

# One Climate Future

# **APPENDIX**

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## **GREENHOUSE GAS INVENTORIES MEMORANDUM**

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## **RESILIENCE MEMORANDUM**

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Memorandum: Resilience Zoning for Resilient Buildings and Land Use

# Memorandum

## Resilience Zoning for Resilience Buildings and Land Use

To: Cities of Portland and South Portland  
From: Linnean Solutions  
Date: May 2020  
Re: Supporting guidance for designing and implementing resilience-based zoning for the One Climate Future Climate Action and Adaptation Plan

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### Introduction

Portland and South Portland are faced with a significant opportunity now to guide all future development in ways that reduce the risk and impacts from climate hazards. Smart development patterns as well as resilient building and site design can allow cities to grow in ways that effectively adapt to the effects of sea level rise and storm surge, higher volumes of stormwater, more intense storms, higher temperatures, as well as accompanying uncertainty. In the following memorandum we recommend that the cities adopt a set of resilience overlays, defined based on exposure to specific climate risks. We outline the purpose of each of these overlays, as well as offer a set of alternate approaches for delineating their boundaries—concluding that it may be in the cities’ best interest to commission a flood risk assessment that maps the boundaries of the future 1% (and 0.2%) annual chance flood, accounting for sea level rise. To address the resilience

challenges across these overlay zones, we outline a set of approaches for requiring or incentivizing resilient building and site parameters, drawing from precedents down the east coast. From these options we propose one model for a resilient quotient that would both allow the cities to enforce specific resilience measures as well as encourage resilience thinking more broadly through a flexible and performance-based approach.

## 1. City-Scale: Resilience Zoning Overlays

Zoning overlays are special zoning districts that are applied on top of (i.e., in addition to) the city's existing base zoning. Overlays make it possible for cities to address certain conditions (such as flood vulnerability) across a specific area that does not necessarily align with the boundaries of the base zones. In the case of resilience zoning, overlays become a way for cities to set requirements or incentives in ways that align with the spatial extent of climate hazards. While there is quite a bit of variation in how resilience overlays can be implemented—discussed in more detail below—we recommend keeping the following principles in mind.

### 1.1. Guiding Principles for Resilience Zoning Overlays

- A) Maintain a whole-city perspective: All parts of the city can play a role. There's a tendency to only focus on specific at-risk areas (such as areas with the highest flood risk) when designing resilience overlays. Requiring or incentivizing action in only these areas misses the opportunity to use the rest of the city as part of an integrated system for increasing resilience. Expanding green infrastructure in higher elevation areas, for example, can reduce flooding in lower elevation areas. Likewise, choosing to restrict development in areas with the highest flood risk can be complemented by incentives to densify and cluster amenities in areas outside flood boundaries. All areas of the city will feel the effects of higher temperatures and more intense storms, and thus all areas of the cities can play a role in mitigating these hazards. For this reason, resilience zoning may be best implemented through a set of resilience overlays, differentiated based on the relative exposure to climate hazards and respective adaptive responses required for different areas of the cities. See Norfolk, VA under precedents (section 3) for an example of resilience overlays that take a whole-city approach.
- B) Allow for the overlays to be dynamic over time. There is a lot of inherent uncertainty in climate models: As a starting point, we do not know how quickly and comprehensively nations globally will be able to reduce greenhouse gas emissions. We are also unable to fully predict the potential catalytic effects of ongoing emissions—including, for example, how drastically the growing instability of the Antarctic Ice Sheet may impact sea level rise. The Maine Geological Survey's inundation areas for sea level rise and storm surge in Portland and South Portland represent our best understanding at this point in time, but will no doubt evolve in the coming years. We recommend designing the cities' zoning guidelines to be able to respond to new information. Aligning zoning boundaries with scenarios (such as the Intermediate sea level rise scenario for 2100 or the FEMA 0.2% annual chance flood) allows the premise to stay consistent (i.e., planning for a certain amount of risk based on a given probability), but allows the inundation area to evolve as our projections improve. We recommend establishing designated timeframes, stipulated in the zoning code, to review the latest climate models and update the boundaries of zoning overlays based on the newest projections.

## 1.2. Defining the Purposes of the Resilience Overlays

All new development in Portland and South Portland can contribute to the resilience of the cities. In order to make that possible, we recommend implementing a set of resilience overlays, differentiated based on the relative exposure to climate hazards. The cities will want to determine both the number of tiers and boundaries of the tiers that would be most effective for each city; guidance on that process is included in section 1.3 below. Generally speaking, however, we recommend resilience overlays designed to meet certain objectives based on the following parameters:

- A) Areas with the Highest Flood Risk (“Tier 1 Flood Overlay”). We recommend that one resilience overlay apply to areas of the cities with the highest flood risk from sea level rise and storm surge. The purpose of the “highest flood risk” overlay would be to guide land use decisions that a) buffer and absorb floodwaters, particularly from sea level rise and storm surge, and b) minimize the net negative impacts of sea level rise and storm surge on the cities, particularly with respect to resident health and safety, protecting public infrastructure and assets, and safeguarding municipal fiscal health. Land use decisions within this resilience overlay would follow the following hierarchy:
- **Priority 1:** Preserve existing natural open space areas as critical assets to buffer and absorb flood- and stormwater.
  - **Priority 2:** Seek opportunities to transition existing land uses to living shorelines or public parks with a primary focus on floodable natural spaces in an effort to restore natural floodplains.
  - **Priority 3:** Encourage development of compatible land uses, as described further below.

Any new construction in these areas would be reserved for low-density, non-residential, and “flood-tolerant uses” that do not fall into a list of incompatible, vulnerable, or hazardous uses, and that meet minimum resilient building design requirements. Such “incompatible, vulnerable, or hazardous uses” would include any building types that provide permanent or temporary shelter (e.g., single-family or multifamily homes, nursing homes, shelters, hotels, etc.) which amplify the need for evacuation and emergency response in a flood event; critical facilities<sup>1</sup> (e.g., critical government buildings, emergency management services, hospitals, schools, etc.); and commercial and industrial uses that could create cascading repercussions if exposed to flood waters (e.g., those with hazardous chemical storage).

