2020

BALTIMORE CITY
NUISANCE FLOOD PLAN

BALTIMORE CITY
DEPARTMENT OF PLANNING
OFFICE OF SUSTAINABILITY

Baltimore Office of Sustainability
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DISCLAIMER

This Nuisance Flood Plan was prepared by the City of Baltimore Department of Planning Office of Sustainability using Federal funds under award number NA18NOS4190145 from NOAA, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

EXECUTIVE SUMMARY

BALTIMORE CITY NUISANCE FLOOD PLAN

BALTIMORE CITY DEPARTMENT OF PLANNING | OFFICE OF SUSTAINABILITY

BACKGROUND

Maryland lawmakers, local and state governments, and citizens recognize that tidally-driven flood events are happening with more frequency. While "nuisance flooding" may not pose a serious threat or result in major damage, it interrupts daily routines and can negatively impact businesses. The definition of nuisance flooding, for the purpose of this plan and in accordance with §3-1001 of the Natural Resource Article of the Maryland Annotated Code, is "*high tide flooding that causes a public inconvenience.*" The legislation requires that the Nuisance Flood Plan include three critical components: 1) Inventory of known flood hazard areas where tidal nuisance flooding occurs; 2) Identification of flood thresholds/ water levels/ conditions that lead to tidal nuisance flooding; and 3) A mechanism to document tidal nuisance flood events from 2020 to 2025. Baltimore City's Nuisance Flood Plan meets and exceeds the State's requirements.

SEA-LEVEL RISE TRENDS & PROJECTIONS

For a variety of reasons, including the increase in global temperatures, the world's sea-levels have been rising over the past 100 years. In Baltimore, the NOAA's tidal gauge 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. Data shows that sea-level rise has a direct effect on the number of nuisance flood events across the globe. Furthermore, NOAA states that high-tide flooding is now 300% to more than 900% more frequent along U.S. coastlines than it was 50 years ago. And although relative sea-level rise is a gradual process, Baltimore is already experiencing some if its negative impacts.

IMPACTED COMMUNITIES

In order to categorize and define the nuisance flood areas within Baltimore, six flood zones were created based on location, topographical features, land use and zoning type, and/or vulnerability indexes. A list of critical infrastructure and transportation assets were identified and for each of the zones. The information is made available in table and map formats. Additionally, tide elevation thresholds were developed for each nuisance flood zone based on the Climate Change Vulnerability application (MDOT's tool).

RANGE & DEPTH OF NUISANCE FLOODING

An assessment of the range and depth of nuisance flooding under current conditions (based on 2015 data), and 2050 and 2100 projections was also performed. The MDOT's Climate Change Vulnerability application was utilized to identify the geographic range and depth of inundation in the six nuisance flood zones. The projections include the area that currently experiences nuisance flooding, and the expected increases in 2050 and 2100. Maps and summary tables are provided for each of the six zones.

EQUITY ASSESSMENT

Equity considerations have been assessed to determine whether nuisance flooding imposes negative impacts over underserved communities in Baltimore. Using an "equity lens" acknowledges societal inequities that are long-standing and that have their roots in generations of unfair structural barriers, and can help inform the selection and prioritization of future mitigation projects.

RESPONSE

City agencies that respond to nuisance flood events were interviewed and a summary of the response process was prepared. The agencies include the Department of Public Works, Department of Transportation and the Baltimore City Fire Department.

IMPACTS & MITIGATION

The most common impacts of nuisance flood include: 1) Risks to public health and safety, 2) Property damage, and 3) Impacts to businesses located near the waterfront. The plan lists mitigation strategies proposed in the 2018 Baltimore City Disaster Preparedness and Planning Project (DP3) that have the potential to mitigate the intensity and extent of nuisance flooding. Additional mitigation strategies utilized by other jurisdictions and new tidal flooding mitigation strategies are also included in the plan.

EVENT TRACKING & CATALOGING

The nuisance flood events that happen from 2020 to 2025 will be identified using outputs from the 3-1-1 Service and the MyCoast application. During the process trial period (2020 to 2025), the data will be collected from each source on a trimestral base; and will require data analysis, validation and cataloguing.. The flooding occurrence data received from each source will be validated based on two primary parameters: location of the event and tide height data. The validated data outputs (from the 3-1-1 Service and the MyCoast application) will be consolidated in an internal data repository of nuisance flood events, and shared with the State. Excel is the software selected as the data repository tool, and the spreadsheet will be known as the Nuisance Flood Tracking Sheet.

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1 INTRODUCTION

Flooding is the most common natural disaster experienced in the United States, and the Baltimore area is no exception. Flooding can be widespread or localized and may develop quickly or over a larger span of time. Some of the various causes of flooding include heavy precipitation events; dam failures; excessive runoff originating from higher elevations (sheet flow); coastal impacts, such as elevated tide heights and storm surges; or the combination of two or more flooding factors. The effects of flooding can lead to life safety concerns, public health issues, in addition to property damage, infrastructure damage, and financial loss.

FLOOD

Any high flow, overflow, or inundation by water which causes damage. In general, this would mean the inundation of a normally dry area caused by an increased water level in an established watercourse, or ponding of water, **that poses a threat to life or property.**

Source: National Climatic Environmental Information (NCEI)

Although flooding is commonly associated with heavy rainfall, or precipitation events, another type of flooding is becoming more prevalent in the Baltimore area. Nuisance floods, or "sunny day floods," are flood events that are not necessarily linked to high precipitation amounts, but lead to "public inconveniences" (NOAA, 2020). The impacts of nuisance flooding may generate area closures, standing water that blocks access to homes and businesses, and impacts on pedestrian and road traffic flow. Additionally, nuisance floods can lead to significant trash accumulation following water recession. This can impact area aesthetics and is costly to clean-up, as public works crews must remove the debris and diverge pedestrian traffic away from the affected spaces. These disruptive flood events overwhelm storm water management systems and cause financial burdens by placing additional stress on local government agencies and businesses located at or near the waterfront.

NUISANCE FLOOD

The definition of nuisance flooding, in accordance with §3-1001 of the Natural Resource Article of the Maryland Annotated Code, is "**high tide flooding that causes a public inconvenience**."

Fells Point Road Closure

Nuisance floods can be caused by a variety of weather and natural system events. Astronomically-influenced extreme tide cycles, long-duration wind events, off-shore storm systems that create tidal surges, and tidal flooding in conjunction with a heavy precipitation event can lead to nuisance floods. Until recently, nuisance floods have occurred, on average, less than 10 days per year in the Baltimore area (UMCES, 2018). However, due to climate change and sea-level change, The National Oceanic and Atmospheric Administration (NOAA) predicts that Baltimore will experience 15-25 nuisance flood events by 2030 and could see as many as 50-160 events by 2050 (NOAA, 2019).

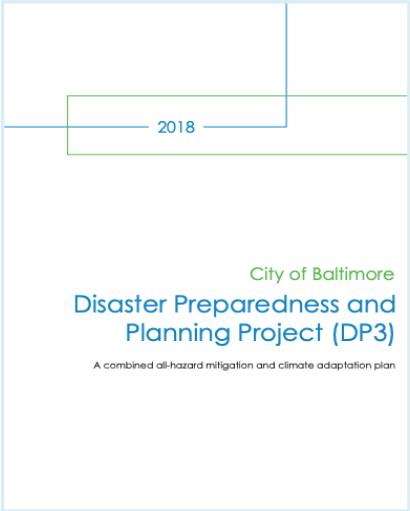
For that reason, it is expected that the effects of nuisance flooding will place substantial pressure on infrastructure and emergency safety resources. Public health and economic impacts will increase, and jurisdictions will be compelled to develop adaptive strategies in response to increased flood events.

In Baltimore, there are several areas of concern when it comes to nuisance flood events. Lower Fells Point and areas along the Inner Harbor promenade have historically been the most impacted areas during nuisance floods. However, as sea-levels continue to rise, other areas in Canton, Locust Point, Middle Branch, Port Covington, Westport, Fairfield, and Curtis Bay have been identified as vulnerable locations. Residential, commercial, industrial, and government properties have been affected as a result of nuisance floods, and new strategies to address its impacts are necessary.

2 BACKGROUND

Maryland Senate Bill (SB) 1006, Sea-level Rise Inundation and Coastal Flooding—Construction, Adaptation, Mitigation, and Disclosure, mandates that local jurisdictions in Maryland experiencing nuisance flood events develop and establish a responsive action plan by **October 1, 2020**. The nuisance flood plan shall be developed in consultation with the Maryland Department of Natural Resources and submitted to the Maryland Department of Planning for approval. Furthermore, the plan must be published on the local jurisdiction's website and updated at least every five years.

Nuisance flood planning for Baltimore City was developed as an addendum to **Baltimore's Disaster Preparedness and Planning Project (DP3)**, which was last updated in December 2018. The DP3 provides the following goals and objectives:



- Protect the health, safety, and welfare of Baltimore City residents and visitors.
- Prevent damage to structures, infrastructure, and critical facilities.
- Build resilience and disaster prevention and planning into all programs, policies, and infrastructure.
- Enhance the City of Baltimore's adaptive capacity and build institutional structures that can cope with future conditions that are beyond past experiences.
- Promote hazard mitigation and climate adaptation awareness.
- Achieve an even higher rating in the Community Rating System (CRS) program.

Sea-level rise, which has direct effects on the frequency of nuisance flood events in Baltimore, has been assessed as a high-risk concern in the City, especially as it relates to the potential impacts expected. According to data provided by NOAA, the main factors that influence sea-level change are listed below (NOAA, 2020).

Sea-level has risen over 6 inches nationally since 1950, but recently, its rate of increase has accelerated. In the last five years, sea-level has risen 66% faster than the historical rate and is now rising by an average of one inch every five years. *Source:* NOAA Tides and Currents (www.tidesandcurrents.noaa.gov)

While it took 60 years for the sea-level to rise about 6 inches nationally, scientists now forecast that in just the next 20 years, the sea will have risen by another 6 inches.

Sources: Sea-level rise from the late 19th century to the early 21st century (link.Springer.com) & NOAA Intermediate Projections

Factors influencing short-term variations in sea-level:

- Waves
- Tidal action
- Specific flood events
- Coastal storms

Factors influencing long-term variations in sea-level:

- Seasonal weather patterns
- Earth's declination cycle
- Changes in coastal and Ocean circulation
- Vertical land motion
- El Nino circulation patterns
- Anthropogenic effects

3 SEA-LEVEL RISE PROJECTIONS

For a number of reasons, including climate change and an increase in global temperature, the world's sea-levels have been rising over the past 100 years. The Intergovernmental Panel on Climate Change (IPCC) released updated models in 2019 and it projects global mean sea-levels (GMSL) will most likely rise between 0.95 feet (0.29m) and 3.61 feet (1.1m) by the end of this century (IPCC, 2019). Moreover, there is a direct correlation between long-term sea-level rise and greenhouse gas (GHG) levels in our atmosphere. GHG directly affect absorption and infiltration rates of solar radiation, and thus, due to both natural and anthropogenic factors, contribute to the warming trends currently observed in both our atmospheric and oceanic temperatures.

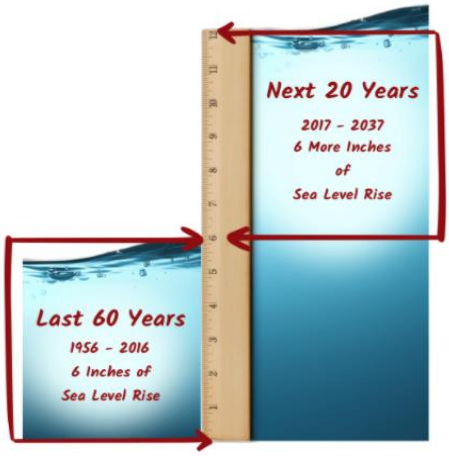
The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change.

The rate of **sea-level rise** is not the same all over the country. In some towns, the sea-level is rising much faster than the national average. On the **East Coast** and the Gulf Coast, the sea is rising by one inch every three years due to sinking land and a slowing Gulf Stream. On the West Coast, the sea-level is increasing at a slower pace than the national average because the land is actually rising due to shifting tectonic plates.

Source: Sealevelrise.org/forecast/

This increase in ocean and atmospheric temperatures are directly linked to the melting rates of both the Greenland and Antarctic ice sheets. A recent study (March 2020) states the Denman glacier, located in eastern Antarctica, has retreated 3 miles in the past 22 years. Additionally, the research in this study notes further glacial instability in the region that is directly linked to climate warming and ozone depletion. The potential exists for rapid retreat of sea ice in the region, and thus a further rise in sea-levels (AGU, 2020). Researchers from the University of California-Irvine, in response to this data, have suggested the complete melting of just the Denman glacier would eventually increase global sea-levels by 5 feet (UCI, 2020). Furthermore, this recent evidence suggests that if current melting trends continue as illustrated in the study, IPCC predictions of a "worst-case scenario" could be realized, which entails a 6.7" rise in sea-levels by 2100 (see below) (Nature, 2019).

Sea ice melt, along with thermal expansion in ocean waters due to higher atmospheric temperatures, are the two primary influential factors on sea-level rise. Figure 1 illustrates IPCC sea-level change projections based on various emission (GHG) reduction scenarios (RCP2.6-RCP8.5) (IPCC, 2019). RCP, or Representative Concentration Pathways, are four scenario-based paths created by the IPCC that could occur based on modeling predictions of various levels of atmospheric GHG. The RCPs are based on natural and anthropogenic contributions on GHG and expected changes that could occur. RCP2.6 would involve strict GHG reductions and seek aspirational goals set forth by the Paris Climate Agreement. This is unlikely to transpire. On the other end of the spectrum, RCP8.5 is based on emission levels continuing to rise through the 21st century, in addition to GHG reaching dangerous levels. This is also unlikely to occur due to new global restrictions and cooperation on GHG levels. However, undiscovered interruptions in natural feedback loops, in addition to recent study data (see above), could contribute to this higher-end modeling. In general, sea-level rise will fall somewhere between RCP2.6 and RCP8.5.



Sources: Sea-level rise from the late 19th century to the early 21st century (link.Springer.com) & NOAA Intermediate Projections

The IPCC estimates are generally considered conservative and typically consider the most likely scenarios to occur. In comparison, data released in NOAA's 2018 National Climate Assessment predicted GMSL rise to be higher than IPCC predictions (USGCRP, 2017). More recent data released by NOAA states that the rise in sea-levels has been accelerating more rapidly, especially since the early 1990s. Whereas sea-levels rose annually on average 0.6" from 1900-2005, they have risen on average 0.14" per year in the period 2006-2015. Figure 2 illustrates global sea-level rise from 1993-2018, in addition to contributing factors. NOAA states that even if the world follows a low greenhouse gas pathway, global sea-levels will likely rise at least 12 inches (0.3 meters) above 2000 levels by 2100. If we follow a pathway with high emissions, a worst-case scenario of as much as 8.2 feet (2.5 meters) above 2000 levels by 2100 cannot be ruled out (NOAA, 2019).

