnerable to wind damage because of the large number of trees. Trees bring down power lines, disrupt traffic patterns, and damage property when they fall. Economically, a windstorm's effects are similar to those of a snowstorm. They halt most economic activity for several days. Many people cannot, or choose not, to come to work because they fear long drives or must take care of damage at home. For local governments, debris removal and power restoration can place a strain on budgets.

Tornadoes

Tornadoes are nature's most violent storms. Spawned from powerful thunderstorms, tornadoes can cause fatalities and devastate a neighborhood in seconds. A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 300 miles per hour. Damage paths can be in excess of one mile wide and 50 miles long. Tornadoes generally occur near the trailing edge of a thunderstorm.

Scientists are unsure if tornadoes will become stronger or more frequent, but with increased temperatures changing the weather in unexpected ways, the risk is real that tornado outbreaks will become more damaging in the future. The lack of certainty in the state of the science does not equate with a lack of risk, since risk is based on possibility. The lack of scientific consensus is a risk factor itself, and we must prepare for a future that could possibly include increased tornado damage. CDC

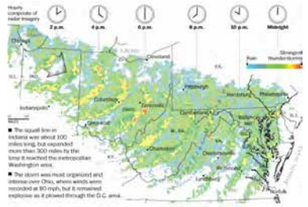
Hurricanes

The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 rating based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. When hurricane storms hit the coast, they can let loose very strong winds, as high as 180 miles per hour. Please visit the Tropical Storms and Hurricanes Poster for more information about hurricanes in Baltimore.

Derechos

A derecho is a widespread, long-lived wind storm that is associated with a band of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to that of tornadoes, the damage typically is directed in one direction along a relatively straight swath.

By definition, if the wind damage swath extends more than 240 miles (about 400 kilometers) and includes wind gusts of at least 58 mph (93 km/h) or greater along most of its length, then the event may be classified as a derecho.



Typically, derecho-producing storm systems move at speeds of 50 mph or greater, and a few have been clocked at 70 mph. Such rapid movement means that darkening skies and other visual cues that serve to alert one to the impending danger (e.g., gust front shelf clouds --- see photo right) appear on very short notice. Advance notice given by a derecho often is not sufficient for one to take protective action

The June 2012 derecho was one of the most destructive and deadly fast-moving severe thunderstorm complexes in North American history. Capital Weather Gang

Wind Maps

Designed by data-visualization artists Fernanda Viegas and Martin Wattenberg, this U.S. wind map conveys Hurricane Sandy's East Coast wind patterns.

The first map (right) shows Sandy approaching the coast on **October 29, 2012 at 9:59AM EDT**

October 30, 2012 at 12:59 AM EDT

The Seaside Park anemometer and National Weather Service recorded a maximum wind gust of 97 miles per hour and sustained wind speeds of 90 miles per hour.

October 30, 2012 at 5:00 PM EDT

National Weather Service wind speeds map (right) shows maximum sustained winds at landfall were estimated at 80 mph, and the broad wind field stretching out hundreds of miles from the center brought damaging wind gust.

Future Predictions

- Derechos are most common in warm weather conditions, with more than 75% occurring between April and August. Maryland is expected to experience one derecho every four years (see map left).
- Future hourly/daily wind gust events are projected to increase late this century under a changing climate. Kenney, 2012
- Climate change, through rising temperatures and water vapour levels for example, is changing the odds of extreme events occurring.
- Wind speeds have risen steadily over the past twenty years and are expected to become more extreme. Pryor and Schoof, 2008
- Severe wind events will flatten trees, damage buildings and homes, and generate flying debris.

Wind Damage, Baltimore City

Hurricane Isabel, 2003

HURRICANES & TROPICAL STORMS

Definitions

A tropical storm is a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has a closed low-level circulation. Tropical cyclones rotate counterclockwise in the Northern Hemisphere. They are classified as follows:

Tropical Depression: A tropical storm with maximum sustained winds of 38 mph (33 knots) or less.
Tropical Storm: A tropical cyclone with maximum sustained winds of 39 to 73 mph (34 to 63 knots).
Hurricane: A tropical cyclone with maximum sustained windes of 74 mph (64 knots) or higher.
In the North Pacific, hurricanes are called typhoons; similar storms in other parts of the world are called cyclones.
Major Hurricane: A tropical cyclone with maximum sustained winds of 111mph (96 knots) or higher, corresponding to a Category 3, 4, or 5 on the Saffir-Simpson Hurricane Wind Scale.

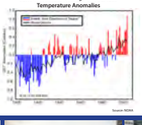
Facts

- Atlantic hurricane seasons since 1995 have been **significantly more active**, e.g. more hurricanes and more intense hurricanes, than the previous two decades. NOAA
- The past decade has seen increased U.S. hurricane landfalls. NOAA

Number of Hurricanes and Major Hurricanes in the Atlantic Basin 1945-2005

Source: NOAA

June-November Average Sea Surface Temperature Anomalies



Source: NOAA

Hurricane History in Baltimore

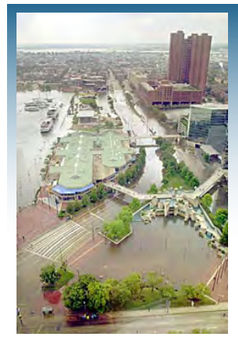
1954	Hurricane Hazel	October 15
1955	Hurricanes Connie and Diane	August 12 and 18
1972	Hurricane Agnes	June 21-23
1979	Hurricane David	September 5-6
1996	Hurricane Fran	September 5
1999	Hurricane Floyd	September 16-17
2003	Hurricane Isabel	September 18
2004	Hurricane Frances	September 8
	Hurricane Ivan	September 17
	Hurricane Jeanne	September 28
2011	Hurricane Irene	August 27-28
	Tropical Storm Lee	September 6-9

Flooding from Hurricane Sandy, 2012

Future Predictions

- A hurricane draws its energy from warm ocean water. The warmer the water, the more powerful hurricanes will be.
- There are recent studies that suggest the warming of the oceans in the Atlantic due to increased **greenhouse gas emissions will provide more fuel to the development and intensification of hurricanes.**
- Warming suggests we can expect more intense hurricanes and persistent active hurricane seasons.
- The average annual number of category 4 and 5 hurricanes, which together cause nearly half of all hurricane damage, has more than doubled since the early 1970's and is likely to continue to increase.