While it feels counter to the cities’ housing goals to restrict housing development in certain areas, it is in effect a proactive and protective measure to ensure that the cities do not lose substantial

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<sup>1</sup> National Flood Insurance Program (NFIP) Floodplain Management Regulations urge jurisdictions to build no new critical infrastructure in the 1% annual chance flood zone. Many jurisdictions require that no new critical facilities be built in the 0.2% annual chance flood zone (which receives credit through the Community Rating System). It is also worth noting that it is much more difficult to secure any Federal funding for critical facilities if they are in the 0.2% annual chance flood zone, including any recovery funding. Under Executive Order 11988, Federal agencies must complete “rigorous alternative site evaluations” before advancing a project in the 0.2% annual chance flood zone as a last resort.

portions of their housing stock to flooding within the next 50 years. It further protects the health and safety of residents by ensuring that fewer people live within these high risk zones, and it helps to reduce the city's financial liability: the cities are on the line to invest in roads, water and sewage, and other public infrastructure to serve development in these areas, which will likely see escalating costs. It also becomes an equity issue: homes and residential units in areas that see frequent flooding will eventually devalue and become some of the most affordable housing on the market. As a result, families with the least financial means to respond in a disaster will end up living in the most at-risk areas of the cities. To the extent practicable, seeking ways to expand the natural floodplain (which can double as public open space amenities) in these highest risk areas will create significant long-term value, both through natural amenities and loss minimization.

- B) Areas with High to Moderate Flood Risk (“Tier 2 Flood Overlay”). It is recommended that a second overlay apply to areas of the cities that fall outside areas of highest flood risk, but that are still likely to see flooding from sea level rise and storm surge under higher sea level rise scenarios and/or under larger flood events. The primary goal for this second overlay would be to encourage new development and redevelopment in these areas to pursue adaptation measures for building and site design that address the flood risk of the given site. Resilient building and site design in this overlay could be either voluntary (incentivized) or required; The cities may consider dividing this overlay into two zones to either require or incentivize adaptation measures based on the level of risk. Again, guidance on determining these boundaries—and on where we recommend requiring building adaptation—is included in section 1.3.
  
- C) Whole-City Overlay: Stormwater and Heat. Areas outside the first two overlays are not vulnerable to flooding from sea level rise and storm surge, but will still feel the effects of higher intensity rainstorms and higher temperatures, and can help the cities adapt to both these stresses. Guided by a whole-city resilience overlay, development and redevelopment could be required or incentivized to meet specific point requirements for stormwater retention and cooling capacity, which in many instances can be addressed simultaneously through preserving open space, green infrastructure, or green/blue roofs. Recommended approaches for addressing stormwater and heat could vary based on whether the site also falls into another resilience overlay.

Figure 1 illustrates a three-tier system for resilience overlays. Note that the figure is purely diagrammatic; Boundaries do not represent actual, proposed, or recommended zones.

### Diagram of a Three-Tiered System for Resilience Overlays



**Figure 1.** Diagram showing a multi-tiered system for resilience overlays. The figure is purely diagrammatic; Boundaries do not represent actual, proposed, or recommended zones.

### 1.3. Defining the Boundaries of the Resilience Overlays

Storms of various magnitudes, sea level rise scenarios, and the timeframe for flood projections are all variables that can shape how we assess “flood risk” in a given area. Based on the resilience overlays suggested in section 1.2, we outline three potential approaches for defining the boundaries of the overlays given different flood risk thresholds and datasets. Again, these approaches define boundaries based on probability-based scenarios (as opposed to a specific elevation) so that the boundaries of the overlays can shift over time as flood projections change. The first two approaches rely on existing geospatial flood risk information; the third approach would require further flood risk analysis.

While we offer these recommendations as a starting point, Portland and South Portland will ultimately need to work across their respective departments to specify the flood thresholds and corresponding resilience overlay boundaries based on what will be most effective for each city. This decision is based not only on level of risk and potential inundation area, but also implications for projected growth in the cities, administrative systems for surveying and updating zone boundaries, buy-in from city staff and residents, among other factors.

### Approach 1: Sea Level Rise Scenarios.

In 2017, the National Oceanic and Atmospheric Administration (NOAA) reported a range of global and regional sea level rise projections based on the three greenhouse gas emissions scenarios.<sup>2</sup> The six global mean sea level (GMSL) rise scenarios include an extreme upper-bound (highest potential sea level rise in 2100), a lower-bound (lowest potential sea level rise in 2100), and four intermediate conditions. Table 1 summarizes these six scenarios and provides probabilities that sea levels will surpass each given height.

**Global Mean Sea Level Rise Scenarios**

Scenario	Global Mean Sea Level Rise	Probability of Exceedance
Low	0.3 meters (1 ft)	94 - 100%
Intermediate Low	0.5 meters (1.6 ft)	94 - 96%
Intermediate	1 meters (3.3 ft)	2 - 17%
Intermediate High	1.5 meters (4.9 ft)	0.4 - 1.3%
High	2 meters (6.6 ft)	0.1 - 0.3%
Extreme	2.5 meters (8.2 ft)	0.05 - 0.1%

**Table 1.** Global mean sea level rise scenarios for 2100 with the corresponding probability that sea level rise will exceed the given threshold. The probability is based on the RCP 2.6 to RCP 8.5 scenarios.

To support planning decisions, NOAA provides guidance on choosing planning thresholds based on the likelihood of the scenarios and the level of risk posed. Using this guidance, we can define the Intermediate scenario as “what is most likely to occur” and the extreme scenario as “how bad can it get.” This is in alignment with recommendations from Portland’s Bayside Adapts Phase 1: Stormwater and Sewer Gap Analysis (“Bayside Adapts”) report.