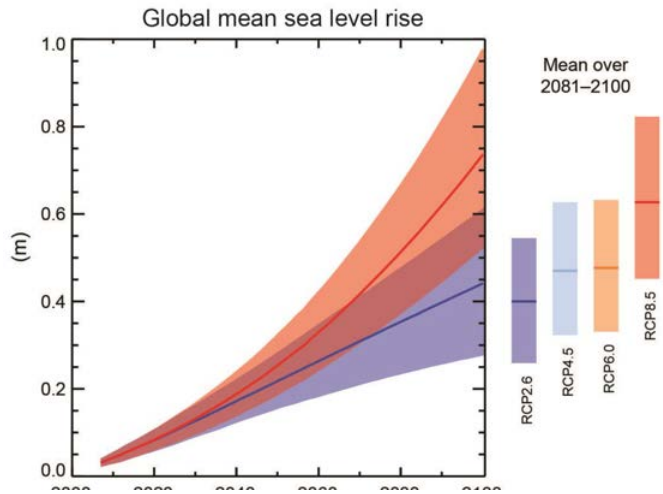


Figure 1: Global mean sea-level rise based on greenhouse gas concentration scenarios. (Source: IPCC Working Group I)

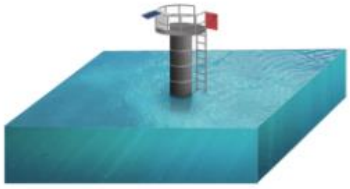
HOW DO SCIENTIST MEASURE SEA-LEVEL?

Scientist have three separate tools to measure the sea-level

BUOYS

SATELLITES

TIDAL GAUGES



The predictions on sea-level rise provided by both IPCC and NOAA are based on strong evidence and a variety of sources, including satellite imagery, tidal gauges, computer modeling and trends, and simple polar ice observations and measurements. On-going monitoring and observations, GHG reduction, and updated computer-based modeling will continue to be important in narrowing down how high sea-levels will rise.

NOAA has released data in 2020 illustrating global coastal sea-level trends as observed over the past 30 years. Figure 3 Illustrates sea-level trends at various East Coast tidal gauge stations. Changes in relative sea-level, either a rise or fall, have been computed at 142 long-term water level stations using a minimum span of 30 years of observations at each location. These measurements have been averaged by month, which removes the effect of higher frequency phenomena in order to compute an accurate linear sea-level trend (NOAA, 2019).

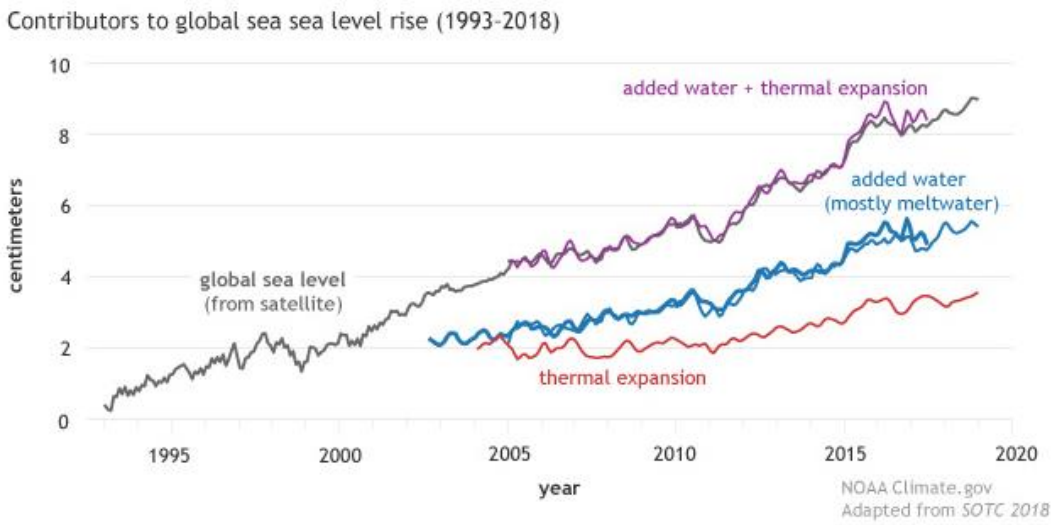


Figure 2: Contributors to global seal-level rise from 1993 to 2018. NOAA Climate.gov graphic, adapted from Figure 3.15a in *State of the Climate in 2018*. (Source: NOAA)

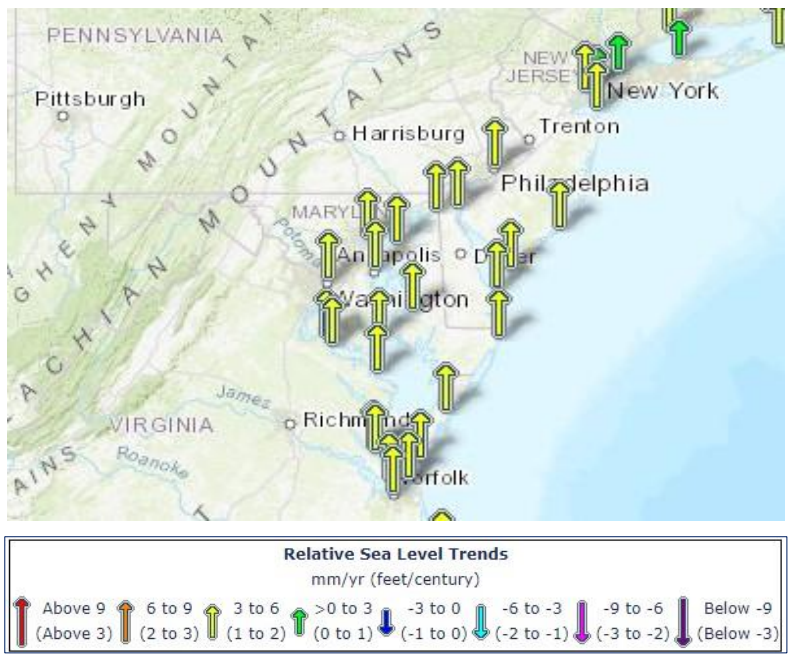


Figure 3: Relative sea-level trends as measured by NOAA for the East Coast of the United States over a 30-year period. (Source: NOAA)

Additional recent studies reveal that sea-level rise is accelerating faster than previously projected due to rapid polar ice sheet melting. Sea-level rise has been greater than anticipated along Mid-Atlantic coastlines, where the waters rise as the flow of the Gulf Stream slows. Furthermore, the United States Geological Survey references a recent study highlighting that sea-level rise will be intensified by continued land subsidence in the Mid-Atlantic region. Due to on-going ice sheet movement and groundwater withdrawal, land elevations have been shrinking in the region for some time. This trend is not expected to change (USGS, 2015; GSA, 2015). As seas continue to rise and land retreats and sinks, mean sea-levels and inundation will exponentially advance.

The rate of **sea-level rise** is not the same all over the country. In some towns, the sea-level is rising much faster than the national average. On the East Coast and the Gulf Coast, the sea is rising by one inch every three years due to sinking land and a slowing Gulf Stream. On the West Coast, the sea-level is increasing at a slower pace than the national average because the land is actually rising due to shifting tectonic plates.

Source: Sealevelrise.org/forecast/

3.1 LOCAL TRENDS

In Baltimore, NOAA's tidal gauge 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**. Statistics from 2018 show sea-level rise projections could range from 1.5 to 3 feet by 2050. Relative sea-level rise projections in Maryland range from 0.9 to 2.1 feet by 2050 and 2.1 to 5.7 feet by 2100 (DP3, 2018). Figure 4 illustrates observed sea-level rise at Baltimore's tidal gauge, along with future projections based on various scenarios. According to a 2018 report conducted by the University of Maryland Center for Environmental Science, there is a 66% probability of a 0.8-foot to 1.6-foot rise in sea-levels along coastal Maryland between 2000 and 2050 (UMCES, 2018). The projection is based on a modest reduction of current greenhouse gas emissions.

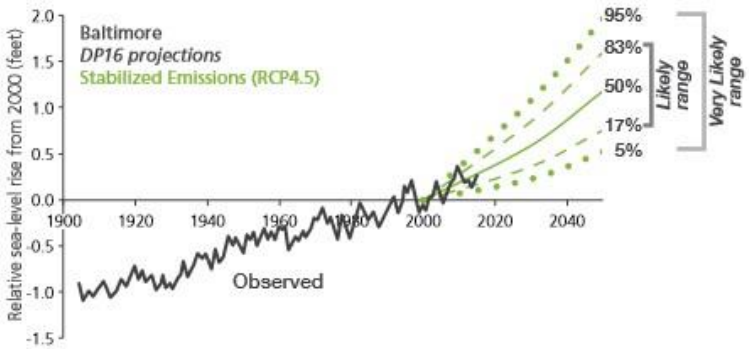


Figure 4: Observed relative sea-level rise at the Baltimore tidal gauge and probabilistic projection of relative sea-level rise through 2050 (Source: University of Maryland Center for Environmental Science, 2018

Figure 5 displays the monthly mean sea-level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea-level datum established by CO-OPS.

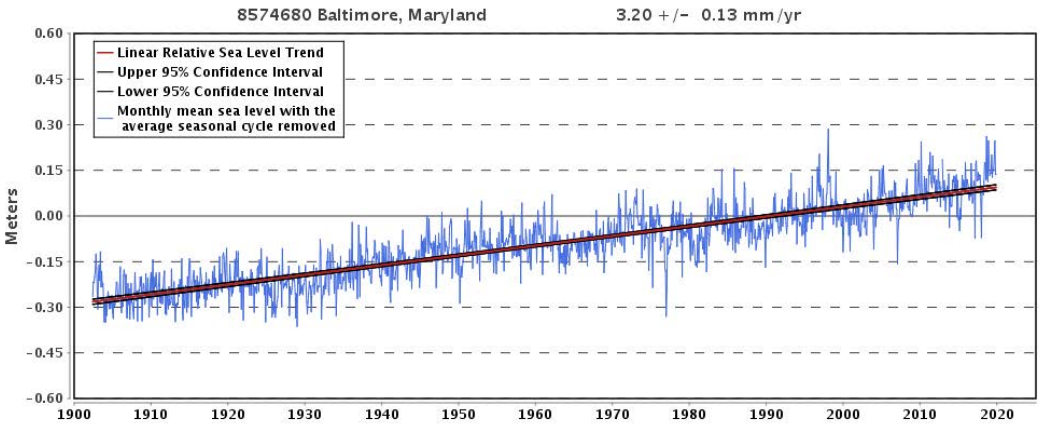


Figure 5: Monthly mean sea-level without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents as measured at Baltimore's tidal station (Source: NOAA)

Figure 6 shows data collected by NOAA from Baltimore's tidal station (8574680) located near Fort McHenry, established in July 1902. The station's annual-mean relative sea-level with its six regionalized sea-level rise scenarios plotted relative to a 1991-2009 baseline period as described in the report on Global and Regional Sea-level Rise Scenarios for the United States. The scenarios illustrated are based on greenhouse gas emission scenarios and their correlating effects on mean sea-level rise. Each of the scenarios exemplifies a specific set of scientific assumptions about 21st century GMSL. For example, the low scenario represents an amount about 5 cm above the extrapolated rate of the GMSL rise trend over the 20th century, while the high scenario represents an upper limit reflecting GMSL rise occurring under more extreme land-ice contributions, as modeled by Pfeffer et al. (2008). The two intermediate scenarios represent rise obtained from the upper-end of the projections from the IPCC Fourth Assessment Report, from climate models using the low-emissions B1 scenario (Intermediate-Low), and several semi-empirical based studies (Rahmstorf et al., 2007; Horton et al., 2008; Intermediate-High).

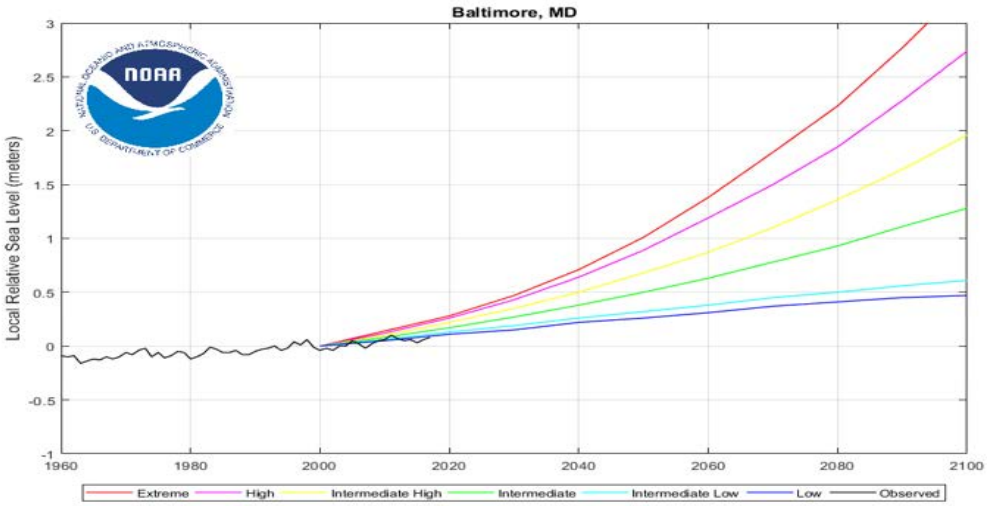


Figure 6: Baltimore tidal station's annual mean relative sea-level with its six regionalized sea-level rise scenarios plotted relative to a 1991-2009 baseline period (Source: NOAA)

Data shows that sea-level rise has a direct effect on the number of nuisance flood events across the globe. **NOAA states that high-tide flooding is now 300% to more than 900% more frequent along U.S. coastlines than it was 50 years ago** (NOAA, 2019). Although relative sea-level rise is a gradual process, its effects are already occurring in Baltimore, and observed events in the city show evidence of impacts caused rising sea-levels. Examples include increased frequencies of minor to moderate levels of coastal inundation caused high tide events, storm events that coincide with high tides, increasing rates of coastal erosion in non-bulkhead areas, and increased seawater intrusion into underground utilities that cause roadway inundation.

As directed by the Maryland Department of Natural Resources (DNR), the Nuisance Flood Plan is based on 2015 Mean Sea-levels with 10% annual storm risks. Although Baltimore City has developed long-term flood assessments on both 1% and 0.2% storm risk events in the DP3, **the purpose of this plan is to create short to medium-term strategies to identify and catalog the areas along Baltimore's coastline that are vulnerable to nuisance flooding, and mitigation strategies that can be deployed to address the impacts**. The plan does not include areas in the watershed that experience riverine flooding, as the response and mitigation strategies for riverine flooding are addressed by Baltimore's DP3 and the impacts observed by such flooding events often go beyond the status of nuisance.

As previously noted, nuisance flood events are predicted to increase significantly in the Baltimore area. Figure 7 illustrates observed and projected annual nuisance flood events for Baltimore. The figure indicates rapid growth of nuisance flood events is likely regardless of which emissions level scenario occurs over time. Although variations can be seen on an annual basis, the number of observed inundation events per year caused by high tide flooding has increased since 2000.