STORM SURGE & COASTAL INUNDATION



Storm Surge from Hurricane Isabel, 2003

Definition

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Storm surge should not be confused with storm tide, which is defined as the water level rise due to the combination of storm surge and the astronomical tide. This rise in water level can cause extreme flooding in coastal areas particularly when storm surge coincides with normal high tide, resulting in storm tides reaching up to 20 feet or more in some cases. Storm surge is produced by water being pushed toward the shore by the force of the winds moving cyclonically around the storm. The impact on surge of the low pressure associated with intense storms is minimal in comparison to the water being forced toward the shore by the wind. Storm surges are extremely dangerous because they are capable of flooding large coastal areas, causing severe devastation.

Source: NOAA

Along the coast, storm surge is often the greatest threat to life and property from a hurricane. In the past, large death tolls have resulted from the rise of the ocean associated with many of the major hurricanes that have made landfall. Hurricane Katrina (2005) is a prime example of the damage and devastation that can be caused by surge. At least 1500 persons lost their lives during Katrina and many of those deaths occurred directly, or indirectly, as a result of storm surge.

Economic Costs

The total impact of coastal inundation and storm surge depends on the depth of the floodwater and the type and number of assets exposed to flooding. Much of Baltimore's economic productivity and community assets are located along the waterfront.

Economic Costs of the Top 10 Most Expensive Hurricanes from 1980-2011

Hurricane	Billions of Dollars
Katrina (2005)	$145
Andrew (1992)	$61.5
Ike (2008)	$38.4
Wilma (2005)	$18.8
Rita (2005)	$18.8
Charley (2004)	$11.9
Ivan (2004)	$16.2
Hugo (1989)	$12.9
Frances (2004)	$10.2
Jeanne (2004)	$9.6

Source: Insurance Information Institute

Coastal Inundation

Coastal Inundation is the flooding of normally dry, low-lying coastal land, primarily caused by severe weather events along the coasts, estuaries, and adjoining rivers. These storms, which include hurricanes and nor'easters, bring strong winds and heavy rains. The winds drive large waves and storm surge on shore, and heavy rains raise rivers.

As destructive as Isabel was, recent computer simulations by government scientists - the most extensive ever for the Chesapeake Bay - show that hurricane storm surges here could get much, much worse.

All low-lying coastal regions, which can cover tens of miles inland, are vulnerable to flooding from storms, and the impact can be substantial.

Much of the densely populated Atlantic coastline lies less than 10 feet above mean sea level, within the reach of strong storm surge events.

Source: Army Corp of Engineers

Inundation events are among the more frequent, costly, and deadly coastal hazards that can impact coastal communities in the U.S. In confined harbors, the combination of storm tides, waves, and currents can severely damage boats, buildings and infrastructure. Salt water intrusion endangers the public health, kills vegetation, and can significantly impact underground infrastructure.

History in Baltimore

A storm surge driven by winds from a weakening Hurricane Isabel produced the worst Chesapeake Bay flooding in 70 years. Waters up to 8 feet above normal tides surged into lower Fells Point and across Pratt and Light streets into downtown Baltimore. Hundreds of basements and businesses flooded. Hundreds of homes in Bowleys Quarters and elsewhere on the bay shore were badly damaged or destroyed. Property damage reached $410 million in Maryland alone.

Notable Storm Surge Events in the United States:

2012	Hurricane Sandy	NY, NJ	13 foot storm surge
2008	Hurricane Ike	Galveston, TX	15-20 foot storm surge
2005	Hurricane Katrina	New Orleans	25-28 foot storm surge
2005	Hurricane Dennis	Florida	7-9 foot storm surge
2003	***Hurricane Isabel***	***Maryland***	***8 foot storm surge***
1989	Hurricane Hugo	S. Carolina	19.8 foot storm surge

Fells Point, Hurricane Isabel, 2003

Fells Point, Hurricane Isabel, 2003

In Baltimore, Fells Point Historic District is in serious danger from flooding because of rising sea levels. Only 3 percent of Baltimore sits in a coastal floodplain, according to the EPA. But because the historic district and the Inner Harbor are in that area, increased flooding is likely to be quite costly for the city. Baltimore already has flooding problems, and they're likely to be made worse by the rising sea levels coupled with storm surge.

Future Predictions

- New research indicates that **rising sea level from climate change will roughly double the risks of storm-related flooding** in coastal communities in Maryland and nationwide.
- Even small amounts of sea level rise make rare floods more common by adding to tides and storm surge.
- Historic local sea level rise rate is1.2 inches/decade. **Conservative sea level rise projections by 2050 is 13 inches or more.**

Flooding in Annapolis, Hurricane Isabel, 2003

Posters Developed for Public Meetings and Education

SEA LEVEL RISE

Definition

Sea Level Rise: Over the past century, the burning of fossil fuels and other human and natural activities has released enormous amounts of heat-trapping gases into the atmosphere. These emissions have caused the Earth's surface temperature to rise, and the oceans absorb about 80 percent of this additional heat.

The rise in sea levels is linked to three primary factors, all induced by this ongoing global climate change:

1. When water heats up, it expands. About half of the past century's rise in sea level is attributable to warmer oceans simply occupying more space. This process is called **Thermal expansion.**

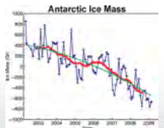
2. Large ice formations, like glaciers and the polar ice caps, naturally melt back a bit each summer. Recently, persistently higher temperatures caused by global warming have led to **greater-than-average summer melting** as well as diminished snowfall due to later winters and earlier springs. This imbalance results in sea levels rising.

3. Increased heat is causing the **massive ice sheets** that cover Greenland and Antarctica to **melt at an accelerated pace**. Scientists also believe meltwater from above and seawater from below is seeping beneath Greenland's and West Antarctica's ice sheets, effectively lubricating ice streams and causing them to move more quickly into the sea. Moreover, higher sea temperatures are causing the massive ice shelves that extend out from Antarctica to melt from below, weaken, and break off.

Since 1955, approximately 90% of the warming in the "earth system" has occured in the worlds ocean. - Sydney Levitus, NOAA

Maryland's coastal areas are experiencing land subsidence (sinking). Sinking land, continued glacier melting, and climate change are causing sea level rise to accelerate. Sea level rise rates in Maryland are nearly twice the global average. Sea levels are expected to rise another 3-5 feet by the year 2100.