Table 2 summarizes the regional relative sea level rise scenarios for 2050 and 2100 for the Greater Portland area, which convert the global scenarios to local projections by taking into account a number of local geological and hydrological factors.<sup>3</sup> Based on the guidance above, it is recommended that Portland and South Portland commit to managing the intermediate scenario (1.48 feet of relative sea level rise), but be prepared to manage the extreme scenario (3.38 feet) when considering a 2050 planning horizon.

<sup>2</sup> These three scenarios include Representative Concentration Pathways (RCP) 2.6, 4.5, and 8.5. The RCP 2.6 scenario represents significant immediate reductions in greenhouse gas emissions, resulting in “net-negative” emissions by 2100. The RCP 4.5 scenario represents moderate reductions in greenhouse gas emissions, resulting in the stabilization of global emissions by 2050 and a decrease in global emissions afterwards. The RCP 8.5 scenario represents continued intensive use of fossil fuels and emission of greenhouse gases. See the One Climate Future Vulnerability Assessment (page 10) for further details.

<sup>3</sup> These factors include variations in the Earth’s gravitational forces, ocean circulation patterns, ice sheet and glacial melt, and vertical movement in the land.

## Sea Level Rise Planning Scenarios for Portland and South Portland

Scenario	Relative Sea Level Rise (feet)	
	2050	2100
Low	0.62	1.12
Intermediate Low	0.82	1.53
Intermediate	1.48 – “Commit to manage”	3.84 – “Commit to manage”
Intermediate High	2.16	6.00
High	2.95	8.72 – “Prepare to manage”
Extreme	3.38 – “Prepare to manage”	10.79 – “Be aware of”

**Table 2.** Sea level rise scenarios for 2050 and 2100 for the Greater Portland region, with corresponding recommendations for city planning.

By 2100, the potential levels of sea level rise across the scenarios deviate from each other quite significantly. Bayside Adapts recommends committing to managing the intermediate scenario (3.84 feet) for a 2100 planning horizon, being prepared to manage the high scenario (8.72 feet), and being aware of and monitoring for the extreme scenario (10.79 feet). When considering the potential area of inundation under these scenarios, we recommend using the relative sea level rise on top of the highest astronomical tide (HAT).<sup>4</sup>

Under this approach, we recommend using the Intermediate scenario for 2100 (3.84 feet above the HAT), which corresponds with the city’s “commit to manage” threshold to delineate areas in the city with the highest flood risk. Using a 2100 timescale sets a longer course trajectory in line with infrastructure development and longer-term development patterns. The boundary for the “Tier 2” flood resilience overlay could thus be defined based on the “prepare to manage” sea level rise scenario (8.72 feet above the HAT). Again, the type of development would not be restricted within this second overlay, but buildings would be encouraged to incorporate flood-resilient building and site parameters.

### Approach 2: FEMA Flood Zones.

Under the National Flood Insurance Program (NFIP), the Federal Emergency Management Agency (FEMA) conducts flood hazard analyses and produces Flood Insurance Rate Maps (FIRMs) to inform communities about flood risk. Municipalities can choose to participate in the NFIP, which involves adopting and enforcing floodplain management ordinances that define building standards for new and existing development in zones with high flood risk. Residents within participating communities are eligible to purchase NFIP flood insurance and can receive disaster assistance for flood-related damage. Both Portland and South Portland are NFIP-participating communities. The FIRMs for Cumberland County were updated in 2017; adoption of the new FIRMs is still pending in both cities.

The FIRMs delineate Special Flood Hazard Areas (SFHAs), which are areas with a 1% annual chance of flooding (often also referred to as the 100-year flood zone). Stated another way, properties in these zones

<sup>4</sup> The highest astronomical tide (HAT) represents the highest tide that can be predicted to occur in the given epoch. It is important to note, however, that meteorological forces (e.g., surge from storms or hurricanes) can make water levels exceed these thresholds.



have a 26% chance of flooding over the course of a 30-year mortgage. These areas include all zones designated with a V or A, including A, AO, AH, AE, VE, and V zones. FIRMs also delineate the inundation area for the 0.2% annual chance flood (often also referred to as the 500-year flood zone). Table 3 summarizes the zones that are most relevant for Portland and South Portland.

### Select FEMA Flood Zones

Special Flood Hazard Areas (1% annual chance flood)	
VE	Coastal areas within the 1% annual chance zone that are also exposed to storm waves over 3 feet. Base flood elevations (BFE) are provided for VE zones.
AE	Areas within the 1% annual chance zone, and where base flood elevations (BFE) are provided. On some FIRMs, the AE zone is divided into a Coastal A zone and the (more inland) AE zone by a Limit of Moderate Wave Action (LiMWA) line. The LiMWA delineates the area that will have exposure to storm waves that are smaller than 3 feet and over 1.5 feet.
AH	Areas subject to shallow flooding (usually ponding) by the 1% annual chance flood where average depths are between 1 and 3 feet. Base flood elevations (BFEs) are shown (and derived from detailed hydraulic analyses).
A	Areas within the 1% annual chance zone, where no base flood elevations (BFE) have been determined.
Moderate Flood Risk Areas (0.2% annual chance flood)	
X (shaded)	Areas that have a 0.2% annual chance of flooding. Properties in this zone have a 6% chance of flooding over the course of a 30-year mortgage.

**Table 3.** Definitions for FEMA flood zones included on FIRMs for Portland and South Portland.

The FIRMs illustrate flooding associated with a particular level of storm, and a relative probability of occurrence. It is important to note that the boundaries of the FEMA flood zones are based on existing shoreline characteristics (including development and land elevation) and historic recurrence intervals for wave and storm dynamics; They do not project effects from climate change. By 2050 under an Intermediate sea level rise scenario, for example, Portland and South Portland could see water levels associated with the 1% annual chance storm ten times as frequently.