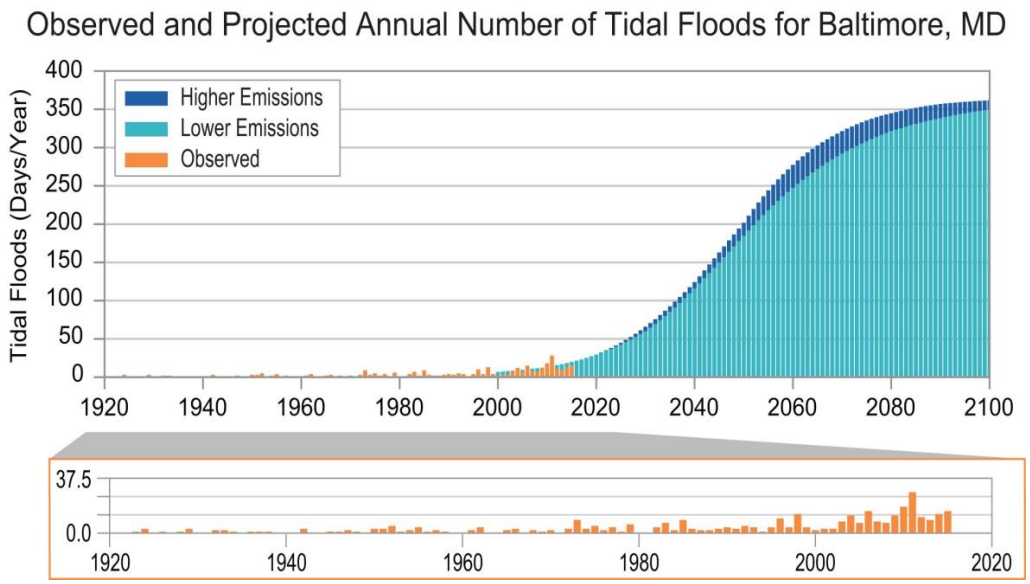


Figure 7: Number of tidal flood days per year for the observed record (orange bars) and projections for two possible futures: lower emissions (light blue) and higher emissions (dark blue) per calendar year for Baltimore, MD (Source: NOAA)

3.2 TYPES AND CAUSES OF NUISANCE FLOOD EVENTS

3.2.1 Tidal Event

Localized areas along Baltimore's shoreline may experience periodic tidal flooding several times per year as a result of astronomical influences, such as specific moon phases and perigean tides. Gravitational forces based on sun and moon positioning in correlation with the Earth's orbital position can cause tides that are higher than what is experienced during typical tidal cycles. Moreover, long-term precipitation cycles, like **El Niño**, along with dynamic ocean circulation patterns can influence tide heights. In combination with continuing land subsidence and other factors, these higher tides inundate land and property and cause nuisance events. Figure 8 is an image of nuisance flooding at Baltimore's Inner Harbor with the absence of precipitation.

EL NIÑO

El Niño is a climate cycle in the Pacific Ocean with a global impact on weather patterns. Forecasters declare an official El Niño when they see both ocean temperatures and rainfall from storms veer to the **east**. Experts also look for prevailing trade winds to weaken and even reverse direction during the El Niño climate phenomenon. These changes set up a feedback loop between the atmosphere and the ocean that boosts El Niño conditions.

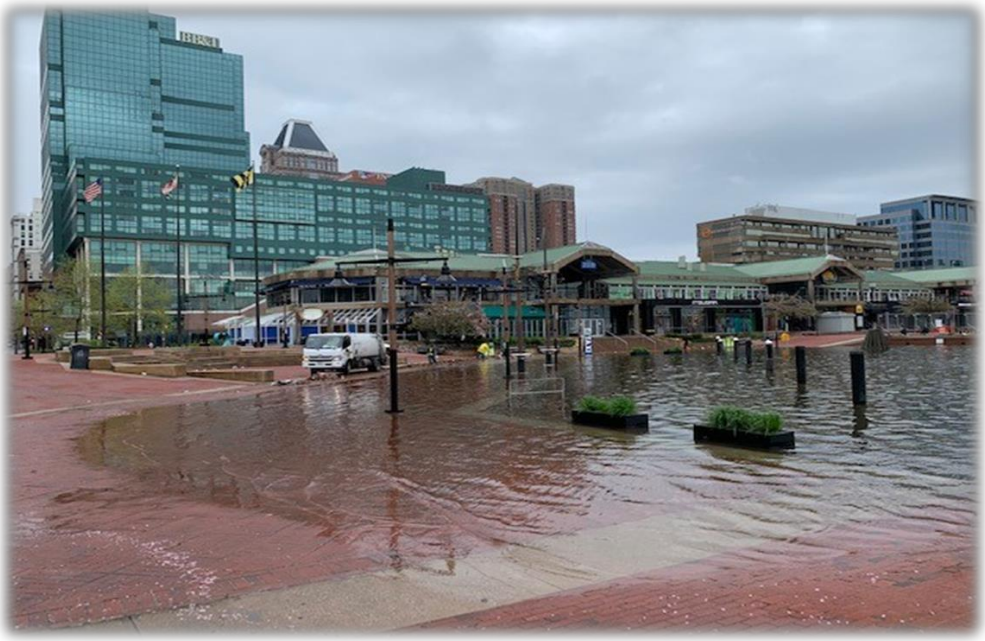


Figure 8: High tide inundation at Baltimore's Inner Harbor on 4/13/2020

3.2.2 Wind-Driven Tidal Event

Fetch, area of ocean or lake surface over which the wind blows in an essentially constant direction, thus generating waves. The term also is used as a synonym for fetch length, which is the horizontal distance over which wave-generating winds blow.

In the most straightforward way, fetch is just the maximum length of open water over which the wind can blow. ... Just as you see ripples on a drink or a bowl of soup when you blow on it, the wind creates ripples on the surface of the sea when it blows over that.

In some instances, nuisance flood events can be caused simply by wind direction in association with a high tide cycle. The duration and velocity of winds are significant factors that determine the severity of wind driven waves and swells. Additionally, the area of water over which the wind travels, or the **fetch**, is also an important element. For example, with a 30-mph wind for 8 hours over a fetch of 16 miles, a wave with a height of over 4 feet can be produced. With strong, focused winds concentrated in a specific direction, water currents are driven onto land and property at specific heights. As high tide water levels rise, significant winds can cause water inundation on shorelines and over seawalls. Piers, roads, walkways, buildings, and drainage systems can all be affected by these conditions. Figure 9 is an illustration of wind-driven water and its effect on sea-level and tides.

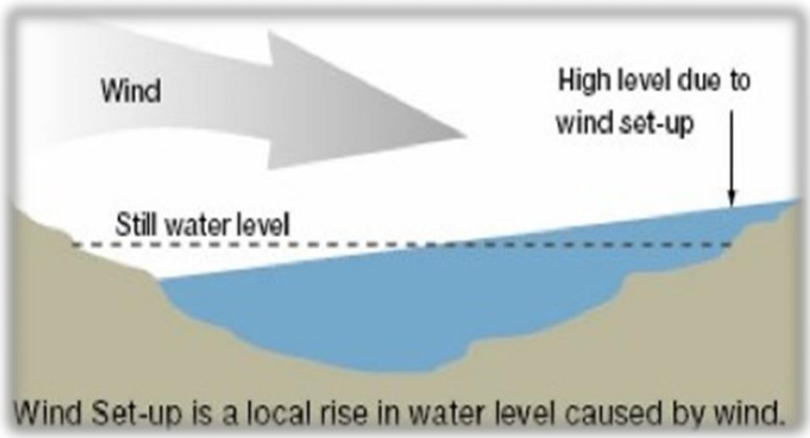


Figure 9: Illustration of wind-driven water that leads to nuisance flooding (Source: Michigan Technological University)

3.2.3 Off-Shore Storm Surge

An additional cause of nuisance flooding can occur when off-shore or near-shore storm events, that may be accompanied by minimal or no precipitation the Baltimore region, lead to storm surges that travel up the Chesapeake Bay.

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.

3.2.4 Combination Event/Heavy Precipitation Aftermath

A combination of weather events can also lead to nuisance flooding in Baltimore in the aftermath of heavy precipitation, as a large rainfall event in correlation with extreme high tide cycles can lead to nuisance flooding. Although nuisance flooding is not generally associated with precipitation events in Baltimore; tidal cycles, tidal backflows, and standing pluvial water in the drainage network when combined with excess precipitation can produce conditions that lead to nuisance flooding. In Baltimore, backflows can occur when the level of water in Baltimore's tidal estuary inlet of the Chesapeake Bay are higher than the drainage outfall. The factors necessary to produce nuisance flooding for this type of event were seen during Hurricane Sandy in 2012. Although Sandy produced pluvial and flash flooding, it also led to secondary nuisance flooding that significantly impacted the Baltimore area. Winds measured over 60-mph, rainfall was over 5 inches, and storm surges overwhelmed Baltimore's drainage system and led to flooding for an extended period. Additionally, the storm surge was enhanced by a full moon phase leading to higher tides. Figure 10 shows standing water in Fells Point following a heavy precipitation event. Drainage of this water is dependent upon storm system capacity and flow rates, along with outfall clearance during tide cycles.

3.2.5 King Tides, Seasonal Effects and Other Factors

To provide further information on tidal flood causes, it is important to expand upon the above material and define another factor prompting nuisance flooding in Baltimore. Spring tides, also known as king tides, significantly influence tidal flooding along coastlines. Although tidal cycles are completely normal, twice per month during the moon's new and full phases, tides are slightly larger due to the moon's stronger gravitational pull coinciding with these specific phases. And its name, spring tide, does not have any relation to the season in which these tides occur. However, three to four times per year an exceptionally high tide, or perigean spring tide, forms due to new or full moon cycles occurring in correlation with the moon at its perigee. Perigee occurs when the moon is closest to the Earth during its natural orbit. Weather is another critical factor that plays a role influencing perigean spring tidal cycles in our region and their likelihood of causing nuisance flooding. Late spring through fall in the Mid-Atlantic region is generally when these higher tides occur. Strong on-shore winds, barometric pressure changes from storms, and ocean circulation patterns in correlation with perigean spring tides can also contribute to nuisance flood events. Figure 11 shows and incorporates the average seasonal cycle of mean sea-level caused by regular fluctuations in coastal temperatures, salinities, winds, atmospheric pressures, and ocean currents, is shown along with each month's 95% confidence interval.

Figure 10: Fells Point flooding as an aftermath of hurricane Isabel in September 2003. (Source: CityLab)

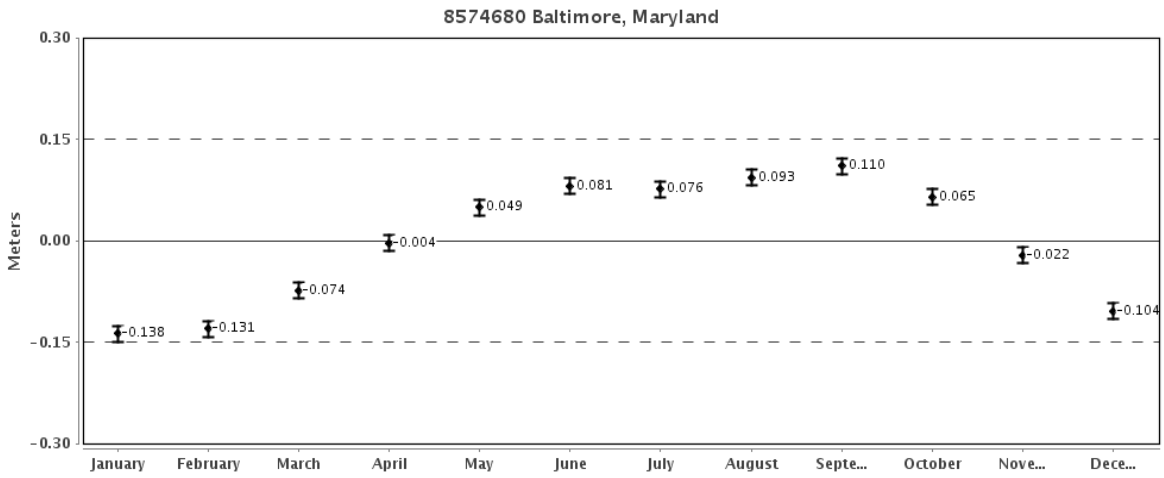


Figure 11: Baltimore tidal station average seasonal cycle of mean sea-level. (Source: NOAA)

For instance, during the weekend of October 11-14, 2019, Baltimore experienced flooding due to such conditions. Nuisance flooding occurred along Baltimore's Inner Harbor promenade and in Fells Point due to the combination of a hunter's moon and the residual effects of tropical storm Melissa. Each year, the full moon that occurs in October is known as a hunter's moon and the event can happen in association when the moon is at its perigee, as it did in 2019. As the hunter's moon generated higher tide cycles during that timeframe, residual on-shore wind and wave patterns from the tropical storm, which was located over 500 hundred miles offshore, raised sea-levels and created nuisance flooding in Baltimore. Tides ran approximately 2.5 feet above normal during this event and Baltimore received only a few passing rain showers from the storm.

Figure 12 illustrates flooding along the Inner Harbor promenade in April 2020. This flooding was influenced by recent moon phases and a strong southerly wind stemming from a passing storm system. Wind forecasts for this date pushed tides up the Bay leading to inundation.

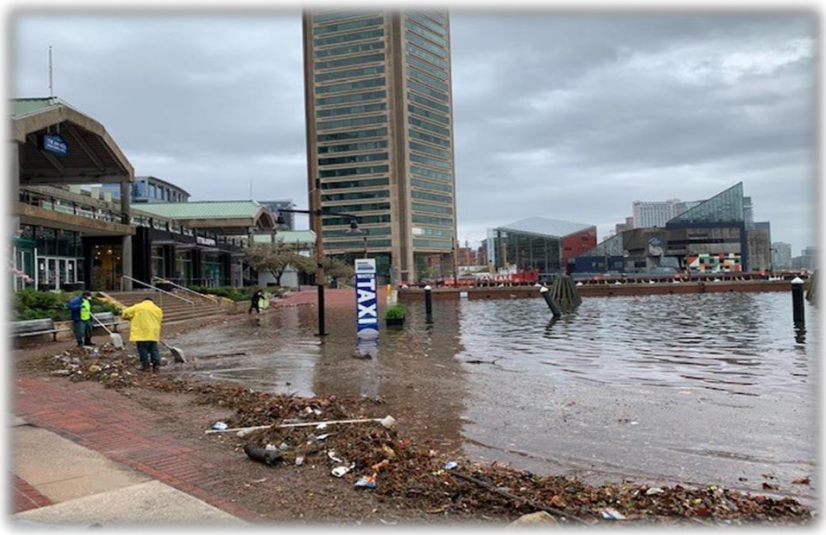


Figure 12: Flooding along Baltimore's Inner Harbor promenade in April 2020.