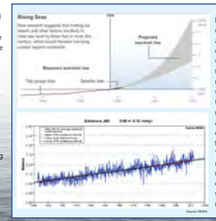
Facts



The chart on the left shows the ice mass changes in Antarctica for the period April 2002 to February 2009. The unfiltered data are blue crosses. Data filtered for the seasonal dependence are red crosses. The best-fitting quadratic trend is shown as the green line. - Chen,Wilson 2009

This shows a significant trend. Every year, the rate of **ice loss** is increasing by 26 Gigatonnes per year.

The effects of Arctic amplification will increase as more summer ice retreats over coming decades. Enhanced warming of the Arctic affects the jet stream by slowing its west-to-east winds and by promoting larger north-south meanders in the flow.



Despite uncertainty about the extent of sea level rise, we do know that higher mean sea levels will increase the frequency, magnitude and duration of flooding from storms. The biggest uncertainty is the amount of water that will come from melting glaciers.

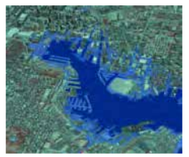
Consequences

When sea levels rise rapidly, as they have been doing, even a small increase can have devastating effects on coastal habitats. As seawater reaches farther inland, it can cause destructive erosion, flooding of wetlands, contamination of aquifers and agricultural soils, and lost habitat for fish, birds, and plants.

Here in Baltimore, we must prepare for when large storms hit land. Higher sea levels mean bigger, more powerful storm surges that can strip away everything in their path. Thousands of people live in areas that will become increasingly vulnerable to flooding.

Oceans will likely continue to rise as, but predicting the amount is an inexact science. A recent study says we can expect the oceans to rise between 2.5 and 6.5 feet (0.8 and 2 meters) by 2100, enough to inundate many parts of Baltimore. More dire estimates, including a complete meltdown of the Greenland ice sheet, push sea level rise to 23 feet (7 meters), enough to submerge massive portions of the city. - National Geographic

The map to the right is an illustration of the impact of flooding that could occur in Baltimore's Inner Harbor and surrounding neighborhoods with a 10 foot storm surge. This map does not include sea level rise.



The series below are images from a study called *Visualizing Sea Level Rise in Maryland's Chesapeake Bay* was created by Maryland Sea Grant staff and Dr. Michael Kearney of the University of Maryland Department of Geography, who estimated approximate sea level rise and storm surge for Baltimore's Inner Harbor.

AIR QUALITY

Definitions

Air pollution comes from many different sources: stationary sources such as factories, power plants, and smelters and smaller sources such as dry cleaners and degreasing operations; mobile sources such as cars, buses, planes, trucks, and trains; and naturally occurring sources such as windblown dust, and volcanic eruptions, all contribute to air pollution. Air Quality can be affected in many ways by the pollution emitted from these sources. These pollution sources can also emit a wide variety of pollutants.

EPA has concluded that there is compelling evidence that many fundamental measures of climate in the United States (e.g., air temperature) are changing, and many of these changes are linked to the accumulation of greenhouse gases (GHG's) in the atmosphere. GHG emissions from the U.S. have increased by approximately 7 percent since 1990 and global GHG emissions are increasing at an even greater rate. Among other impacts, climate change also contributes to worsening air quality that can endanger public health

Air Quality Index

The Air Quality Index (AQI) is an index for reporting daily air quality. It tells you how clean or polluted your air is, and what associated health effects might be a concern for you. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air.

EPA calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health .

The Baltimore-Washington metropolitan region has the nation's second worst traffic and ozone problems. - Chesapeake Bay Foundation

Air Quality in Baltimore

Many people live in areas where outdoor ozone, small particles, and toxic pollutants pose serious health concerns. Outdoor air pollution can affect our health over short periods of time and have a cumulative long-term impact. It can also damage vegetation, degrade water quality, and make our skies hazy. The Baltimore air quality index is a median value which considers the most hazardous air pollutants. Baltimore's air quality index is 0.3% greater than the Maryland average and 8.1% greater than the national average. The Baltimore, MD pollution index is the sum of the most hazardous air pollutants displayed in pounds. Baltimore's pollution index is 35.4% greater than the Maryland average and 48.3% greater than the national average.

Baltimore smog is sixth-worst among U.S. cities. - USA Today

Air pollution can affect our health in many ways. Numerous scientific studies have linked air pollution to a variety of health problems including:

(1) aggravation of respiratory and cardiovascular disease;
(2) decreased lung function;
(3) increased frequency and severity of respiratory symptoms such as difficulty breathing and coughing;
(4) increased susceptibility to respiratory infections;
(5) effects on the nervous system, including the brain, such as IQ loss and impacts on learning, memory, and behavior;
(6) cancer; and
(7) premature death.

Some sensitive individuals appear to be at greater risk for air pollution-related health effects, for example, those with pre-existing heart and lung diseases (e.g., heart failure/ischemic heart disease, asthma, emphysema, and chronic bronchitis), diabetics, older adults, and children.

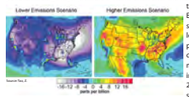
Airshed

An **airshed** is a geographic area where air pollutants from sources "upstream" or within the area flow and are present in the air. Much of our air originates in areas of the Midwest dominated by polluted emissions from powerplants and motor vehicles.

Nearly one-third of the nitrogen entering the Chesapeake Bay arrives through the air, and half of that loading originated as nitrous oxides rising from sources like coal-burning power plants and factories along the Ohio River valley (right) and other urban and industrial sites located far from the Bay. The Bay's airshed covers over 570,000 square miles and extends into 12 states.

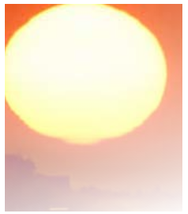
Future Predictions

Weather has a major influence on the spreading and surrounding concentrations of air pollutants. Large high-pressure systems often alter the normal temperature profile, trapping pollutants at the Earth's surface. Increased summer temperatures will lead to an increase in air pollution concentrations in cities, including Baltimore. The maps show projected changes in ground-level ozone for the 2090's, averaged over the summer months, relative to 1996-2000, under lower and higher emissions scenarios (both GHG's and emissions).