Although the FIRM flood zones do not incorporate sea level rise projections, in Portland and South Portland the 0.2% annual chance flood zone (as delineated in the 2017 preliminary FIRMs) aligns quite closely to the projected inundation area for the Intermediate sea level rise scenario for 2100 on top of the highest astronomical tide. Using the boundaries for the 0.2% annual chance flood could therefore double as a proxy for accounting for the projected effects from sea level rise for the cities' "commit to manage" scenario. Using the FEMA delineation provides some administrative convenience: these zones are already (and recently) surveyed and mapped, and the boundaries will already have legal standing (once adopted) for floodplain

regulations. Furthermore, as communities participating in the NFIP, Portland and South Portland are already required to follow NFIP floodplain management requirements in the Special Flood Hazard Areas. Designing the resilience overlay to cover Special Flood Hazard Areas as well as the 0.2% annual chance flood zone could allow for more streamlined overlap between NFIP floodplain management requirements, International Codes, and the resilience overlay.

The boundary for the Tier 2 flood risk overlay, however, would still need to be delineated by the “prepare to manage” sea level rise scenario for 2100 (8.72 feet above the HAT), as no additional threshold exists on the FIRMs.

### **Approach 3: Future Special Flood Hazard Areas, Accounting for Sea Level Rise.**

As a third approach, the Tier 1 flood resilience overlay for the highest flood risk could be delineated based on a projection of the future 1% annual chance flood zone (i.e., the future FEMA Special Flood Hazard Area) that accounts for sea level rise. We recommend using a future date 50 years from now or longer (e.g., 2070 or 2100) and incorporating the effects of sea level rise from the Intermediate sea level rise projection (i.e., Portland and South Portland’s “commit to manage threshold”) or higher. This approach has significant benefits:

- It incorporates more information about flood risk than either of the other two approaches in defining the boundaries of the overlay zones, including sea level rise projections and the probability and hydrologic/hydraulic dynamics of storm events.
- It creates more consistent messaging. For example, under the NFIP floodplain management regulations, properties within the Special Flood Hazard Areas (1% annual chance flood zone) must abide by certain building regulations. The resilience overlay would outline where the 1% annual chance flood zone will likely be at a future date in order to proactively prepare for sea level rise.

It should be noted that basing the boundaries of the Tier 1 flood resilience overlay on the combined effects of sea level rise and future storms will result in a much larger boundary than the other two approaches, particularly if using the 1% annual chance storm for 2100 under the Intermediate sea level rise scenario. With the understanding that this could create significant constraints, particularly on housing development, the following approach outlined in Table 4 could be one way to tailor the overlays based on the combined effects of sea level rise and storms.

### Tailoring the Resilience Overlay Scheme for Approach 3

Resilience Overlay	Basis of Boundary	Zoning Parameters
Tier 1: Highest Flood Risk	Future high tide (no storm) conditions in 2100 under the Intermediate sea level rise scenario	<ul style="list-style-type: none"> <li>• Land use decisions prioritize the preservation and creation of natural spaces (based on hierarchy of land use)</li> <li>• Restrictions on the development of incompatible, vulnerable, or hazardous uses</li> <li>• All development (compatible uses) shall meet resilient building requirements</li> </ul>
Tier 2: High Flood Risk	Future 1% annual chance storm in 2100 with the Intermediate sea level rise scenario	<ul style="list-style-type: none"> <li>• All development (or all development requiring development review) shall meet resilient building requirements</li> </ul>
Tier 3: Moderate Flood Risk	Future 0.2% annual chance storm in 2100 with the Intermediate sea level rise scenario	<ul style="list-style-type: none"> <li>• Development is encouraged to consider resilient building parameters as part of a broader suite of resilience considerations in the whole-city overlay</li> </ul>
Tier 4: Whole-City Overlay	Entire city	<ul style="list-style-type: none"> <li>• Development is either required or incentivized to meet specific point requirements for stormwater retention and cooling capacity</li> </ul>

**Table 4.** Potential approach for tailoring the resilience overlay scheme based on boundaries that account for both sea level rise and storm flooding.

Ultimately, the cities’ risk tolerance will inform which combinations of scenarios—sea level rise and storm levels—are used to determine the boundaries and corresponding requirements. We recommended the Intermediate scenario to align with the cities’ “commit to manage scenario.” A more risk averse approach could include basing the three flood resilience overlays on the Intermediate-High or High (the “prepare to manage”) sea level rise scenario, keeping all other variables the same. A less risk averse (more risk tolerant) approach could include basing all boundaries on an earlier year, such as 2070, or recommending (as opposed to requiring) resilient building requirements in Tier 2.

Using both sea level rise and storm probabilities for a resilience overlay would require an additional hydrodynamic flood risk assessment to determine the inundation areas for floods at various recurrence intervals (e.g., 1%, 0.2%) at a future date, accounting for sea level rise. This study could be commissioned in tandem with the stormwater drainage assessment in Action CR 4.1. For reference, Boston has used this methodology for defining its “Coastal Flood Resilience Zoning Overlay District,” based on hydrodynamic modeling by the University of Massachusetts Boston and the Woods Hole Group. (Boston defines its Resilience Zoning Overlay District based on the 1% annual chance flood for 2070, accounting for 40 inches of sea level rise or the “High” sea level rise scenario). See precedents section below for links and further details.

## Summary of Approaches

Table 5 summarizes the three proposed approaches, including a subset of potential advantages and disadvantages for each. While the third approach requires additional flood modeling, it has a number of advantages that make it the recommended approach.