4 PLANNING PROCESS OVERVIEW

The Nuisance Flood Plan provides an assessment of nuisance flooding in Baltimore, identifies critical and City-owned assets located within the areas of concern, and includes a detailed evaluation of vulnerable areas prone to this type of flooding. The assessment was developed through a comprehensive planning process based on literature review and Geographic Information System (GIS) analysis, including projections and modeling data from vetted sources along with georeferenced data of critical infrastructure and facilities. Public input, historical information and photographic archives were also utilized for the identification of the coastal areas prone to nuisance flooding.

The **identification of nuisance flooding hot-spots** was developed based on the Maryland Department of Transportation and State Highway Administration's Climate Change Vulnerability database (MDOT SHA Climate Change Vulnerability). The layer "2015 Mean Higher High Water- 10% Annual Chance (10 Year Storm) Flood Depth Grid" was used to delineate the baseline nuisance flooding hot-spots because it closely reflected the nuisance flooding conditions observed in documented historical events. The term **baseline conditions are referred to as current conditions** throughout the plan.

In order to validate the hot-spots identified with the MDOT SHA Climate Vulnerability Tool, a **stakeholder survey** was prepared and distributed to property owners of parcels located within the nuisance flood hot-spots, to community associations located at and near the target areas, and profit and non-profit organizations identified as holding a special interest in waterfront areas of Baltimore City. Interviews with property owners were also conducted to validate the nuisance hot-spots data generated by the modeling and GIS analysis. It is important to note that the planning process was designed to be adaptive, as it allows for the incorporation of new scientific data related to sea-level rise as predictions become available.

After nuisance flooding hot-spot identification, **the coastal area was divided into six zones of interest**. The zones were defined based on location, topographical features, land use and zoning type, frequency of nuisance flooding events based on historical data, and/or vulnerability indexes. Additional information about each zone is included in Section 4 Affected Communities and Asset Identification.

The data produced by the tide gauge located on the Northwest Branch Patapsco River in combination with documented historical events were utilized to define the **tide heights, also known as nuisance flooding thresholds**. The flooding thresholds correspond to water elevations that could produce nuisance flooding in different locations along Baltimore's coastal areas.

Interviews were conducted with the City agencies that are responsible for responding and addressing nuisance flood events. The information gathered from the responding agencies was used to develop Section 6 Response Approach of the plan. The agencies that were interviewed for the plan included Baltimore City Fire Department (BCFD), and its Office of Emergency Management (OEM) and the 3-1-1 Service; Baltimore City Police Department (BCPD); Baltimore City Department of Transportation (DOT); and Baltimore City Department of Public Works (DPW), and its Bureau of Water and Wastewater and Bureau of Solid Waste. Each agency and office described how they are notified of a nuisance flooding, and the process followed to respond to the event, if applicable. Based on the information provided by the agencies, the plan presents recommendations to enhance the response approach to nuisance flooding in Baltimore.

A list of mitigation strategies is also presented to address the impacts of nuisance flooding. The mitigation approaches include the two main components listed below and can be found on Section 7 Impacts and Mitigation Strategies.

- Strategies provided in the DP3 that have the potential to address nuisance flood events.
- Technologies and approaches under development or being utilized by other jurisdictions that also experience nuisance flooding.

The mitigation strategies from the DP3 included in this plan were elaborated in 2018 during the last plan update. The present plan, with the intention to verify the current relevance and implementation status of the approaches, sorted the strategies per each responsible City agency, listed the items in an online survey, and requested an update on each item. The responses provided by the stakeholder agencies were assessed and a status update is provided for each mitigation category from Section 7.4 to Section 7.7.

The additional mitigation strategies listed in the plan, including new technologies and approaches, were assembled based on research. It is important to note that additional refinement to the list, and recommendations regarding which mitigation strategies should be considered for each of the nuisance flood hot-spots is still needed.

Section 8 Event Tracking and Cataloging was developed based on the information provided by the responding agencies and by DNR for the section that described the MyCoast application. Additional information about the development of the proposed process for tracking and cataloging of nuisance flood events can be found in that section.

4.1 PLAN UPDATES

The Nuisance Flood Plan, as required by Maryland House Bill 1427 (2019), must be updated every five (5) years or less, and therefore, the next plan update is scheduled to take place on or before October 1st, 2025.

In addition to the plan update that must happen according to the schedule required by the State of Maryland, the Baltimore City Planning Commission has requested yearly plan updates to be conducted as public presentations during Planning Commission meetings. The plan updates must include a summary of the data collected to date; an overview of the observed trends; and an assessment of the process established in the plan to identify and catalog the nuisance flood events, including challenges and opportunities.

5 IMPACTED COMMUNITIES AND ASSET IDENTIFICATION

After evaluating models, projections and studies from a variety of sources, including data provided by NOAA, United States Army Corp of Engineer (USACE), and MDOT, **several areas have been identified as vulnerable to nuisance flooding within Baltimore City**. Roadway water depths were assessed at 0.10 feet to over 2 feet of inundation on ground surfaces. MDOT modeling methodology is based on USACE statistics regarding calculated sea-level changes. Final sea-level change figures are based on a combination of figures including NOAA tidal reference station data, natural land grade/elevation, and glacial isostatic adjustment. When specifically referencing gauge data from the northwest branch of the Patapsco River, NOAA defines flood stage as listed on Table 1.

Table 1 Flood stage category and tide heights for NOAA's tidal gauge at the Northwest Branch Patapsco River at Baltimore/ Fort McHenry.

FLOOD STAGE CATEGORY	TIDE HEIGHT
Near flood	2.5 - 2.99 feet
Minor flood	3 - 4.99 feet
Moderate flood	5 – 5.99 feet
Major flood	6 feet and above

In order to categorize and define the nuisance flood areas within Baltimore, **six flood zones were created based on location, topographical features, land use and zoning type, and/or vulnerability indexes**. The zones are defined starting from the most southern area and moving clockwise along the coastline as follows (Figure 13):

- **Zone 1:** Fairfield Area, Curtis Bay Industrial Area, Hawkins Point
- **Zone 2:** Middle Branch/Reedbird Parks, Cherry Hill, Port Covington, Spring Garden Industrial Area, Carroll-Camden Industrial Area
- **Zone 3:** Inner Harbor
- **Zone 4:** Fells Point
- **Zone 5:** Canton, Canton Industrial Area, Locust Point Industrial Area
- **Zone 6:** Dundalk Marine Terminal, Holabird Industrial Park Area

Following the definition of the different zones affected by nuisance flooding, asset identification was performed. Within each established zone, modeling, projections and/or historical data were utilized to determine where nuisance flooding occurs or have the potential to occur. Once the areas prone to nuisance flooding were determined, specific asset identification in the target areas was performed. For this plan, both critical infrastructure assets, as defined by Federal Emergency Management Agency (FEMA) guidelines, and Baltimore City-owned assets are identified.

5.1 CRITICAL INFRASTRUCTURE

The United States Cybersecurity and Infrastructure Agency (CISA) defines critical infrastructure as assets, systems, and networks, whether physical or virtual, that are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof. These defined guidelines are followed by the Federal Emergency Management Agency (FEMA) in their response to national emergencies. Critical infrastructure is ultimately identified through the National Infrastructure Protection Plan, created in 1998 and updated in 2013. Infrastructure is categorized into sixteen different sectors including chemical, commercial facilities, communications, dams, emergency services, financial services, government facilities, information technology, transportation systems, commercial facilities, critical manufacturing, defense industrial based facilities, energy, food and agriculture, healthcare and public health, nuclear systems and waste, and water and wastewater system sectors. Within each sector infrastructure is further categorized into subsectors that outline specific sites and categories. For example, the commercial facilities sector is further itemized into entertainment/media, lodging, gaming, outdoor events, public assembly, real estate, and sports leagues. The critical manufacturing sector is further categorized into primary metal manufacturing, machinery manufacturing, electrical

equipment, appliance, and component manufacturing, and transportation equipment manufacturing (CISA, 2020). It is important to note that national monuments, postal, and shipping services were removed from the National Infrastructure Protection Plan in 2013; however, these assets are identified within this plan.

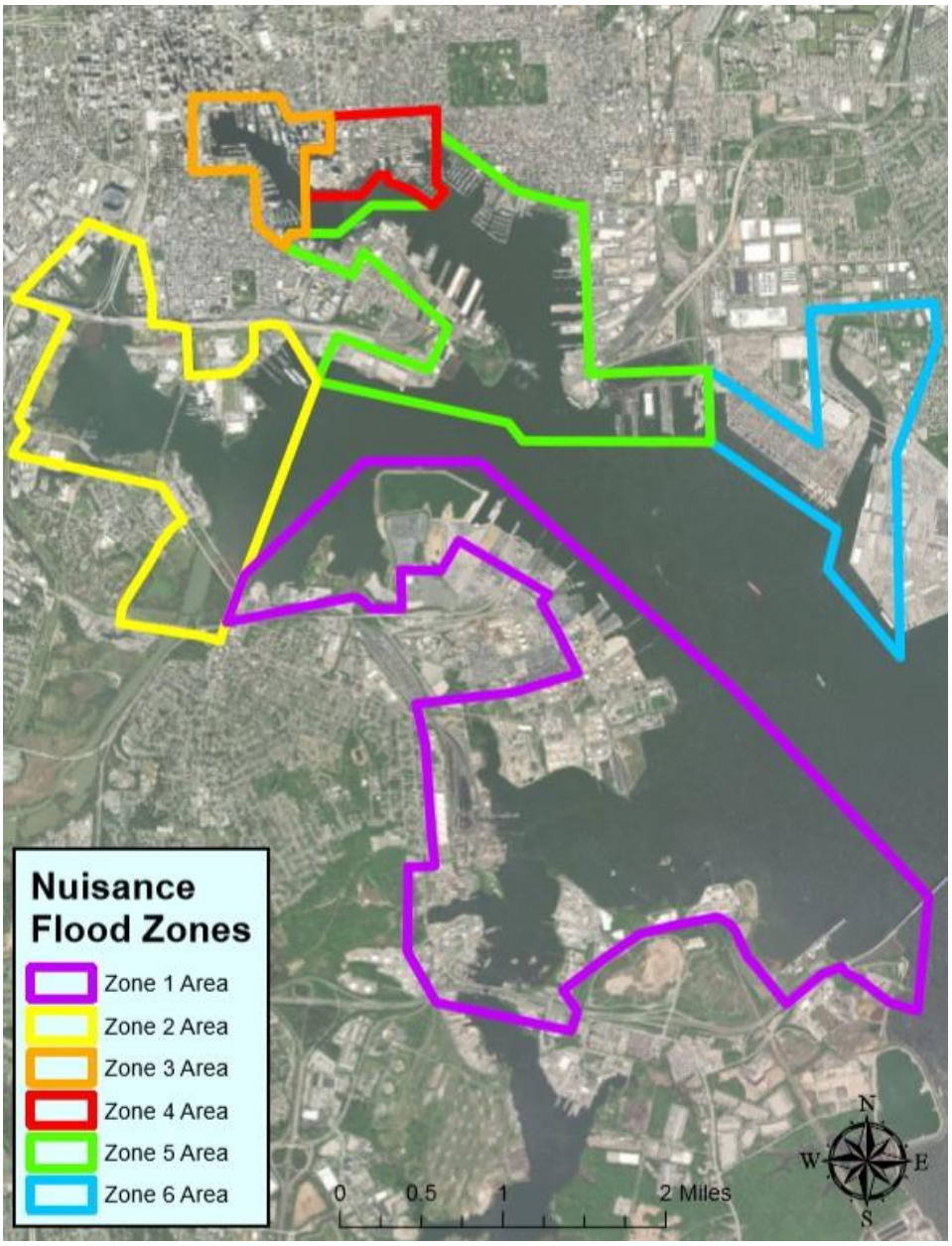


Figure 13: Nuisance Flood Zones for Baltimore City

5.1.1 Zone 1

Zone 1, the largest and most southern zone, includes the highly industrialized areas of Fairfield, Hawkins Point, and Curtis Bay. Land use and zoning for the area is primarily maritime industrial and general industrial use with small

portions of open space and light/medium commercial use. According to the USACE, this area is considered highly vulnerable to tidal flooding, specifically due to the number of critical infrastructure elements located within the zone (USACE, 2015). The susceptible areas identified through projections and modeling include various marine port activity, fuel and utility infrastructure, railroad transportation, water and wastewater treatment, chemical manufacturing, and other critical infrastructure. Shoreline stabilization in much of this area includes constructed bulkheads and seawalls that protect marine and port services; however, there are some soft, exposed shorelines in the area that are held by revetments, levees, and/or simple wetland buffers. Figure 14 shows areas of concern in Zone 1 according to 2015 baseline calculations identified in MDOT modeling (MDOT, 2019). Table 2 illustrates both critical infrastructure and Baltimore City owned infrastructure identified within the areas of concern, while Table 3 shows roads that may become inundated due to nuisance flooding based on the same MDOT modeling. Figure 15 shows locations of critical infrastructure and City-owned property identified within Zone 1, along with affected transit routes.

Strictly based on MDOT modeling, **the most frequent nuisance flooding within Zone 1 could be expected in several areas when Patapsco River tidal gauge levels exceed 4 feet**. This would include coastal areas near Fort Armistead Park, coastal areas adjacent to W.R. Grace and Company, several piers within the Fairfield Auto Port property, the intersection of Hanover Street and Frankfurst Avenue, and land areas south of the Patapsco Wastewater Treatment Plant along Asiatic Avenue. As gauge levels increase new areas would be affected and water depths within initial areas would grow deeper and more far-reaching. Due to the nature of ownership in this area, additional feedback from property owners and other stakeholders, along with field verification, is necessary in order to include confirmed observations of nuisance flooding.

5.1.1.1 Stakeholder Feedback

Public outreach efforts validated some of the nuisance flood areas identified through MDOT modeling. Appendix C illustrates ground truth data from survey respondents confirming where nuisance flooding has been observed. Additionally, a new area of concern was established as the intersection of Hanover Street and Frankfurst Avenue. The information was identified by several survey respondents as a problem area during nuisance flooding. Disruptions of road, bike, and pedestrian transit at this intersection were noted as being moderate to significant during nuisance flood events. Multiple survey participants also provided information stating that during nuisance flood events near the Patapsco Wastewater Treatment Plant, sewage has both infiltrated harbor water and nearby adjacent property grounds.