Indoor Air Quality

The quality of indoor air is important for both comfort and health. Poor indoor air quality has been tied to symptoms like headaches, fatigue, trouble concentrating, and irritation of the eyes, nose, throat and lungs. Some specific diseases have been linked to specific air contaminants, like asthma with damp indoor environments. Poor ventilation (lack of outside air), problems controlling temperature, high or low humidity, and other activities in or near a building can affect indoor air quality.



EXTREME HEAT

Definitions

Excessive Heat Watches: are issued when conditions are favorable for an excessive heat event in the next 24 to 72 hours. A Watch is used when the risk of a heat wave has increased but its occurrence and timing is still uncertain. A Watch provides enough lead time so that those who need to prepare can do so.

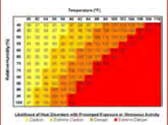
Excessive Heat Warning/Advisories are issued when an excessive heat event is expected in the next 36 hours. These products are issued when an excessive heat event is occurring, is imminent, or has a very high probability of occuring. The Warning is used for conditions posing a threat to life or property. An advisory is for less serious conditions that cause significant discomfort or inconvenience and, if caution is not taken, could lead to a threat to life and/or property.

Heat is the number one weather-related killer in the United States, resulting in hundreds of fatalities each year. In fact, on average, excessive heat claims more lives each year than floods, lightning, tornadoes and hurricanes combined. - NWS

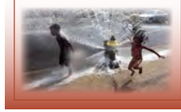
Heat Index

The Heat Index is a measure of how hot it really feels when relative humidity is factored with the actual air temperature.

To find the Heat Index temperature, look at the Heat Index chart below. As an example, if the air temperature is 96°F and the relative humidity is 65%, the heat index--how hot it feels--is 121°F. The Weather Service initiates alert procedures when the Heat Index is expected to exceed 105°-110°F (depending on local climate) for at least 2 consecutive days.

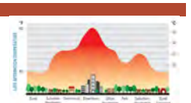


Since heat index values were devised for shady, light wind conditions, exposure to full sunshine can increase heat index values by up to 15°F. also, strong winds, particularly with very hot, dry air, can be extremely hazardous.



Urban Heat Island

A Urban Heat Island (UHI) is a metropolitan area, which is consistently hotter than the surrounding area due to human activities. The main cause of the urban heat island is modification of the land surface by urban development which uses materials which effectively retain heat.

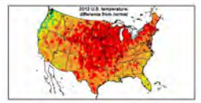


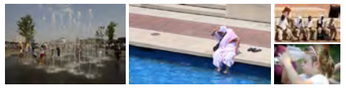
In general, cities are warmer than rural areas because asphalt, concrete, steel, and bricks absorb sunlight and release heat back into the atmosphere. The relationship between temperature and land cover is shown in this pair of images. The top image shows how developed the landscape around Baltimore is. Areas that are red have a high concentration of cement and asphalt (impervious surfaces), while white areas are primarily covered by plants. - NASA

This bottom image shows the approximate temperature of the land surface (how hot the land would be to the touch) on a summer's day in Baltimore. The highest temperatures are yellow, while cool temperatures are deep purple. Spikes in temperature away from the city occur along the spokes of development radiating out from the city and near the airport. - NASA

Heat Events in Baltimore

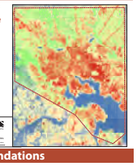
- According to the U.S. "State of the Climate" report released by NOAA's National Climatic Data Center, **2012 was the warmest year on record in the contiguous U.S.** (Lower 48 states), in records dating to 1895.
- Baltimore City had its warmest year on record since 1949
- Extreme heat can be lethal, especially for our most vulnerable citizens.





Future Predictions

- Average air temperatures are projected to increase by about 3°F by mid-century. Average summer temperatures could **increase by as much as 9°F with extended heat waves** later in the century under the higher emissions scenario.
- The number of days with air temperatures exceeding 90°F is **projected to double** (and could even triple) by the end of the century. Under the higher emissions scenario, each year could average more than 24 days of air temperatures exceeding 100°F.



Human Health Impacts and Recommendations

When the body heats too quickly to cool itself safely, or when you lose too much fluid or salt through dehydration or sweating, your body temperature rises and heat-related illness may develop. Heat disorders share one common feature: the individual has been in the heat too long or exercised too much for his or her age and physical condition.

Heat Cramps	Painful spasms of muscles. Heavy Sweating	Firm pressure on muscles, or gentle massage. Give sips of water. If nausea occurs, discontinue.
Heat Exhaustion	Heavy sweating, weakness, skin cold, pale and clammy. Weak pulse. Fainting.	Get victim out of sun. Lay down and loosen clothing. Apply wet cloth. Give sips of water. If vomitting continues, seek medical attention.
Heat Stroke	High body temperature (106 F or higher). Hot dry skin. Rapid and strong pulse.	Find emergency medical assistance immediately. Move victim to cooler environment and reduce body temperature with a cool bath. Do not give fluids.

* Drink plenty of water or juice
* Avoid alcohol and caffeine
* Wipe skin with cool water as needed
* Reduce outside activities
* Wear light-weight and light-colored clothing
* Stay inside during the hottest time of day (between 11 a.m. and 4 p.m.)
* Seek relief in air-conditioning

ADDITIONAL NATURAL HAZARDS

Earthquakes

Most earthquakes occur when great stresses building up within the earth are suddenly released This sudden release of this stored energy causes movement of the earth's crust along fractures, called faults, and generates shock waves. These shock waves, or seismic waves, radiate in all directions from the focus, much as ripples radiate outward in two dimensions when a pebble is dropped into a pond. Although most earthquakes are associated with movement along faults, they can also be triggered by volcanic activity, by large landslides, and by some types of human activity. However, in areas not known for frequent earthquakes, pinpointing the cause of the rare tremor can be very difficult.

Very little is known about the causes of earthquakes in the eastern United States. In general, there is no clear association among seismicity, geologic structure, and surface displacement, in contrast to a common association in the western U.S.