### Summary of Approaches for Delineating Boundaries

Approach	Approach 1. Sea Level Rise Scenarios	Approach 2. FEMA Flood Zones	Approach 3. Future SFHA, accounting for SLR
Tier 1 Boundary	Inundation area for the Intermediate sea level rise scenario for 2100	Inundation area for the present day 0.2% annual chance flood	Inundation area for future (e.g., 2075 or 2100) 1% annual chance flood under the Intermediate scenario for sea level rise (or see recommended variant)
Tier 2 Boundary	Inundation area for the High sea level rise scenario for 2100	Inundation area for the High sea level rise scenario for 2100	Inundation area for future (e.g., 2075 or 2100) 0.2% annual chance flood under the Intermediate scenario for sea level rise
Advantages	<ul style="list-style-type: none"> <li>Boundaries account for future sea level rise</li> <li>Geospatial data exists (but see note below)</li> </ul>	<ul style="list-style-type: none"> <li>Boundaries account for storm hydrodynamics and probabilities</li> <li>Geospatial data exists (for Tier 1) and is already regulatorily enforceable under NFIP floodplain management regulations</li> <li>The 0.2% flood zone aligns closely with inundation areas for the Intermediate sea level rise scenario so could serve as a (rough) proxy for flood risk from sea level rise</li> </ul>	<ul style="list-style-type: none"> <li>Boundaries account for storm hydrodynamics and probabilities as well as sea level rise projections</li> <li>Geospatial data would be based on hydrologic and hydraulic studies with a high level of technical credibility</li> <li>Boundaries would conceptually align with flood risk boundaries used for NFIP floodplain management regulations</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>Currently available geospatial data is derived using methodologies that result in a lower level of precision for planning</li> </ul>	<ul style="list-style-type: none"> <li>Boundaries represent present day flood risk, and do not account for sea level rise; Using the 0.2% annual chance flood zone is only a</li> </ul>	<ul style="list-style-type: none"> <li>Geospatial data does not currently exist, requiring new flood risk assessments</li> </ul>

	<p>purposes; Creating overlay zones informed by this data would require significant discretion from planning departments</p> <ul style="list-style-type: none"> <li>• Inundation zones do not account for storm probabilities or hydrodynamics</li> <li>• Boundaries for sea level rise scenarios are less conceptually aligned with methods for delineating flood risk in existing regulations for floodplain management</li> </ul>	<p>rough proxy for the effects of sea level rise</p> <ul style="list-style-type: none"> <li>• Flood zones from FEMA studies do not show an inundation zone that accounts for more worse-case projections (due to sea level rise) that would be relevant for the Tier 2 overlay</li> </ul>	
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**Table 5.** Summary of approaches for delineating boundaries for Tier 1 and Tier 2 resilience overlays.

## 2. Site-Scale: Resilient Site and Building Parameters

The cities' zoning, and specifically the resilience overlays discussed above, will set the parameters for resilient site and building design for new development and substantial redevelopment. In this section, we outline a number of the specific approaches to increasing the resilience of buildings and sites. The Cities may choose to set prescriptive or performance-based requirements, incentivize adaptive approaches, or offer voluntary guidelines. This variation will be based on the level of exposure to climate hazards, the magnitude of potential impact, and the degree to which the adaptation measure could contribute to the overall resilience of the city.

### 2.1. Overview of Zoning Mechanisms

Table 6 summarizes a range of zoning approaches, or mechanisms, commonly used for enforcing or guiding resilient building and site parameters.

**Overview of Zoning Mechanisms**

Type of Mechanism	Description	Example
Prescriptive requirements	A requirement that the building/site is built to a certain standard	<ul style="list-style-type: none"> <li>• Buildings must have a one-foot freeboard if in a Special Flood Hazard Area (Maine Floodplain Management Requirements)</li> </ul>

Performance-based requirements	A requirement that the building/site performs in a certain way; one common method is to require the building/site to meet certain point thresholds, whereby points can be earned through achieving certain standards or incorporating certain features	<ul style="list-style-type: none"> <li>• Development must contribute to public realm cooling, the mitigation of heat island effects, and a greener city by implementing several strategies to reduce heat from a menu of options to meet a set score (the “cool factor”) (Cambridge, MA “Cool Factor” Resilience Zoning)</li> <li>• Developers earn points for adopting resilient measures (e.g., for flood risk reduction, stormwater management, energy resilience, etc.); Developments must meet certain point thresholds based on size and type of development (Norfolk, VA Resilience Quotient System)</li> </ul>
Standards or guidelines	A set of standards and recommendations to encourage building owners to voluntarily adopt resilience building parameters	<ul style="list-style-type: none"> <li>• The Coastal Resilience Design Guidelines help residents and businesses assess their coastal flooding hazards, help in identifying design measures to reduce risks, and provide detailed and consistent standards for project reviews by BPDA and other City agencies (Boston Resilience Zoning Design Guidelines) (Note: Projects that undergo Large Project Review are required to provide planning responses for coastal flooding.)</li> </ul>
Incentives	Developments receive some sort of benefit or concession in exchange for integrating resilience parameters; These parameters could be prescriptive, performance-based, or points-based	<ul style="list-style-type: none"> <li>• A density bonus can be achieved for developments that implement any of the following actions: incorporate LID stormwater systems onsite; undertake or fund a stream restoration project within the subwatershed; achieve green building certification; construct a greenway trail with public use easement; retain at least 50% of soils in hydrologic groups A and B, as defined by USDA; protect wildlife habitat corridors of at least 100 feet wide; among other actions (James City County, VA Zoning Code).</li> </ul>

**Table 5.** Summary of zoning mechanisms for enforcing or guiding resilient zoning parameters.

## 2.2. Resilient Building and Site Parameters

Below are three different resilience zoning models based on precedents from other cities that could inform Portland and South Portland's resilience zoning approach. We envision the models as additive in contributing to the resilience of the cities, and suggest a way that all three models could be combined in one framework.

### **Prescriptive Requirements: Building Freeboards**

The NFIP requires structures within the 1% annual chance floodplain to be at or above the base flood elevation (BFE).<sup>5</sup> Maine floodplain management standards require a one-foot freeboard<sup>6</sup> above the BFE. Many Maine communities have chosen to exceed that standard. For example, York requires a two-foot freeboard for all development in the 1% annual chance flood zone; Saco requires a three-foot freeboard for all development in the 1% annual chance flood zone; and Damariscotta requires a three-foot freeboard in tidal areas (e.g., V and VE zones) and a two-foot freeboard in non-tidal areas (e.g., AE zones). Maine communities are able to design their own floodplain management standards as long as they meet or exceed state standards. It's recommended that Portland and South Portland implement higher freeboard standards within the current 1% annual chance flood zone (e.g., three feet), and consider extending freeboard requirements to the full area designated under the Tier 1 flood resilience overlay (areas with the highest flood risk).