Table 2: Critical infrastructure and Baltimore City owned infrastructure identified in Zone 1 areas of concern

ASSET	LOCATION	INFRASTRUCTURE TYPE
Masonville Cove Environmental Center	1000 Frankfurst Avenue	Educational Facilities
Patapsco Wastewater Plant	3501 Asiatic Avenue	Emergency Alert System
FMC Corporation	1701 E Patapsco Avenue	Emergency Alert System
FMC Chemical	1703 E Patapsco Avenue	Chemical Sector
Chevron USA Products Company, Inc.	1955 Chesapeake Avenue	Transportation Systems
Citgo Petroleum Facility	2201 Southport Avenue	Energy Services
Motiva Oil Refinery	2400 Petrolia Avenue	Energy Services
Patapsco Water/Wastewater	3501 Asiatic Ave	Wastewater &Water Treatment
USALCO	3801 Asiatic Ave	Chemical Sector
S.T. Services	1800 Frankfurst Avenue	Energy Services
DGS Garage	3501 Asiatic Avenue	Energy Services
Sunoco	2155 Northbridge Avenue	Energy Services
Center Terminal	3100 Vera Street	Energy Services
Hess Fuel Terminal	6200 Pennington Avenue	Energy Services
Sunoco	6200-A Pennington Avenue	Energy Services

Griffith Oil Services	2155-B Northbridge Avenue	Energy Services
Colonial Pipeline	3625 Fairfield Road	Energy Services
Delta Chemical Company	2601 Cannery Avenue	Chemical Sector
Geo Specialty Chemicals	1920 Benhill Avenue	Chemical Sector
Sasol North America, Inc.	3441 Fairfield Road	Chemical Sector
Baltimore Harbor Tunnel South	1200 Frankfurst Avenue	Transportation Systems
Kinder Morgan Terminals	3901 Asiatic Ave	Transportation Systems
CSX Transportation Systems	Multiple Locations	Transportation Systems
W R Grace and Company	5500 Chemical Road	Chemical Sector
W R Grace and Company	5500 Chemical Road	Emergency Alert System
U.S. Coast Guard Yard	2401 Hawkins Point Road	Maritime Security
Liquid Transfer Facilities	6101 Pennington Avenue	Energy Services
Fort Armistead Park	4000 Hawkins Point Road	City Infrastructure
U.S. Concrete Products, LLC	200 Frankfurst Avenue	Critical Manufacturing
Vulcan Materials Company	420 Frankfurst Avenue	Critical Manufacturing
Fairfield Auto Terminal	3100 Childs Street	Transportation Systems
U.S. Gypsum	5500 Quarantine Road	Critical Manufacturing
Holcim U.S., Inc.	3800 Hawkins Point Road	Critical Manufacturing
Yara North America	4000 Hawkins Point Road	Chemical Sector
Vane Brothers Company	2100 Frankfurst Avenue	Transportation Systems
Buckeye Terminals	3100 Block Pennington Avenue	Transportation Systems

Table 3: Possible road inundations from nuisance flood events in Zone 1

ROAD	LOCATION	NEIGHBORHOOD
Asiatic Avenue	Btw Northbridge Avenue & south end of street	Fairfield Area
Cannery Avenue	Btw Leo Street & east end of street	Fairfield Area
Southport Avenue	Entire length	Fairfield Area
Patapsco Avenue	East of Coal Pier Road	Curtis Bay Industrial Area
Fort Armistead Road	East end near harbor	Hawkins Point
Hanover Street	Adjacent to Frankfurst Avenue intersection	Fairfield Area

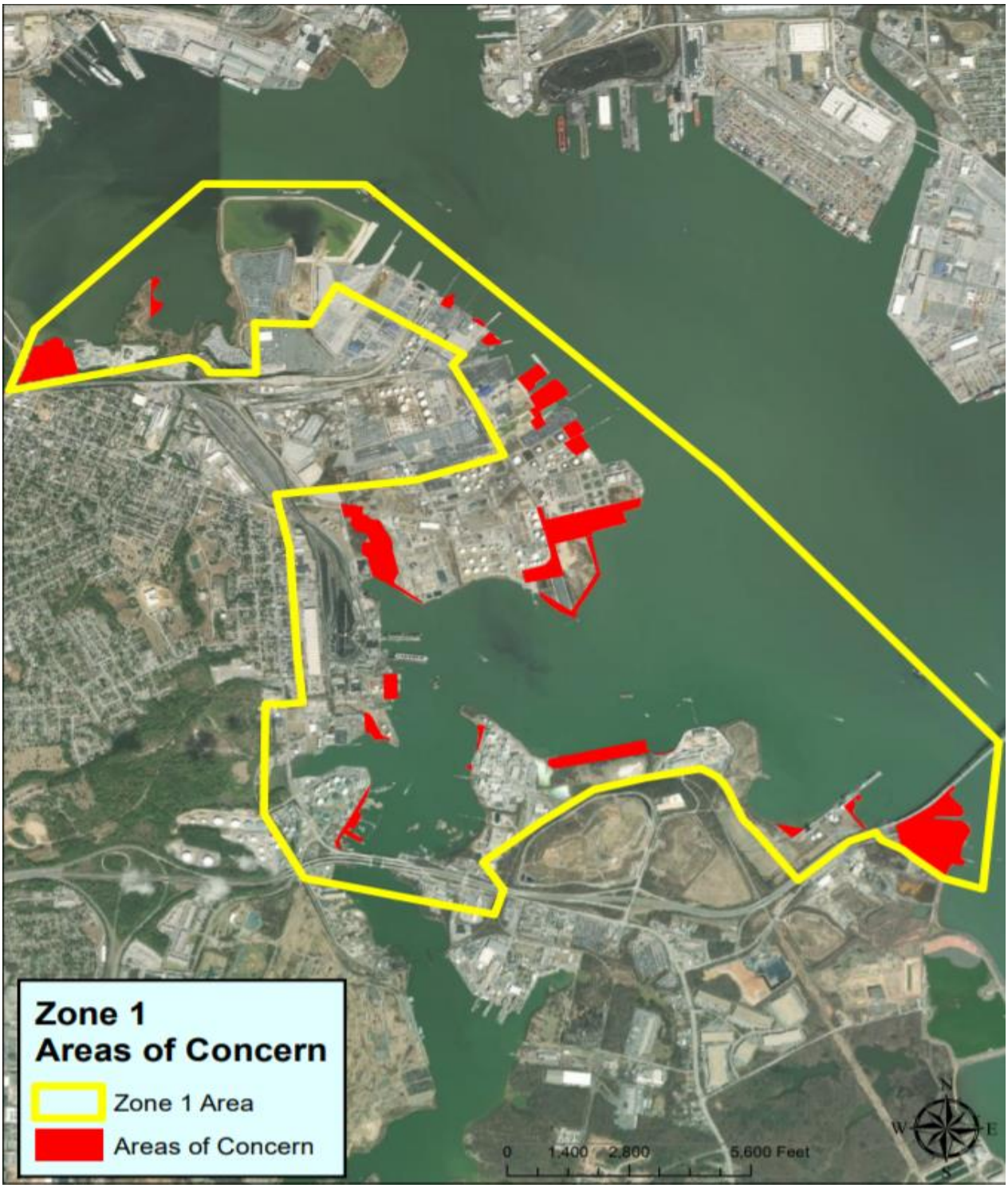


Figure 14: Nuisance flooding areas of concern in Zone 1

Figure 15: Zone 1 nuisance flooding effects on critical and city-owned infrastructure, along with affected transit routes based on current conditions

5.1.2 Zone 2

Zone 2 includes the areas of Middle Branch and Reedbird Parks, Cherry Hill, Port Covington, Spring Garden Industrial Area, and Carroll-Camden Industrial Area. Land use is mixed and includes light/medium commercial, light industrial, low-density row home residential, transit-oriented, preservation space, open space and hospital use. The shoreline protection ranges from seawall to wetland buffers. Roughly two-thirds of the land in the Middle Branch and Reedbird Parks area is recreational, and the other one-third is located on hospital property. The shoreline is protected by both seawall and wetland buffers in this neighborhood. A small portion of the Cherry Hill neighborhood is located within the Zone 2 boundary and is primarily recreational park land with wetland buffer.

Port Covington is a developing waterfront area that is expected to rapidly change over the next few years. The area contains a mix of seawall and wetland buffer protection. Spring Garden and Carroll-Camden Industrial Area are zoned primarily for industrial and downtown use and possess seawall and wetland buffer protection. Table 4 and Figure 17 list critical assets and City-owned infrastructure found within Zone 2. The south end of Insulator Drive is the only road that has been identified as impacted by nuisance flood within Zone 2 based on 2015 data. Figure 16 highlights areas of concern, while Figure 17 shows affected transit routes identified in Zone 2.

Based on MDOT modeling, in addition to field verification and confirmed observational data, **nuisance flooding within Zone 2 could be expected in several areas when Patapsco River tidal gauge levels exceed 4 feet**. This would include coastal areas to the rear of the Horseshoe Casino, areas along BGE's Spring Garden yard, land adjacent to Middle Branch Marina, the boat launch area in Middle Branch Park, Harbor Hospital property and coastal areas adjacent to hospital property, wetland areas of Reedbird Park, and land adjacent to the DPW's yard located near Reedbird park. Additionally, the intersection of Hanover Street and Frankfurst Avenue has been identified as an area of concern after stakeholder outreach. Tidal gauge threshold levels above 5 feet would significantly impact BGE's Spring Garden Yard, areas adjacent to Warner Street, and most shoreline areas of Middle Branch Park. Due to the nature of ownership in certain areas of Zone 2, feedback from property owners and other stakeholders, along with field verification, is necessary in order to include confirmed observations of nuisance flooding.

5.1.2.1 Stakeholder Feedback

Public outreach efforts provided information that allowed an expansion on initial areas of concern within Zone 2. Areas of concern were expanded along the Harbor Hospital property after survey respondents provided observational information and feedback. Additionally, survey responses for Zone 2 stated that nuisance flooding is causing bank erosion along the Harbor Hospital property, and bike routes along the Middle Branch trail flood regularly. Survey responses also mentioned the commencement of a $23 million investment and redevelopment of Reedbird Park and how this project may address nuisance flooding on the site.

Table 4: Critical infrastructure and Baltimore City owned infrastructure identified in Zone 2 areas of concern

ASSET	LOCATION	INFRASTRUCTURE TYPE
BGE Substation	2033 Kloman Street	Energy Services
DGS Garage/Solid Waste Management	701 Reedbird Avenue	City Infrastructure
Conduit Maintenance	1400 Leadenhall Street	City Infrastructure
BGE Switching Station	1500 Leadenhall Street	Energy Services
Cherry Hill Bath House	100 Reedbird Avenue	Emergency Alert System
Medstar Harbor Hospital	3001 South Hanover Street	Healthcare & Public Health
Vietnam Veteran's Memorial	2825 S Hanover St	Landmark
Middle Branch Park	3301 Waterview Avenue	City Infrastructure
Cherry Hill Park	101 Reedbird Avenue	City Infrastructure
Reed Bird Island Park	Potee Street and Frankfurst Avenue	City Infrastructure
Cherry Hill Fieldhouse and Pool Building	101 Reedbird Avenue	City Infrastructure
Cherry Hill Park	101 Reedbird Ave	City Infrastructure
West Covington Park	101 West Cromwell Street	City Infrastructure
BGE Spring Gardens Service Center	1699 Leadenhall Street	Energy Services
Hanover Street Bridge	Hanover Street Bridge	Emergency Alert System
Swann Park	201 West McComas Street	City Infrastructure
Middle Branch Marina	3101 Waterview Avenue	Transportation Systems

Figure 16: Nuisance flooding areas of concern in Zone 2

Figure 17: Zone 2 nuisance flooding effects on critical and city-owned infrastructure, along with affected transit routes based on current conditions

5.1.3 Zone 3

Baltimore's Inner Harbor, **Zone 3**, is known for its many museums, restaurants, residences, businesses, marine activity, and recreation. Although Baltimore's harbor is one of the area's primary assets, the city's proximity to such a large water feature comes with its complexities. As noted above, tidal flooding in the Inner Harbor has presented a problem in the past, and in concurrence with increasing sea-levels, the problem will continue to produce challenges for the future. The Inner Harbor area has been designated as Zone 3 in the Nuisance Flood Plan and includes the recently developed area of Harbor East. Due to its proximity to other nuisance flood zones, Zone 3 is bounded primarily to the north by Pratt Street, to the west by Light Street, to the east by South Eden Street, and to the south along Key Highway to Webster Street. Land use is primarily zoned for open space and light/medium commercial use. The vast majority, if not all of Zone 3 shoreline is composed of bulkheads.

Several parts of the Inner Harbor area already experience nuisance flooding, and additional areas have been identified as vulnerable. Figure 22 illustrates areas of concern within Zone 3. Table 5 lists critical and City-owned infrastructure, while Figure 23 shows infrastructure location and affected transit routes mapped within Zone 3. As we move away from primarily industrial and recreational uses in Zones 1 and 2, cultural and historical landmarks are also included in the infrastructure list. These have been identified as significant landmarks to the City's identity. Table 5 includes non-critical infrastructure assets, and Table 5 lists roads that may become inundated during nuisance flood events.

Several areas in Zone 3 have been identified as nuisance flood hot-spots when the northwest branch Patapsco River gauge levels exceed 3.5 feet. The areas include the Inner Harbor promenade at the amphitheater, the lower promenade near the Maryland Science Center, the promenade directly west of the World Trade Center, most promenade areas directly between the two Harbor Place Pavilions, and the area east of Rusty Scupper restaurant. Tide heights reaching the 5 -6 feet range can cause nuisance flooding in areas east of the World Trade Center, along the east and west side of Pier 3 and 4, and along the west side of Pier 5. Nuisance flood areas listed above have been confirmed through confirmed observational data, NOAA observations, field verification, and MDOT modeling.

5.1.3.1 Stakeholder Feedback

Public outreach efforts for Zone 3 provided some observational ground truthing data for areas of concern. Appendix C illustrates survey results regarding respondent's reports of nuisance flooding. Additional survey feedback noted the negative effects of nuisance flooding on business operations, pedestrian/tourist access and transit, and the issue of trash and odor caused by flood events.