The mid-Atlantic and central Appalachian region, including Maryland, is characterized by a moderate amount of low-level earthquake activity. In Maryland, there are numerous faults, but none is known or suspected to be active. Because of the relatively low seismic energy release, this region has received relatively little attention from earthquake seismologists. - NWS

History

The earliest recorded earthquake in Maryland occurred in Annapolis, on April 24, 1758. The shock lasted 30 seconds and was preceded by subterranean noises. Additional felt reports were received from a few points in Pennsylvania. Since then, Marylanders have experienced a number moderate-sized earthquakes in nearby states with only minimal effects.

In August, 2011 an earthquake in central Virginia jolted Baltimore and much of the East Coast. Thousands of people felt the quake and small pockets of the city experienced moderate damage.

So many people East Coast crust is "older and colder," which makes it a more efficient transmitter of seismic energy. The Virginia quake also struck at a depth of just 6 kilometers. That's unusual as most strong quakes occur deeper in the Earth's crust. The depth of a quake has a direct relationship with how intense humans at the surface perceive its shaking to be.

Future Concerns

Data from the 2011 Virginia earthquake shows East Coast tremors can travel much farther and cause damage over larger areas than previously thought.

Based on current science and studies, Maryland has a very low chance of experiencing a damaging earthquake in a 50-year period. However, we should continue to plan ahead and be prepared for the chance of another earthquake impacting the area in the future.

Climate-Sensitive Diseases

Changes in climate may enhance the spread of some diseases. Disease-causing agents, called pathogens, can be transmitted through food, water, and animals such as deer, birds, mice, and insects. Climate change could affect all of these transmitters.

Food-borne diseases

- Higher air temperatures can increase cases of salmonella and other bacteria-related food poisoning because bacteria grow more rapidly in warm environments. These diseases can cause gastrointestinal distress and, in severe cases, death.
- Flooding and heavy rainfall can cause overflows from sewage treatment plants into fresh water sources. Overflows could contaminate certain food crops with pathogen-containing feces.

Water-borne Diseases

- Heavy rainfall or flooding can increase water-borne parasites such as Cryptosporidium and Giardia that are sometimes found in drinking water. These parasites can cause gastrointestinal distress and in severe cases, death.
- Heavy rainfall events cause stormwater runoff that may contaminate water bodies used for recreation (such as lakes and beaches) with other bacteria. The most common illness contracted from contamination at beaches is gastroenteritis, an inflammation of the stomach and the intestines that can cause symptoms such as vomiting, headaches, and fever. Other minor illnesses include ear, eye, nose, and throat infections.

Animal-borne Diseases

- The geographic range of ticks that carry Lyme disease is limited by temperature. As air temperatures rise, the range of these ticks is likely to continue to expand northward. Typical symptoms of Lyme disease include fever, headache, fatigue, and a characteristic skin rash.
- In 2002, a new strain of West Nile virus, which can cause serious, life-altering disease, emerged in the United States. Higher temperatures are favorable to the survival of this new strain.

Lightning

Lightning is a bright flash of electricity produced by a thunderstorm. All thunderstorms produce lightning and are very dangerous. If you hear the sound of thunder, then you are in danger from lightning. Lightning kills and injures more people each year than hurricanes or tornadoes; between 75 to 100 people. Lightning is an electric current. Within a thundercloud, many small bits of ice bump into each other as they move around in the air. All of those collisions create an electric charge. After a while, the whole cloud fills up with electrical charges. The positive charges or protons form at the top of the cloud and the negative charges or electrons form at the bottom of the cloud. That causes a positive charge to build up on the ground beneath the cloud. The grounds electrical charge concentrates around anything that sticks up, such as mountains, people, or single trees. The charge coming up from these points eventually connects with a charge reaching down from the clouds and - lightning strikes!

Flooding

Flooding is a very common weather event that has caused some of Maryland's worst disasters. From 1995-1996, Maryland had a number of major floods that resulted in two disaster declarations.

Rainfall

Heavy rainfall can lead to flash flood events. These tend to come after short periods of heavy rain and most often affect small streams and creeks. General flooding comes from more prolonged steady rain and tends to affect larger streams and rivers. Intense rainfall will likely grow significantly heavier in most of the United States by the final decades of the century.

Riverine

Riverine flooding is another way to say river floods. When a river reaches its floodstage, water can rise and spill over the banks of the river. The amount of flooding is usually a function of the amount of precipitation in an area, the amount of time it takes for rainfall to accumulate, previous saturation of local soils, and the terrain around the river system. With large rivers the process is relatively slow. The rain water enters the river in many ways.

Some rain will fall into the river directly, but that alone doesn't make the river rise high. A lot of rain water will run off the surface when the soil is saturated or hard.

Coastal

Coastal flooding is commonly caused by a combination of tidal surges caused by winds and low barometric pressure, and they may be exacerbated by high upstream river flow. Coastal areas may be flooded by tropical storm events or hurricanes. A storm surge, from either a tropical storm, falls within this category and can cause devastating flooding. (See Storm Surge poster for more information)

Infrastructure Failures

Old infrastructure is a major problem in Baltimore. During the seasonal changes, the ground shifts and the water mains break. The City still has pipes that are over 100-years-old.

The failure of a dam or a levee can also cause catastrophic flooding in several ways: structural failures due to problems with construction, rainfall or flood waters that exceed their capacity or natural disasters that cause damage.

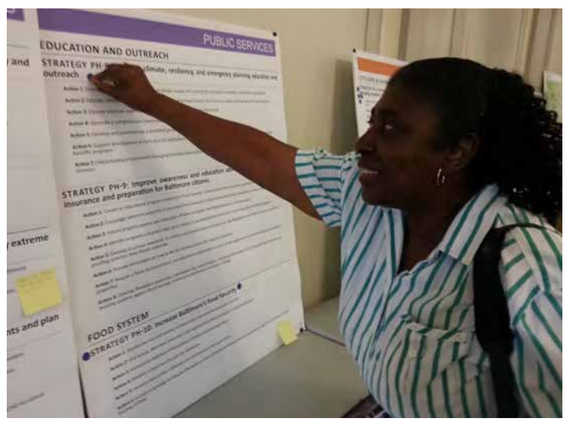
Our water infrastructure has been crumbling beneath our feet and cannot be ignored," - DPW worker