### **Performance-Based Requirements: "Cool Factor"**

The Cambridge, MA Resilience Zoning Task Force has proposed a strategy for ensuring that future development helps to mitigate the heat island effect in the city and contribute to cooling in the public realm. Under this scheme, development is required to meet a "cool factor" which is calculated based on points received for integrating features such as green roofs, cool roofs, vegetation, tree canopy, shading structures, and paving with specified solar reflectance indices. The points for each feature are calculated based on the square footage of that feature multiplied by a "multiplication factor." The multiplication factor is based on the relative effectiveness of the strategy in contributing to cooling (e.g., shade trees have a higher factor than turf grass), as well as other co-benefits (e.g., green roofs and vegetation have higher factors because of their added stormwater management benefits). Cambridge also has added a feature that gives extra points for if and when cooling features are within twenty feet of the public right of way, thereby contributing to cooling the public realm. The total square footage of the cooling features, multiplied by the multiplication factors, is then divided by the total square footage of the site to give a consistent measurement across different sized sites. By weighting each of the strategies, the "cool factor" can contribute to a number of city resilience benefits such as preserving larger existing trees, absorbing stormwater, and shading the public realm.

### **Performance-Based Requirements: Resilient Quotients for Development Review**

Norfolk, VA has implemented a Resilient Quotient as part of their development review process. New development and substantial redevelopments are required to meet certain point totals, based on the type and size of development. Points must be earned across three categories: Risk Reduction, Stormwater Management, and Energy Resilience, with at least one to two points (depending on the size of the project)

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<sup>5</sup> FEMA defines the base flood elevation (BFE) as the elevation above sea level to which the flood is expected to rise during the base flood. The base flood is the 1-percent annual chance flood or 100-year flood.

<sup>6</sup> FEMA defines the freeboard as a factor of safety or a buffer (of extra elevation on a building) between the predicted base flood elevation levels (BFE) and a building's lowest occupiable floor for residential uses, or dry floodproofing for non-residential uses.

coming from each category. Norfolk’s Resilience Quotient also offers a compliance path for development of single-family homes. This points-based system accounts for the fact that there are ultimately many ways that new development can increase the resilience of their building or site, and that the best approaches will likely vary, depending on the size of the development and the type of use. Developments are encouraged to address specific resilience challenges, while allowing for flexibility in the approach.

Table 6 summarizes a set of resilient building and site parameters that could become part of a resilience quotient for development review. The list draws on the precedents mentioned above as well as a number of other resources, summarizing a subset of parameters that we think would be most effective at achieving resilience goals for Portland and South Portland. It should be noted that this is no means an exhaustive list, and the specifics of each parameter (as well as the points allocated) would need be crafted and vetted by city departments to ensure that it best facilitates the design, review, and construction of resilient new development.

A significant opportunity for this model is that new construction could be required to earn points within specific categories based on the resilience overlay in which they are located. New development within the Tier 1 overlay (area of highest flood risk), for example, could be required to earn points by meeting one of the conditions under “Flood-resilient building form,” thereby meeting elevation requirements under the NFIP. Development in this zone could also be required to achieve the most points across the other flood resilience parameters. Development outside areas with flood risk could have much more flexibility in choosing how the project meets its resilience points threshold. The Cities may also consider offering an exemption for exemplary building performance (e.g., net zero buildings or passive house), as long as the building meets any necessary flood resilience requirements.

### Resilient Building and Site Parameters

Parameter	Methods for Achieving the Parameter	Notes
Component 1: Resilience to flooding from storms and sea level rise		
Flood-resilient building form	<ul style="list-style-type: none"> <li>a) Elevate on open foundation (applicable for buildings in VE or coastal A flood zones)</li> <li>b) Elevate on solid foundation with filled subgrade space (applicable for buildings not exposed to wave action)</li> <li>c) Elevate on fill (applicable for buildings not exposed to wave action)</li> <li>d) Wet floodproofing, which allows floodwaters to enter and exit portions of a building that are not used for living space (applicable for non-residential)</li> <li>e) Dry floodproofing, which inhibits water from entering a space (applicable for non-residential buildings in areas with low flood elevations and structures that can withstand hydrostatic and hydrodynamic loads from flooding)</li> </ul>	<p>Developments could be instructed to choose one of these options and to meet a specific elevation (e.g., 1-3 feet above BFE depending on site risk) in alignment with city design guidelines (see the Boston Resilience Design Guidelines for an example)</p> <p>Meeting this category could be required for areas with high flood risk, and optional for areas that are at a lower risk of flooding.</p>



<p>Flood-resilient critical utility systems</p>	<ul style="list-style-type: none"> <li>a) Elevate electrical and mechanical equipment on pedestals or platforms above flood elevations</li> <li>b) Relocate electrical and mechanical equipment to a higher floor or roof</li> <li>c) Protect electrical and mechanical equipment in place through anchoring and dry floodproofing (to be used only if options a and b are not feasible)</li> </ul>	<p>See box above (Notes for flood-resilient building form).</p>
<p>Flood-resilient building and landscape systems</p>	<ul style="list-style-type: none"> <li>a) Include flood-damage resistant materials, based on NFIP classifications, in areas that may be exposed to floodwaters (applicable for non-residential)</li> <li>b) Flood-proof elevators by protecting or relocating vulnerable motors and controls, protecting the elevator cab, and providing backup power (applicable for buildings with elevators)</li> <li>c) Incorporate backup water management systems including sump pumps or backflow preventers</li> <li>d) Design flood-tolerant landscapes using materials that will not corrode with saltwater and plant species that can best withstand floods and saltwater inundation; prepare landscape maintenance plans for flushing plant-toxic salts from soils with water and soil amendments</li> <li>e) Secure large site objects (e.g., fuel tanks, rainwater cisterns, benches, bike racks) to prevent mobilization of debris and/or release of hazardous material</li> </ul>	<p>Buildings within flood-risk areas could get resilience points for meeting these conditions.</p>
<p>Component 2: Managing stormwater from higher intensity rain events</p>		
<p>Stormwater capture, infiltration, and evapotranspiration</p>	<ul style="list-style-type: none"> <li>a) Capture, infiltrate, and/or evapotranspire the first 1" of rainfall from 100% of impervious area onsite and 0.4" from all pervious surfaces, employing vegetated systems to the fullest extent practicable</li> <li>b) Capture, infiltrate, and/or evapotranspire the first 1.5" of rainfall from 100% of impervious area onsite and 0.4" from all pervious surfaces, employing vegetated systems to the fullest extent practicable</li> <li>c) Capture, infiltrate, and/or evapotranspire the first 2" of rainfall from 100% of impervious area onsite and 0.4" from all pervious surfaces, employing vegetated systems to the fullest extent practicable</li> </ul>	<p>Different point allocations would be awarded for the various tiers. The cities could alternatively specify infiltration based on meeting the volume of particular design storms. The primary goal would be to award points for achieving thresholds above thresholds that are required in the stormwater ordinances.</p>