Table 5: Critical infrastructure and Baltimore City owned infrastructure identified in Zone 3 areas of concern

ASSET	LOCATION	INFRASTRUCTURE TYPE
Harborplace & The Gallery	200 East Pratt Street	Commercial Facilities
The Power Plant	601 East Pratt Street	Commercial Facilities
Inner Harbor East	801 Lancaster Street	Commercial Facilities
Wells Fargo Financial Services	725 South Eden Street	Financial Services
Financial Services of America	600 East Pratt Street	Financial Services
DPW Museum	751 Eastern Ave	Educational Facilities
Columbus Center	701 East Pratt Street	Educational Facilities
Baltimore Visitor Center	401 Light Street	Government Facilities
Maryland Science Center	601 Light Street	Educational Facilities
Top of the World Observation Level	401 East Pratt Street	Educational Facilities
National Aquarium	501 East Pratt Street	Educational Facilities
Baltimore Maritime Museums	301 East Pratt Street	Educational Facilities

Eden Street Pole Mount	700 Block S Eden Street	Emergency Alert System
Whole Foods	711 South Central Avenue	Food & Agriculture
CVS Pharmacy	630 South Exeter Street	Healthcare & Public Health
Bagby Furniture	509 South Exeter Street	Landmark
MECU Pavilion	731 Eastern Avenue	Commercial Facilities
Seven Foot Knoll Lighthouse	Pier 5, Baltimore	Landmark
Christopher Columbus	300 President St	Landmark
Inner Harbor Park	398 E Pratt St	City Infrastructure
Inner Harbor Park	399 E Pratt St	City Infrastructure
Rash Field Park	201 Key Highway	City Infrastructure
Baltimore Inner Harbor Marina	400 Key Hwy	Transportation Systems
Harbor Connector	Harbor East	Transportation Systems
Harbor Connector	Rusty Scupper	Transportation Systems
Bearing Point	400 E Pratt St	Commercial Facilities
Robert Half International	401 E Pratt St	Commercial Facilities
Harbor Bank of Maryland	1000 Lancaster Street	Financial Services
CVS Pharmacy	400 E Pratt St	Healthcare & Public Health
Harbor View Marina	500 Harborview Drive	Transportation Systems
Harbor East Marina	40 International Drive	Transportation Systems

Table 6: Possible road inundations from nuisance flood events in Zone 3

ROAD	LOCATION	NEIGHBORHOOD
Pratt Street	Btw Commerce Street & Constellation Way	Inner Harbor
Beluga Boulevard	Entire length	Inner Harbor
Gunther Circle	Entire length	Inner Harbor
South Central Avenue	South of Fleet Street	Inner Harbor
Light Street	At Pratt Street intersection	Inner Harbor

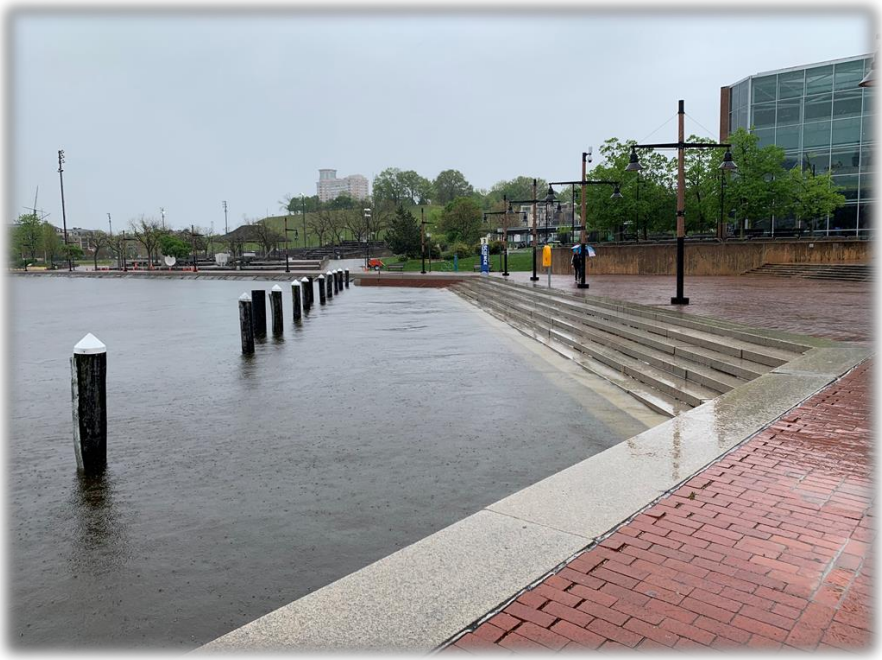


Figure 18: Nuisance flooding near the lower promenade of the MD Science Center in May 2020. The northwest branch Patapsco River tidal gague registered a 4.3 feet tide hight during this period

Figure 19: Nuisance flooding along the Inner Harbor promenade in May 2020. The northwest branch Patapsco River tidal gague registered a 4.3 feet tide hight during this period

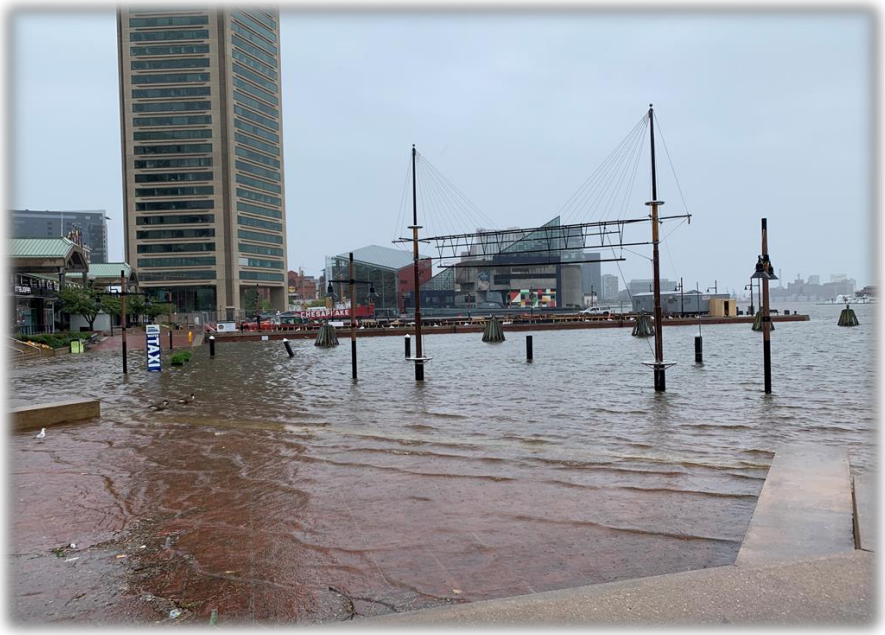


Figure 20: Nuisance flooding covering the Inner Harbor amphitheater area in May 2020. The northwest branch Patapsco River tidal gague registered a 4.3 feet tide hight during this period

Figure 21: Nuisance flooding pushing debris and litter onto the Inner Harbor promenade in May 2020. The northwest branch Patapsco River tidal gague registered a 4.3 feet tide hight during this period.

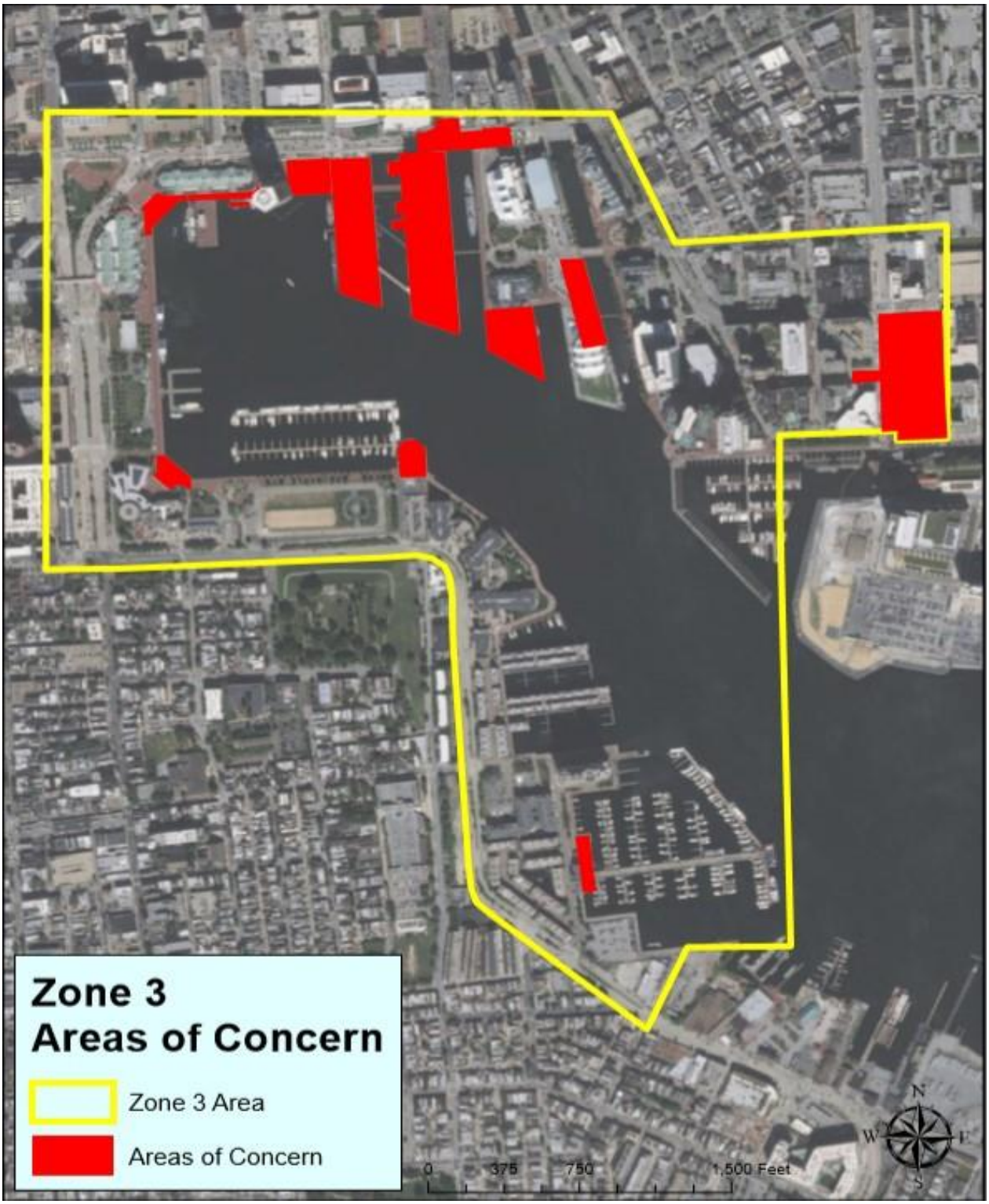


Figure 22: Nuisance flooding areas of concern in zone 3

Figure 23: Zone 3 nuisance flooding effects on critical and city-owned infrastructure, along with affected transit routes based on current conditions

5.1.4 Zone 4

Zone 4, Baltimore's historic Fells Point waterfront district, established in 1763, is a vibrant and diverse neighborhood consisting of residences, restaurants, businesses, and hotels. Annual festivals, historic tours, a newly-renovated vendor market, and a lively nightlife scene draw locals and visitors to the community. Over 160 buildings in the Fells Point neighborhood are listed on the National Historic Registry, and the community has witnessed much during its 250-plus year history. Due to its proximity to the waterfront, Fells Point is highly vulnerable to nuisance flood events, and has experienced significant flooding in its long history. Baltimore City has already developed flood mitigation guidelines for the Fells Point area through the Commission for Historical & Architectural Preservation (CHAP). Although these guidelines have been established, it is still important to identify areas and assets that will continue to experience an increase in nuisance flood events.

Land use in Zone 4 is primarily business district, public access, open space, residential-traditional row houses, and light/medium commercial use, but there is also light industrial present. The shoreline in zone 4 is almost completely bulkheaded. Based on 2015 mean sea-level and the predicted frequencies of 10-year storm events, several areas have been identified as nuisance flood hot-spots within the Fells Point area. Figure 27 illustrates areas of concern within Zone 4. The nuisance flood areas listed below have been confirmed through NOAA data, field verification and MDOT modeling data.

Table 7 lists critical and City-owned infrastructure within Zone 4, while Table 8 shows roads that may become inundated during nuisance flooding. Figure 28 maps critical infrastructure and potential impacts on transit routes in Zone 4.

Observed nuisance flooding has been well documented within Zone 4 due to its frequency. **Several areas in the Fells Point region have been identified as nuisance flooding hot-spots when the northwest branch Patapsco River tidal gauge levels reach 3.5 feet**. This includes the east end of Thames Street moving north up South Wolfe Street, the south end of Ann Street, the south end of Fell Street, the Thames Street waterfront near the Sagamore Pendry Hotel, and land adjacent to the Frederick Douglass-Isaac Myers Maritime Park. As gauge levels crest 5 feet, the Fells Point promenade floods in many areas, water inundates western parts of Lancaster Street and adjacent promenade areas, the south end of Broadway Street begins to flood, water approaches Caroline Street, and the intersection of Ann Street and Thames Street floods. When tidal levels are accompanied by moderate to heavy precipitation that overwhelm the stormwater system, side streets and properties east and west of Broadway Street and primarily north to Aliceanna Street can become flooded. Tidal backflow also contributes to flooding under these conditions in Zone 4. Nuisance flood areas listed above have been confirmed through confirmed observational data, NOAA observations, field verification, and MDOT modeling.

5.1.4.1 Stakeholder/Public Feedback

Public outreach efforts for Zone 4 provided some observational ground truthing data for areas of concern. Appendix C illustrates survey results regarding respondent's reports of nuisance flooding. Additional survey feedback noted the negative effects of nuisance flooding on business operations, transit routes, and residential property damage.

Table 7: Critical infrastructure and Baltimore City owned infrastructure identified in Zone 4 areas of concern

ASSET	LOCATION	INFRASTRUCTURE TYPE
CFG Community Financial Services	1615 Thames Street	Financial Services
Enoch Pratt Free Library	606 S Ann St	Government Facilities
Living Classrooms	802 South Caroline Street	Educational Facilities
Frederick Douglass-Isaac Myers Maritime Park	1417 Thames Street	City Infrastructure
Crossroads School	802 South Caroline Street	Educational Facilities
The New Century School	742 South Ann Street	Educational Facilities
Fells Point Maritime Museum	1724 Thames St	Educational Facilities

Robert Long House	812 S Ann St	Landmark
United States Postal Service	714 South Wolfe Street	Federal Facilities
7-11 Convenience Store	1615 Thames Street	Food & Agriculture
Broadway Market	800 South Broadway	Food & Agriculture
St. Stanislaus Kostka Church	708 S Ann St	Landmark
Four Bay House	1733 Aliceanna St	Landmark
Admiral Fell Inn	888 South Broadway Street	Landmark
Merchant House	1732 Thames Street	Landmark
Hollingworth-Steele House	931 Fell Street	Landmark
Two Sisters Houses	614 South Wolfe Street	Landmark
Leeke Academy	1627 Aliceanna Street	Landmark
Fell Family Tomb	1607 Shakespeare Street	Landmark
Ann Fell House	1600 Shakespeare Street	Landmark
Thames Street Corridor	Thames Street	Landmark
H & S Bakery	603 S Bond St	Food & Agriculture
Thames Street Park	1832 Thames Street	City Infrastructure
Thames Street Park	1833 Thames Street	City Infrastructure
Lemko House	603 South Ann Street	Commercial Facilities
Harbor Connector	Maritime Park	Transportation Systems
M&T Financial Services	1310 Point Street	Financial Services
Wells Fargo Financial Services	725 South Eden Street	Financial Services
BB&T Financial Services	1510 Fleet Street	Financial Services
Meyer Seed Company of Baltimore	600 S. Caroline Street	Food & Agriculture
Northeast Foods	601 S. Caroline Street	Food & Agriculture
Hendersons Wharf Marina	1001 Fell Street	Transportation Systems
Rendia, Inc.	1820 Lancaster Street, #110	Information Technology