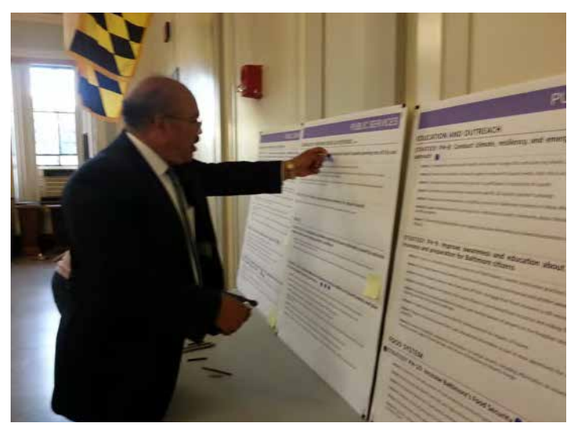
Video Screen Images, Baltimore City

Interactive Feedback at Public Meetings

Voting Exercise

Description of the exercise





INFRASTRUCTURE

ENERGY

STRATEGY IN-1: Protect and enhance the resiliency and redundancy of electricity system

Action 1: Work with the Maryland Public Service Commission (PSC) to minimize power outages from the local utility during extreme weather events by identifying and protecting critical energy facilities located within the City

Action 2: Evaluate the City of Baltimore utility distribution system, and identify "underground utility districts" using BGE's May 2013 short term reliability improvement plan

Action 3: Support BGE's collaboration with the Maryland Public Service Commission to implement various smart grid solutions that will provide the City with real-time access to data during events

Action 4: Identify, harden and water seal critical infrastructure relative to electrical, heating, and ventilation hardware within the flood plain

Action 5: Increase resiliency in our energy generation system by encouraging the development of decentralized power generation and developing fuel flexibility capabilities

Action 6: Develop a comprehensive maintenance and training program for City employees at facilities with backup generators to ensure proper placement, hook-up and ability to use during hazard events

Action 7: Install external generator hookups for critical City facilities that depend on mobile generators for backup power

Action 8: Partner with the Public Service Commission and the local electric utility to evaluate protecting power and utility lines from all hazards

Action 9: Determine low-laying substation vulnerability and outline options for adaptation and mitigation

Action 10: Evaluate and protect low laying infrastructure – switching vaults, conduit and transformers

STRATEGY IN-2: Increase energy conservation efforts

Action 1: Increase energy efficiency across all public and private sectors through education, efficiency retrofits, and building management systems

Action 2: Encourage critical facilities and institutions to connect to existing cogeneration systems, or develop new cogeneration systems

Action 3: Continue the City's electricity demand-response program during peak usage or pre-blackout periods

STRATEGY IN-3: Ensure backup power generation for critical facilities and identified key infrastructure during power outages

Action 1: Investigate off-grid, on-site renewable energy systems, generators, and technologies for critical facilities to ensure redundancy of energy systems

Action 2: Seek funding to purchase and install generators for all city building designated as critical to agency functions

Action 3: Develop Combined Heat and Power (CHP) co-generation plants at identified critical facilities

Action 4: Evaluate and ensure backup power generation is available to healthcare facilities (nursing homes, critical care facilities, hospitals, etc.)

LIQUID FUELS

STRATEGY IN-4: Protect and manage liquefied natural gas sites and (City) fueling stations before and during hazard events

Action 1: Work with BGE to ensure existing preparedness plans for Spring Gardens liquefied natural gas site incorporate its vulnerability to present and predicted flooding, storm surge and sea level rise

Action 2: Adopt building code that requires anchoring of 50 gallon storage tanks or larger

Action 3: Work with BEG to monitor efforts to protect the natural gas system against flooding

BUILDINGS

CITY CODES & DESIGN GUIDELINES

STRATEGY B-1: Develop and implement hazard resilience measures for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.

Action 1: Require all hazardous materials within the floodplain to be elevated a minimum of three feet above the Base Flood Elevation (BFE)

Action 2: Require new critical facilities to be designed with redundant operating systems

Action 3: Require pre-wiring for generators at all facilities designated critical to agency operations and hazard response

Action 4: Develop stricter resiliency measures or flood mitigation practices for critical facilities

Action 5: Develop partnership with private fueling stations to provide backup generators in exchange for a commitment to fueling emergency response vehicles during a hazard event

Action 6: Ensure storage of and access to diesel fuel for generators in critical facilities

Action 7: Require backup solar powered street lights and signals are integrated along evacuation routes and high traffic areas

STRATEGY B-2: Enhance building codes that regulate building within a floodplain or near the waterfront

Action 1: Design projects to be resilient to a mid-century sea level rise projection and adaptable to longer-term impacts

Action 2: Incorporate climate change and coastal hazard considerations into building codes by increasing freeboard requirements to two feet as buildings are redeveloped and renovated

Action 3: Continue to regulate to the existing tidal floodplain delineation

Action 4: Incorporate outfall elevation regulations into buildings and natural resource codes

Action 5: Develop Construction Best Practices for development within floodplains

Action 6: Train all code enforcement and building inspectors about flood proofing techniques and the local floodplain ordinance

STRATEGY B-3: Strengthen city codes to integrate anticipated changes in climate

Action 1: Review zoning code (floodplain, drainage, stormwater management, erosion control) and strengthen code (where necessary) in order to better protect citizens and increase resiliency in buildings

Action 2: Review and amend existing codes to require more flood structures in the floodplain

Action 3: Reduce development in 100-year flood plain

Action 4: Utilize open space category in zoning code to protect sensitive areas (e.g. stormwater sites, steep slopes, floodways, etc.)

Action 5: Review and increase Base Floodplain Elevation (BFE) standards to the highest available State, Federal or local elevation level

Action 6: Evaluate and update stormwater management regulations to avoid increases in downstream flooding

Action 7: Adopt design requirements that include wet and dry flood proofing techniques

Action 8: Review and consider adoption of the International Green Construction code

Action 9: Strengthen city codes to help reduce urban heat island impacts

STRATEGY B-4: Update a list of flood prone and repetitive loss buildings to consider for acquisition

Action 1: Continue to acquire property (including repetitive loss properties) in the special flood hazard areas where feasible and appropriate

Action 2: Prioritize Hazard Mitigation Assistance funding for mitigation of repetitive loss properties and severe repetitive loss properties

Action 3: Develop a creative financing program to increase the flood resiliency of industrial buildings

NATURAL SYSTEMS

URBAN PARKS AND FOREST

STRATEGY NS-1: Utilize green corridors and parks to help protect surrounding communities from the impacts of hazard events