Component 3: Reducing the heat island effect and cooling the public realm

Planting	<ul style="list-style-type: none"> <li>a) Incorporate lawn or turf area with a minimum of 8" soil depth</li> <li>b) Incorporate small plantings with herbaceous or woody plants less than two feet tall at maturity with a minimum of 18" soil depth</li> <li>c) Incorporate large plantings with herbaceous or woody plants more than two feet tall at maturity with a minimum of 24" soil depth</li> </ul>	Points could be allocated based on the percent of site area, and weighted based on relative contributions to cooling with (a) having the smallest cooling effect and (c) the largest.
Green roofs	<ul style="list-style-type: none"> <li>a) Include a green roof with at least 4" of soil depth</li> <li>b) Include a low-intensive green roof with plants less than two feet tall at maturity with a minimum of 18" soil depth</li> <li>c) Include an intensive green roof with plants over two feet tall at maturity with a minimum of 24" soil depth</li> <li>d) Include a green roof (either a, b, or c) in addition to solar photovoltaic installation to improve the outputs and effectiveness of both systems</li> </ul>	Points could be allocated based on the percent of site area, and weighted based on relative contributions to cooling with (a) having the smallest cooling effect and (d) the largest.
Tree canopy	<ul style="list-style-type: none"> <li>a) Plant small tree species (i.e., canopy spread of 8' to 15', 1" caliper) with a minimum of 600 cu. ft. of soil per tree</li> <li>b) Plant medium tree species (i.e., canopy spread of 16' to 21', 2" caliper) with a minimum of 700 cu. ft. of soil per tree</li> <li>c) Plant large tree species (i.e., canopy spread of 25' to 30', 2.5" caliper) with a minimum of 800 cu. ft. of soil per tree</li> <li>d) Preserve large existing trees on site (i.e., 20' or greater in height)</li> </ul>	Points could be allocated based on the percent of site area, and weighted based on relative contributions to cooling with (a) having the smallest cooling effect and (d) the largest.
Hardscape and structures for heat mitigation	<ul style="list-style-type: none"> <li>a) Install a cool roof with solar reflectance values in line with LEED V4 requirements</li> <li>b) Incorporate paving with a solar reflectance index (SRI) of 39 or higher (in line with LEED V4 requirements)</li> <li>c) Incorporate shade structures with a solar reflectance index (SRI) of 39 or higher (in line with LEED V4 requirements)</li> </ul>	Points could be allocated based on the percent of site area. A cool roof should be awarded lower point values than a green roof to account for the much larger range of benefits created from a green roof.

Component 4: Soil Health		
Soil Structure and Content	<p>Meet healthy soil standards through one of four options:</p> <ul style="list-style-type: none"> <li>a) Leave native soil and vegetation undisturbed and protect from compaction during construction</li> <li>b) Amend existing site topsoil or subsoil on site</li> <li>c) Remove and stockpile existing topsoil during grading, reapply, and amend in place</li> <li>d) Import topsoil mix, including compost, to achieve appropriate pH and sufficient soil organic matter and depth</li> </ul>	<p>Points would be allocated for achieving healthy soils through one of the four methods. Healthy soils would be based on specifications, including depth of topsoil (e.g., 6 inches), soil organic matter (e.g., greater than 5%), and achieving a pH suitable for the plantings on site.</p>
Component 5: Resilience to storms and power outages		
Passive survivability	<ul style="list-style-type: none"> <li>a) Demonstrate that the building meets passive survivability standards (in line with LEED V4 requirements; one compliance path includes passive house certification)</li> </ul>	
Energy resilience	<ul style="list-style-type: none"> <li>a) Provide reliable onsite backup power to meet critical loads (in line with LEED V4 requirements)</li> <li>b) Establish operating procedures for how the project will handle loss of power, transition to a backup source of power, and transition back to normal operation</li> </ul>	<p>Greater point values should be awarded to backup power systems that help advance the cities' carbon mitigation goals (e.g., bi-modal solar-electric systems with battery storage, combined heat and power)</p>
Resistance to high winds	<ul style="list-style-type: none"> <li>a) Design buildings and associated structures to withstand the minimum wind loads as outlined in the Maine building codes</li> <li>b) Secure site equipment, landscape features, awnings, and other appendages to minimize mobilization and debris</li> </ul>	
Component 6: Community resilience		
Amenities for social resilience	<ul style="list-style-type: none"> <li>a) Integrate a community room that can serve as a resilience hub (offering space for supporting social resilience; backup power for cell phone charging, medication refrigeration, and AC; and space to provide emergency information)</li> <li>b) Provide community garden space (which may be located as a rooftop garden) for residents and for</li> </ul>	<p>Option (a) is application for larger-scale developments, particularly mixed-use or residential. Option (b) is applicable for mixed-use or residential development.</p>

	urban gardening purposes at a ratio of 50 square feet per residential dwelling unit	
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**Table 6.** Resilient building and site parameters. Concepts drawn primarily from the Boston, MA Coastal Flood Resilience Design Guidelines (Draft 2019); the Norfolk, VA Building a Better Norfolk zoning ordinances (2020); the Cambridge, MA Resilience Zoning Task Force materials (2019); Somerville Zoning Ordinance (2019); King County, Washington Post-Construction Soil Standard (2005); and the Vermont Post Construction Soil Depth and Quality Standard (2017). See precedents below for further details.