Table 8: Possible road inundations from nuisance flood events in Zone 4

ROAD	LOCATION	NEIGHBORHOOD
Lancaster Street	South Exeter Street and east to the end	Fells Point
Aliceanna Street	Btw South Exeter & South Bond Street	Fells Point
Aliceanna Street	Btw South Durham Street & Boston Street	Fells Point
South Eden Street	Btw Lancaster Street & Aliceanna Street	Fells Point
South Spring Street	Btw Lancaster Street & Fleet Street	Fells Point
South Caroline Street	Btw Thames Street & Eastern Avenue	Fells Point
Fleet Street	Btw South Spring Street & South Dallas Street	Fells Point
South Dallas Street	Btw Aliceanna Street & Dock Street	Fells Point
Dock Street	Entire length	Fells Point
Thames Street	South Broadway Street and east to the end	Fells Point
South Broadway Street	In area of Thames Street	Fells Point
Fell Street	South of Thames Street	Fells Point
South Ann Street	South of Thames Street	Fells Point

South Wolfe Street	Btw Fleet Street & Fell Street	Fells Point
South Durham Street	Btw Lancaster Street & Aliceanna Street	Fells Point
South Chapel Street	Near Aliceanna Street	Fells Point
South Washington Street	Btw Fleet Street & Aliceanna Street	Fells Point
South Castle Street	Btw Fountain Street & Aliceanna Street	Fells Point
South Chester Street	Near Aliceanna Street	Fells Point

Figure 24: Nuisance flooding along Thames Street in Fells Point in May 2020. The northwest branch Patapsco River tidal gague registered a 4.3 feet tide hight during this period

Figure 25: Nuisance flooding in Fells Point in May 2020. The northwest branch Patapsco River tidal gague registered a 4.3 feet tide hight during this period

Figure 26: Nuisance flooding and stormwater system backflow along Thames Street In May 2020. The northwest branch Patapsco River tidal gague registered a 4.3 feet tide hight during this period

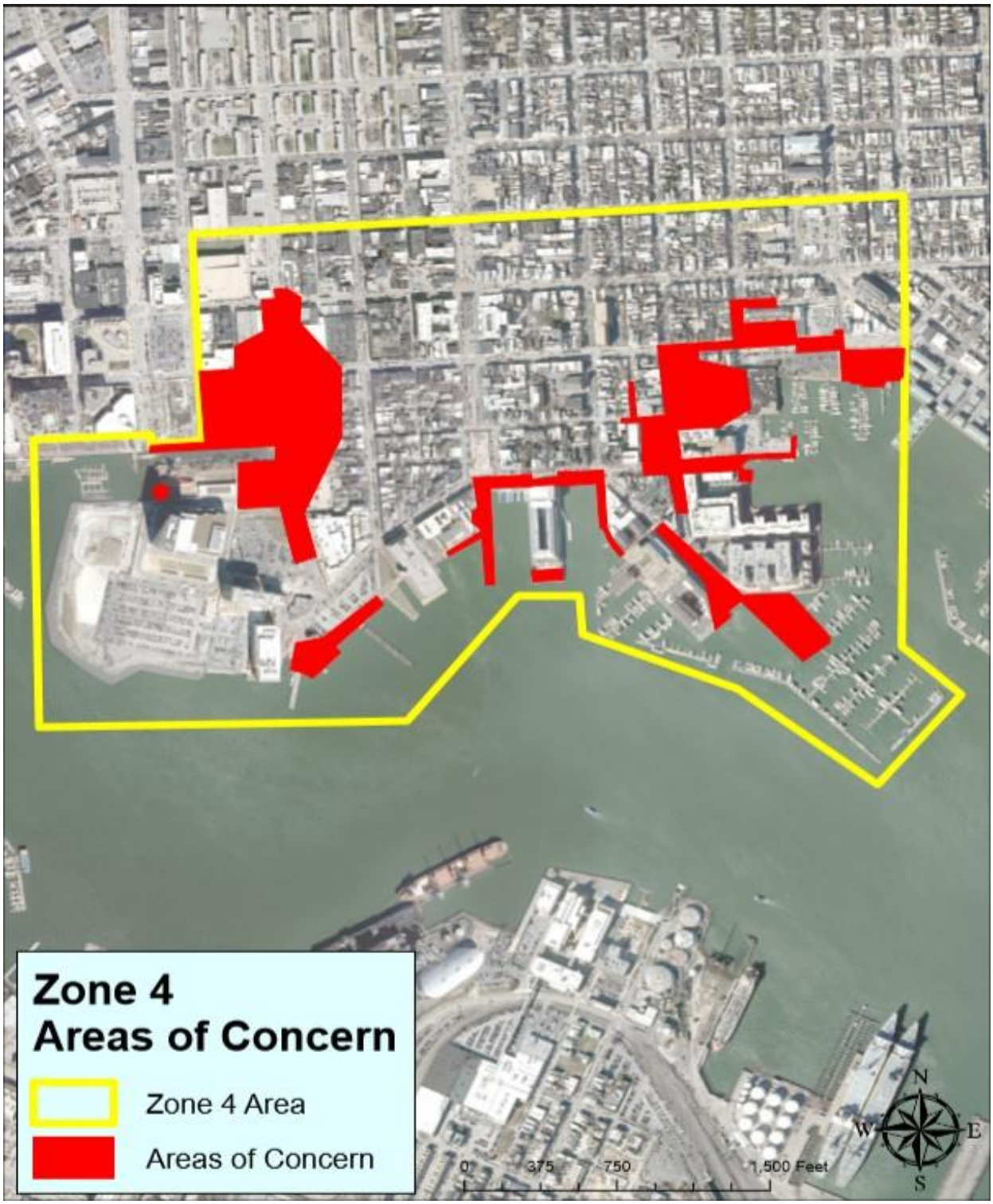


Figure 27: Zone 4 nuisance flooding areas of concern in Baltimore, Maryland

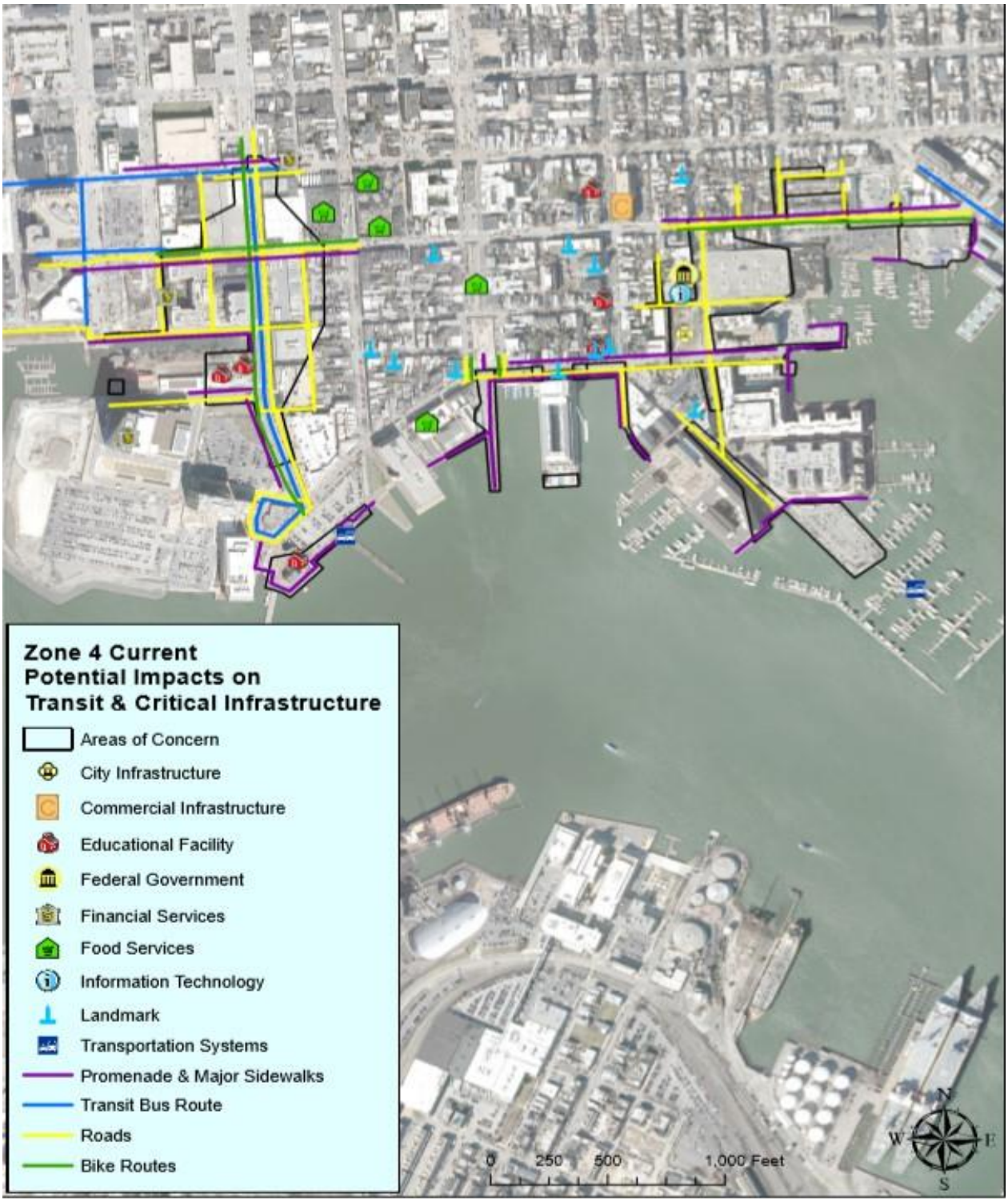


Figure 28: Zone 4 nuisance flooding effects on critical and city-owned infrastructure, along with affected transit routes based on current conditions

5.1.5 Zone 5

Zone 5 includes the neighborhoods of Canton, Canton Industrial Area, and Locust Point Industrial Area. Canton and parts of Locust Point have experienced significant change and growth over the past 20 years and are now some of the most sought out residential areas in Baltimore for young professionals. Both Canton and Locust Point are walkable communities and have long maritime histories dating to 1775. A significant portion of Canton and Locust Point industrial areas located within Zone 5 are zoned for maritime and general industrialized land use; however, there are several areas in these neighborhoods designated for open space. Land use in Canton ranges from small to intensive commercial use to traditional residential zoning and has several overlay zones to promote preservation of view corridors and public use. Large portions of the shoreline in these neighborhoods are composed of bulkheads, although several areas are secured with by rip rap, especially in the open space areas. Figure 29 illustrates areas of concern within Zone 5.

Table 9 shows critical and City-owned infrastructure within Zone 5, while Table 10 shows roads that may become inundated during nuisance flooding. Figure 30 maps infrastructure and potential impacts on transit routes in Zone 5.

Based on MDOT modeling and confirmed observational data, **nuisance flooding within Zone 5 typically begins to occur as northwest branch Patapsco River gauge levels exceed 5 feet**. This water level height presents issues for piers located along Clinton Street, several marinas and promenade areas near Boston Street, coastal areas along Canton Waterfront Park (especially near the boat launch), wetland areas immediately south of Fort McHenry National Monument, and the water taxi stop at Fort McHenry. Modeling predicts nuisance flooding near the USACE and U.S. Naval Support property, and the Baltimore City Fire Boat station near Leahy Street; however, Baltimore City Fire Department officials have confirmed that this area typically does not flood unless tide heights exceed 6 feet. Additional feedback and field verification from private property owners is necessary to confirm nuisance flooding in certain areas of Zone 5.

5.1.5.1 Stakeholder Feedback

Minimal stakeholder/public feedback was received for Zone 5.

Table 9: Critical infrastructure and Baltimore City owned infrastructure identified in Zone 5 areas of concern

ASSET	LOCATION	INFRASTRUCTURE TYPE
Rukert Terminals	2021 South Clinton Street	Energy Services
Boston Street Pier Park	2601 Boston Street	City Infrastructure
Canton Waterfront Park	3001 Boston Street	City Infrastructure
Anchorage Promenade Park	2300 block of Boston Street	City Infrastructure
MD Port Authority Pier 1	2000 S Clinton Street	Emergency Alert System
Apex Oil	1622 South Clinton Street	Energy Services
DPW Joint Marine Facility	3201 Boston St	Transportation Systems
Baltimore Museum of Industry	1415 Key Highway	Educational Facilities
Fort McHenry National Monument	2400 East Fort Avenue	Federal Facilities
Fire Department Repair Shop	1407 Key Highway	Emergency Alert System
US Army Corps of Engineers	2299 East Fort Avenue	Federal Facilities
Navy Operational Support Center	1201 Halsey Road	Federal Facilities
Fire Maintenance Bureau	1407 Key Highway	Emergency Services
Fire Boat Station	2609 Leahy Street	Emergency Services
Harbor Connector	Multiple Locations	Transportation Systems
Harbor Connector	North end of Hull Street	Transportation Systems
Domino Sugar	1100 Key Hwy	Food & Agriculture
Anchorage Marina	2501 Boston Street #200	Transportation Systems

Oasis Marinas at Lighthouse Point	2780 Lighthouse Point #E	Transportation Systems
Canton Cove Marina	S. Linwood Avenue	Transportation Systems
Baltimore Marine Center Fuel Pier	1800 S. Clinton Street #2	Energy Services
Clinton Street Marine	1910 S. Clinton Street	Transportation Systems
Keystone Ship Berthing	2000 S. Clinton Street	Transportation Systems
Console Marine Terminals	3800 Newgate Avenue	Transportation Systems

Table 10: Possible road inundations from nuisance flood events in Zone 5

ROAD	LOCATION	NEIGHBORHOOD
Eastbourne Avenue	Near harbor's edge	Canton Industrial Area
Harborview Drive	300 block	Locust Point Industrial Area
Hull Street	Near harbor's edge	Locust Point Industrial Area
Leahy Street	Entire length	Locust Point Industrial Area
Halsey Road	Entire length	Locust Point Industrial Area
King Circle	Entire length	Locust Point Industrial Area