Action 1: Evaluate green corridors and parks for possible improvements for flood management and air quality improvement

Action 2: Increase the resiliency of park facilities and buildings

STRATEGY NS-2: Increase and enhance the resilience and health of Baltimore's urban forest

Action 1: Anticipate future changes in temperature and weather by developing a comprehensive list of plant and tree species or varieties known to have a broad range of environmental tolerances

Action 2: Establish and routinely update a comprehensive tree inventory to anticipate insect and forest structural impacts of climate change

Action 3: Establish a comprehensive maintenance program that includes pruning for sound structure and the removal of hazardous limbs and trees. First focus on vulnerable infrastructure nearby such as essential facilities and roads

Action 4: Continually adjust and modify planting details and specifications to assure the health and longevity of trees

Action 5: Increase the urban tree canopy and target areas with urban heat island impacts

Action 6: Proactively communicate and collaborate with the City of Baltimore on the removal of trees around electric distribution lines to minimize power outages

STRATEGY NS-3: Create an interconnected network of green spaces to support biodiversity and watershed based water quality management

Action 1: Support the Growing Green Initiative to increase green space and pervious services in areas where there is significant abandonment and opportunities to reduce the urban heat island effect

Action 2: Convert vacant and distressed row house lands into meaningful and connected space (parkland)

Action 3: Complete a watershed based habitat analysis for the City

Action 4: Create a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation

Action 5: Certify Baltimore as a Community Wildlife Habitat through the National Wildlife Foundation (NWF)

STRATEGY NS-4: Expand, protect and restore riparian areas in the city

Action 1: Conduct regular maintenance of stream restoration projects and stormwater quality facilities

Action 2: Require riparian buffers with all new development and capital projects

Action 3: Evaluate current regulations regarding stream buffers and floodplains and modify them (if appropriate)

STRATEGY NS-5: Preserve and create new ecological buffer efforts and support creating more (e.g. wetlands) along coastal areas

Action 1: Integrate natural buffer requirements, such as wetlands and soft shorelines, into new development or redevelopment

Action 2: Complete stream restoration projects in Baltimore City and County stream valleys that lead into the coastal wetlands so as to increase habitat and reduce sedimentation

Action 3: Identify and evaluate areas in the Critical Area buffer to prioritize ecological buffer restoration efforts and areas that could be enhanced to serve as natural storm surge barriers

PUBLIC SERVICES

EMERGENCY PREPAREDNESS & RESPONSE

STRATEGY PH-1: Strengthen emergency preparedness coordination between local government, NGOs, and private entities by updates to the City Emergency Operations Plan (EOP) and related Emergency Support Functions (ESF)

Action1: Identify and develop a common database that all city government agencies and departments should utilize for hazard information, preparedness and response

Action 2: Ensure consistency and integration with existing and future response plans within and between agencies

Action 3: Continue to identify and improve coordination with Key Partners including private sector, State partners, Federal partners, community, universities and industry leaders through Local Emergency Planning Committee

Action 4: Coordinate outreach efforts of the Mayor's Office of Emergency Management, Mayor's Office of Neighborhood and Constituent Services, Baltimore City Health Department and Maryland Emergency Management Agency (MEMA) to leverage messages related to all-hazards emergency preparedness

Action 5: Develop strong working relationships with local experts to provide technical assistance to refine and improve city government emergency preparations

Action 6: Review and improve specific response plans contained in the EOP and related ESFs that relate to extreme weather events (snow, heat, flood, wind, electrical outages, and other hazard events)

Action 7: Ensure equipment purchases and communication systems are compatible across agencies and jurisdictions

Action 8: Encourage all animal rescue and care shelters to further develop their internal plans for animal's health and safety during and after a hazard event

Action 9: Ensure all animal rescue and care shelters located within the floodplain are provided the support to apply for and obtain funds to relocate

Action 10: Develop and implement a case study of hospital-based practices that foster community resilience to climate change

STRATEGY PH-2: Develop a Hazard Awareness Program

Action 1: Create a standardized early warning system for citizens, as well as visitors

Action 2: Evaluate and improve community health center strategies for communicating with patients during an emergency

Action 3: Educate citizens about the early warning system and actions to take when enacted

Action 4: Prepare and integrate occupational health and safety message and instructions for first responders

Action 5: Hold climate specific seminars for hospital emergency and sustainability managers

STRATEGY PH-3: Designate community leaders and organizations that can assist and provide support during hazard events

Action 1: Prior to a hazard event, identify lead contacts serving vulnerable populations and coordinate actions to maximize safety and information sharing

Action 2: Develop a community group coordination plan and implementation guide

Action 3: Identify and evaluate plans already in place and work to improve utilization of community based leaders to assist in preparedness and response

Interactive Feedback at Public Meetings

Budgeting Exercise

The DP3 Budget Exercise provided each Town Hall participant with $600 worth of DP3 money and asked, "With a limited budget, where do you suggest the city spend money to create a more resilient Baltimore?" Each participant placed the DP3 money in the box or boxes to indicate which strategies they wished the city to invest.

A total of $___ DP3 money was allocated by the public as follows:

The preferences expressed through this exercise ....