### 3. Precedents

Below is a short list of precedents that have been referenced in the sections above, or that could provide further helpful reference.

#### **Boston, MA Resilience Design Guidelines**

Resource: Coastal Flood Resilience Design Guidelines<sup>7</sup>

Description: The Design Guidelines outline a resilience zoning overlay based on the 2070 1% annual chance flood and offer a set of design guidelines for adaptation approaches—also offering a consistent standard for the city’s development review process. Currently only projects subject to Large Project Review are required to demonstrate that they have met the resilience guidelines.

#### **Boston, MA Guidelines for Public Right of Ways**

Resource: Climate Resilience Design Standards and Guidelines for Protection of Public Rights of Way<sup>8</sup>

Description: The Standards and Guidelines are a resource for engineers and designers to serve as guidance when protecting the public right-of-way using flood barriers. Flood barriers include, for example, vegetated berms, seawalls, raised roadways, and deployable flood barriers.

#### **Cambridge, MA Cool Points**

Resource: Climate Resilience Zoning Task Force Technical Presentation on Resilient Zoning<sup>9</sup>

Description: This presentation summarizes a set of draft approaches for implementing resilience zoning in Cambridge, including the structure for the “Cool Points” system to address the heat island effect. With this presentation (see link in footnote) are a number of other resources including a PDF showing how the Cool Points would be calculated.

<sup>7</sup> City of Boston, MA. (2020, draft). Coastal Flood Resilience Design Guidelines. Retrieved from <http://www.bostonplans.org/getattachment/d1114318-1b95-487c-bc36-682f8594e8b2>

<sup>8</sup> City of Boston, MA (2018). Climate Resilience Design Standards and Guidelines for Protection of Public Rights of Way. Retrieved from [https://www.boston.gov/sites/default/files/imce-uploads/2018-10/climate\\_resilient\\_design\\_standards\\_and\\_guidelines\\_for\\_protection\\_of\\_public\\_rights-of-way\\_no\\_appendices.pdf](https://www.boston.gov/sites/default/files/imce-uploads/2018-10/climate_resilient_design_standards_and_guidelines_for_protection_of_public_rights-of-way_no_appendices.pdf)

<sup>9</sup> City of Cambridge, MA. (2019). Climate Resilience Zoning Task Force Technical Presentation on Resilient Zoning. Retrieved from <https://www.cambridgema.gov/~media/Files/CDD/ZoningDevel/OtherProjects/resilienttaskforce/crtzfinalpresentation20191010.pdf>

### **Enterprise Community Partners Multifamily Building Resilience**

Resource: Ready to Respond: Strategies for Multifamily Building Resilience<sup>10</sup>

Description: This report offers resilience retrofit strategies for owners of multifamily buildings to make their properties more resilient against the effects of extreme weather events (along with guidance for assessing climate risk and identifying the appropriate strategy).

### **James City County, VA Resilience Zoning**

Resource: James City County, VA County Code<sup>11</sup>

Description: James City County incentivizes a number of resilience (and sustainability) parameters—including stormwater management, stream restoration, habitat preservation, green building certification—in exchange for density bonuses.

### **King County, Washington Soil Standards**

Resource: Achieving the Post-Construction Soil Standard

Description: King County requires new construction to meet post-construction soil standards with respect to topsoil depth, soil organic matter, pH, and amendment practices. This resource is the guidebook for how to meet the county's standards.

### **Norfolk, VA Resilience Zoning**

Resource: Building a Better Norfolk: A Zoning Ordinance for the 21<sup>st</sup> Century<sup>12</sup>

Description: The Norfolk, VA zoning code includes a whole-city approach for resilience zoning through a “coastal resilience overlay” and an “upland resilience overlay.” The Norfolk zoning code also implements a Resilience Quotient for encouraging resilient building and site design.

### **Somerville Green Score**

Resource: Somerville Zoning Ordinance<sup>13</sup>

Description: The updated Somerville, MA zoning code (adopted in 2019) requires new construction to meet a baseline “Green Score” that is measured as a combined weighted value of a number of urban landscape elements that help to manage stormwater, filter pollutants, reduce the urban heat island effect, sequester carbon dioxide, and improve air quality.

### **Vermont Post-Construction Soil Standards**

Resource: Vermont Post-Construction Soil Depth and Quality Standard<sup>14</sup>

Description: The State of Vermont requires post construction soil standards for topsoil depth, minimizing compaction, and retaining soil organic matter. This resource is the worksheet that must be submitted with new construction projects.

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<sup>10</sup> Enterprise Community Partners. (2015). Ready to Respond: Strategies for Multifamily Building Resilience. Retrieved from <https://www.enterprisecommunity.org/resources/ready-respond-strategies-multifamily-building-resilience-13356>

<sup>11</sup> City of James City County. County Code. Retrieved from [https://library.municode.com/va/james\\_city\\_county/codes/code\\_of\\_ordinances?nodeId=CD\\_ORD\\_CH24ZO\\_ARTVDI\\_DIV14PLUNDEDIPU](https://library.municode.com/va/james_city_county/codes/code_of_ordinances?nodeId=CD_ORD_CH24ZO_ARTVDI_DIV14PLUNDEDIPU)

<sup>12</sup> City of Norfolk, VA. (2020). Building a Better Norfolk: A Zoning Ordinance for the 21<sup>st</sup> Century. Retrieved from <https://www.norfolk.gov/DocumentCenter/View/35581/Adopted-Zoning-Ordinance?bidId=>

<sup>13</sup> See page 447 of City of Somerville (2019). Somerville Zoning Ordinance. Retrieved from <https://www.somervillezoning.com/>

<sup>14</sup> Vermont Post Construction Soil Depth and Quality Standard (2017). Retrieved from <https://anweb.vt.gov/PubDocs/DEC/ENB/STORM/2498-Attachment%203%20-%20Worksheets.pdf>