Town Hall Presentations

April 30, 2013

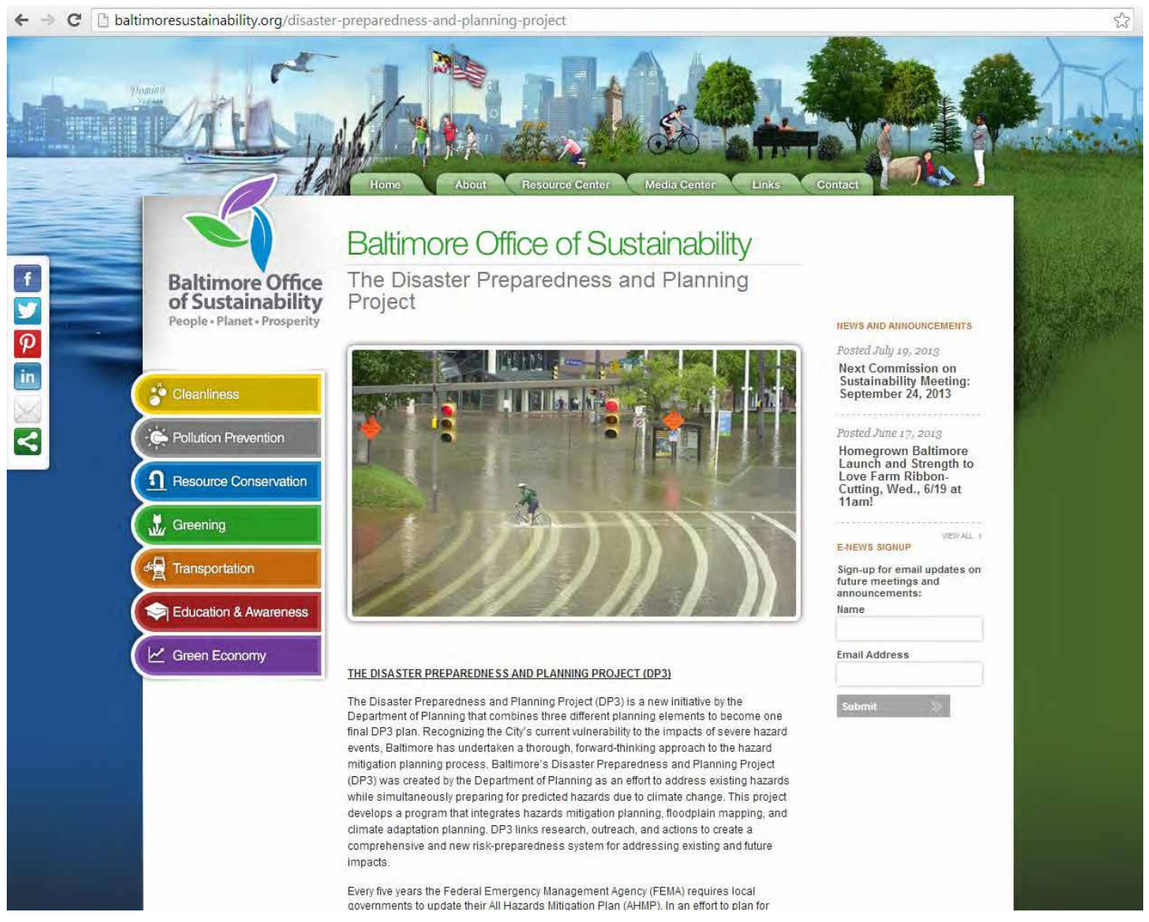
Community Meetings

April 30, 2013

Online Opportunities

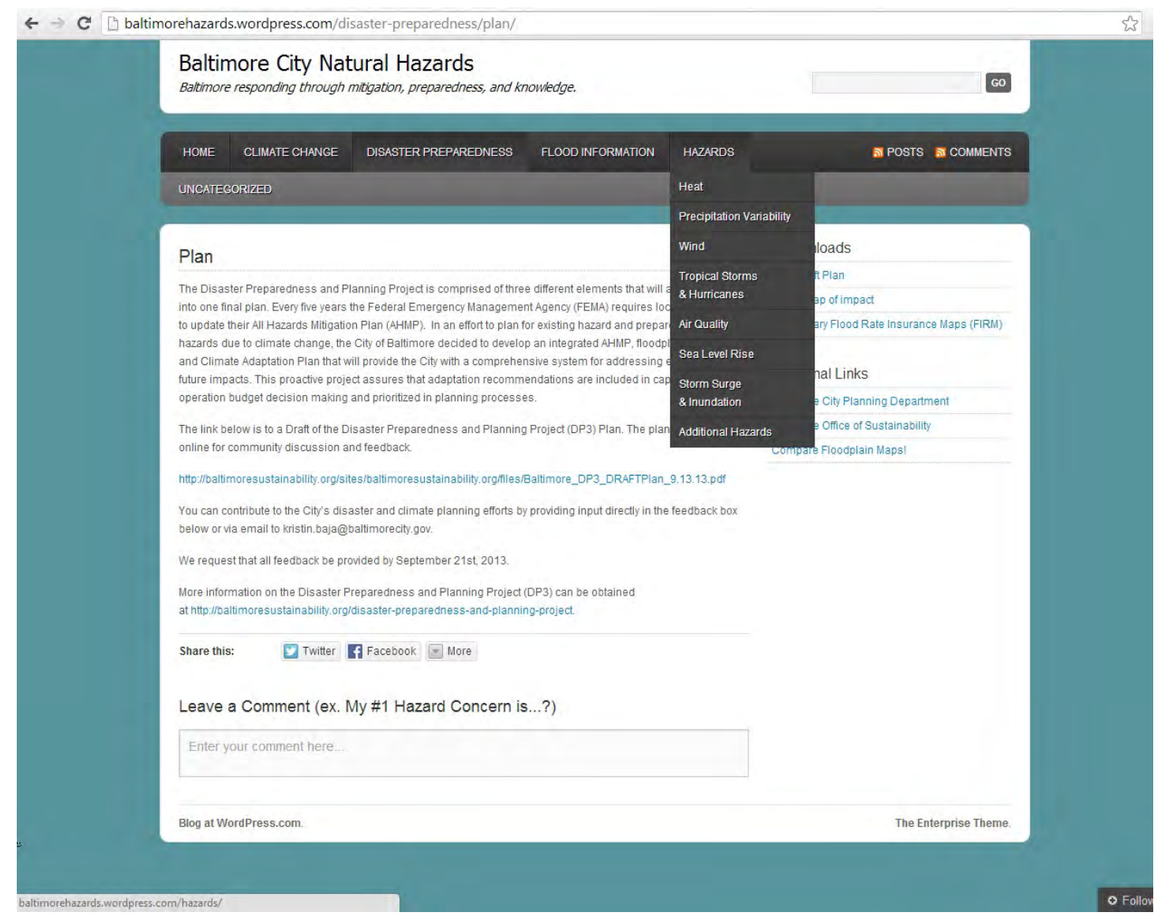
Baltimore Office of Sustainability Website

Placeholder for Text



Baltimore Natural Hazards Website

Placeholder for Text



Appendix G: Spreadsheet of Strategies and Actions

Prioritization

Appendix H: Critical Facilities

Baltimore City Critical Facilities

Appendix I: Engineering Study

Fells Point

Appendix J: Health Impacts Assessment

Background

Appendix K — References

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