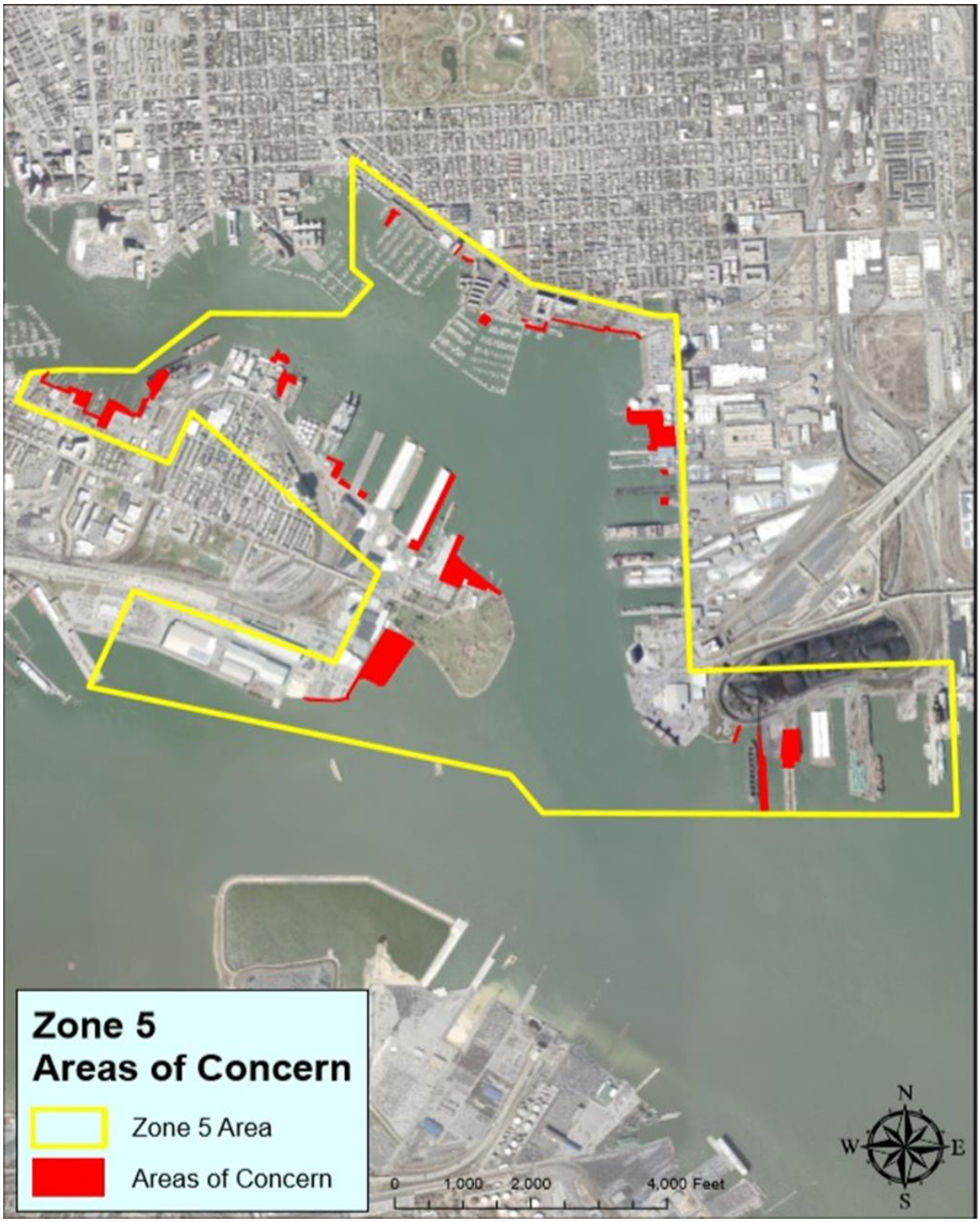


Figure 29: Nuisance flooding areas of concern in zone 5

Figure 30: Zone 5 nuisance flooding effects on critical and city-owned infrastructure, along with affected transit routes based on current conditions

5.1.6 Zone 6

Zone 6 contains portions of the Dundalk Marine Terminal and Holabird Industrial Park neighborhoods. Land use in this area is primarily marine industrial and generalized industrial zoning; however, it also contains open space, office industrial campus use, and is adjacent to various residential properties. Nuisance flooding in Zone 6 is caused by tidal effects on Colgate Creek, a tributary of the Patapsco River. Although the Maryland Port Authority/State of Maryland has developed their own plan for nuisance flooding as it affects port property and activities, it is still important to identify critical infrastructure within the City boundaries for this plan. Most of the southern shoreline on Colgate Creek is protected primarily by seawall and rip rap, while the remaining areas to the north are primarily protected by forest and wetland buffer. Figure 31 illustrates areas of concern within Zone 6..

5.1.6.1 Stakeholder/Public Feedback

No stakeholder/public feedback was received for Zone 6.

Table 11 shows critical and City-owned infrastructure within Zone 6, while Table 12 shows roads that may become inundated during nuisance flooding. Figure 32 maps infrastructure and potential impacts on transit routes in Zone 6.

Based on MDOT modeling alone, nuisance flooding in Zone 6 occurs along Colgate Creek, a tributary directly feeding the Patapsco River. Due to the primary nature of ownership in Zone 6, field verification and interviews with property owners are necessary, but **modeling predicts nuisance flood inundation with 4 feet tide heights along the western shoreline of Colgate Creek** between Broening Highway and the railroad bridge, and along northern Colgate Creek banks moving up into Fort Holabird Park.

5.1.6.2 Stakeholder/Public Feedback

No stakeholder/public feedback was received for Zone 6.

Table 11: Critical infrastructure and Baltimore City owned infrastructure identified in Zone 6 areas of concern

ASSET	LOCATION	INFRASTRUCTURE TYPE
P & O Ports of Baltimore	2700 Broening Hwy	Major Employer
Pixelligent Technologies, LLC	6411 Beckley Street	Chemical Sector
Profectus Biosciences	6411 Beckley Street	Chemical Sector
Fort Holabird Park	6401 Beckley Street	City Infrastructure

Table 12: Possible road inundations from nuisance flood events in Zone 6

ROAD	LOCATION	NEIGHBORHOOD
Broening Highway	Near Colgate Creek	Holabird Industrial Area
Van Deman Street	South of Beckley Street	Holabird Industrial Area

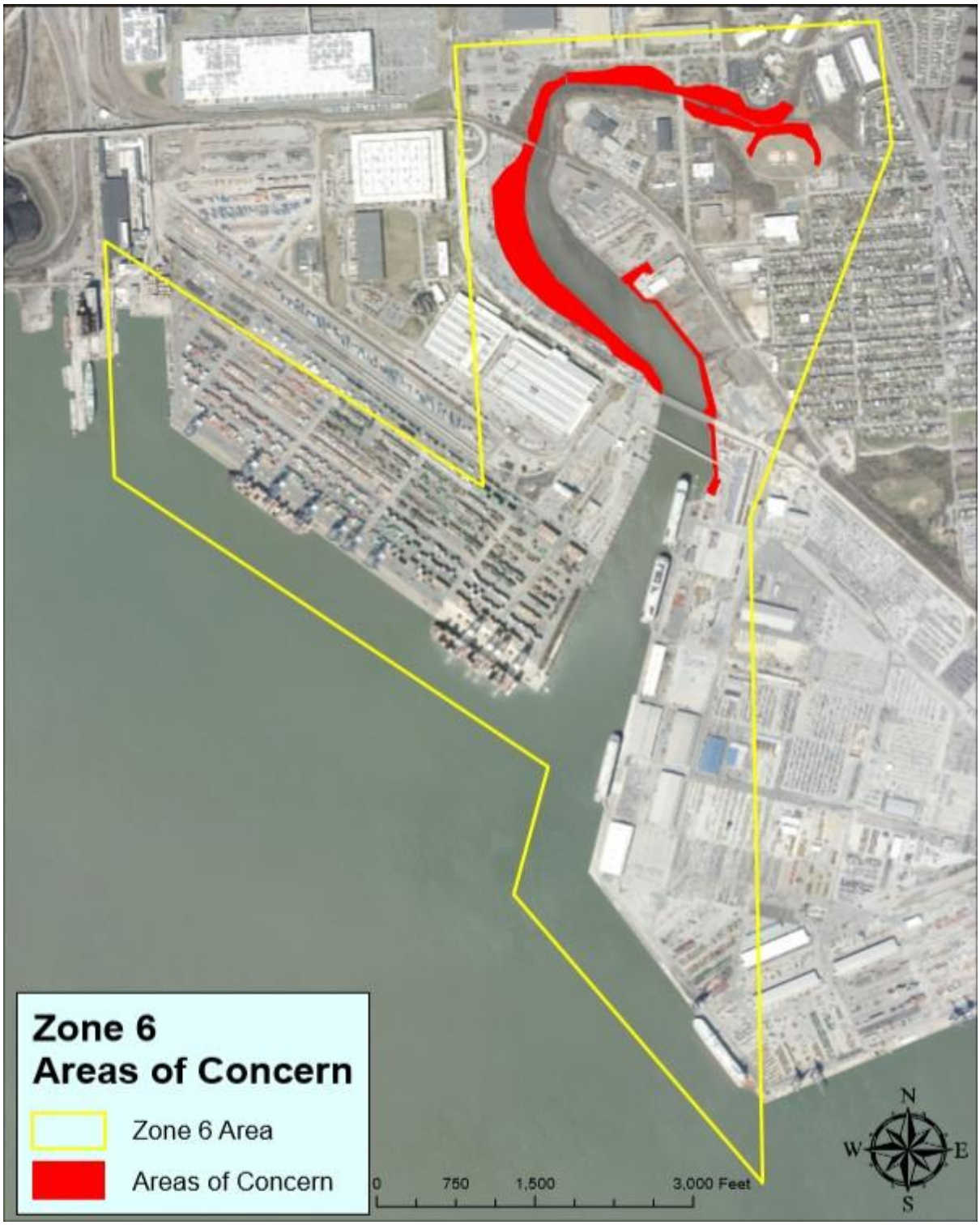


Figure 31: Nuisance flooding areas of concern in zone 6

Figure 32: Zone 6 nuisance flooding effects on critical and city-owned infrastructure, along with affected transit routes based on current conditions

5.2 RANGE AND DEPTH OF NUISANCE FLOODING

The maps included in this section illustrate the range and depth of nuisance flooding under current conditions (based on 2015 data) and 10% storm chance, and 2050 and 2100 projections. The MDOT Climate Change Vulnerability tool was utilized to identify the geographic range and depth of inundation in the six nuisance flooding zones. Background information provided by the USACE on the modeling data discloses that projections are based on sea-level rise and land subsidence predictions. Water depth information was collected utilizing NOAA tidal gauge stations data, which utilizes North America Vertical Datum of 1988 (NAVD 88). Corrections and adjustments were made based on glacial isostatic data (USACE, 2015). It is important to note that **the illustrations provided for 2050 and 2100 are based on a no-action scenario, and do not include recommended or planned mitigation strategies**.

5.2.1 Zone 1 Projections

Based on MDOT modeling, nuisance flooding currently affects an estimated 38 acres of land in Zone 1. Figure 33 illustrates both the range/extent and estimated water depths for current conditions within the zone. As we plan for the future, MDOT modeling predicts that nuisance flooding will grow to 94 acres in Zone 1 by 2050, and by the year 2100 nuisance flooding will encompass 372 acres in this zone. Figure 34 and Figure 35 provide details on the extent and water depths associated with nuisance flooding in 2050 and 2100, respectively. These modeling predictions are based upon present-day parameters and sea-level rise estimations. Table 13 provides estimated areas within Zone 1 to be affected by nuisance flooding based on model year. An analysis of the ensuing modeling shows that significant impacts on Port of Baltimore operations, energy resources, and other infrastructure could potentially be affected by nuisance flooding in the future without the proper implementation of successful mitigation strategies.

Table 13: Predicted estimations of areas within Zone 1 affected by nuisance flooding based on model years

MODEL YEAR	AREA (ACRES)	OVERALL INCREASE (%)
2015	38	---
2050	94	147%
2100	372	296%

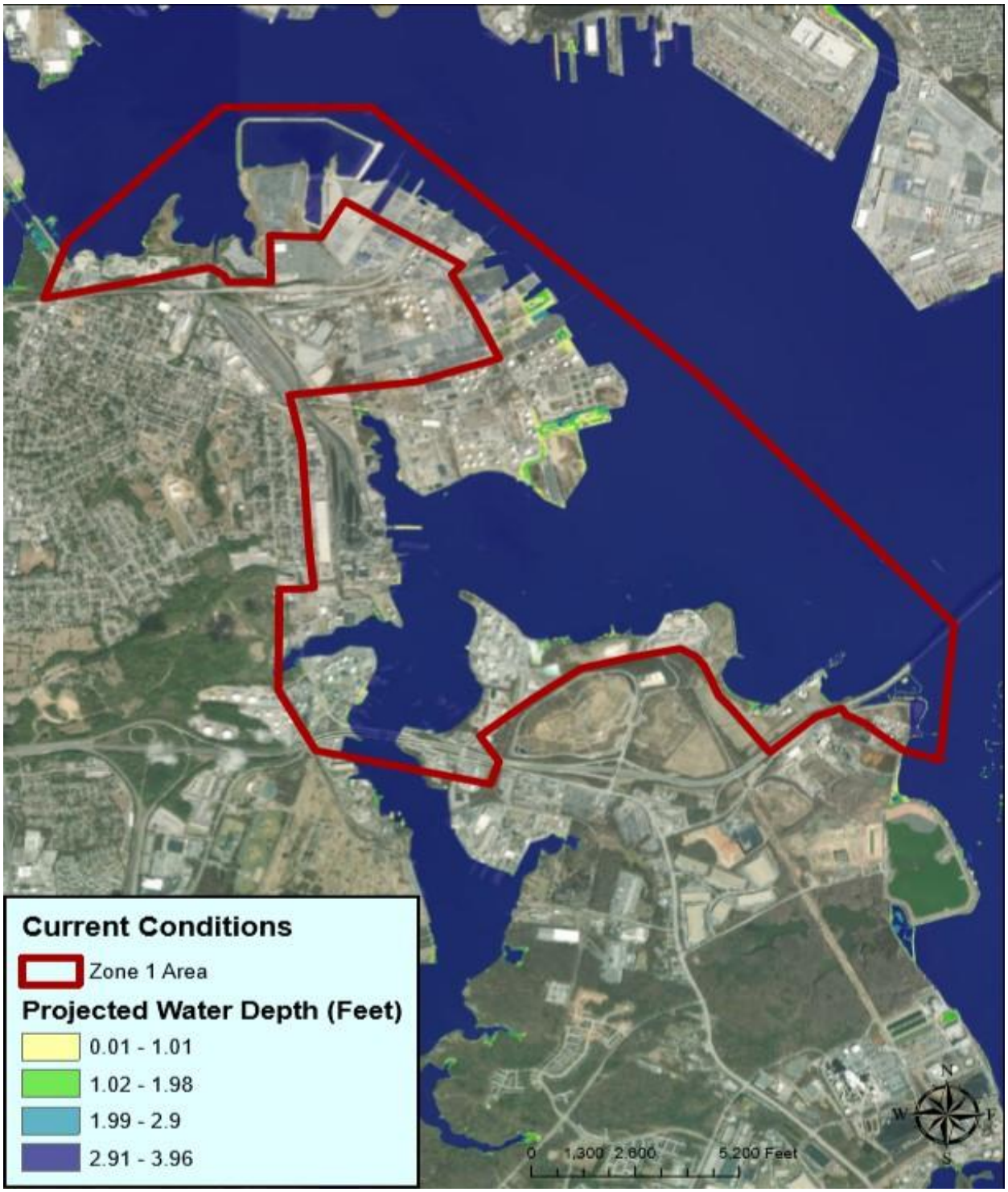


Figure 33: Zone 1 2015 baseline water depths (current conditions)

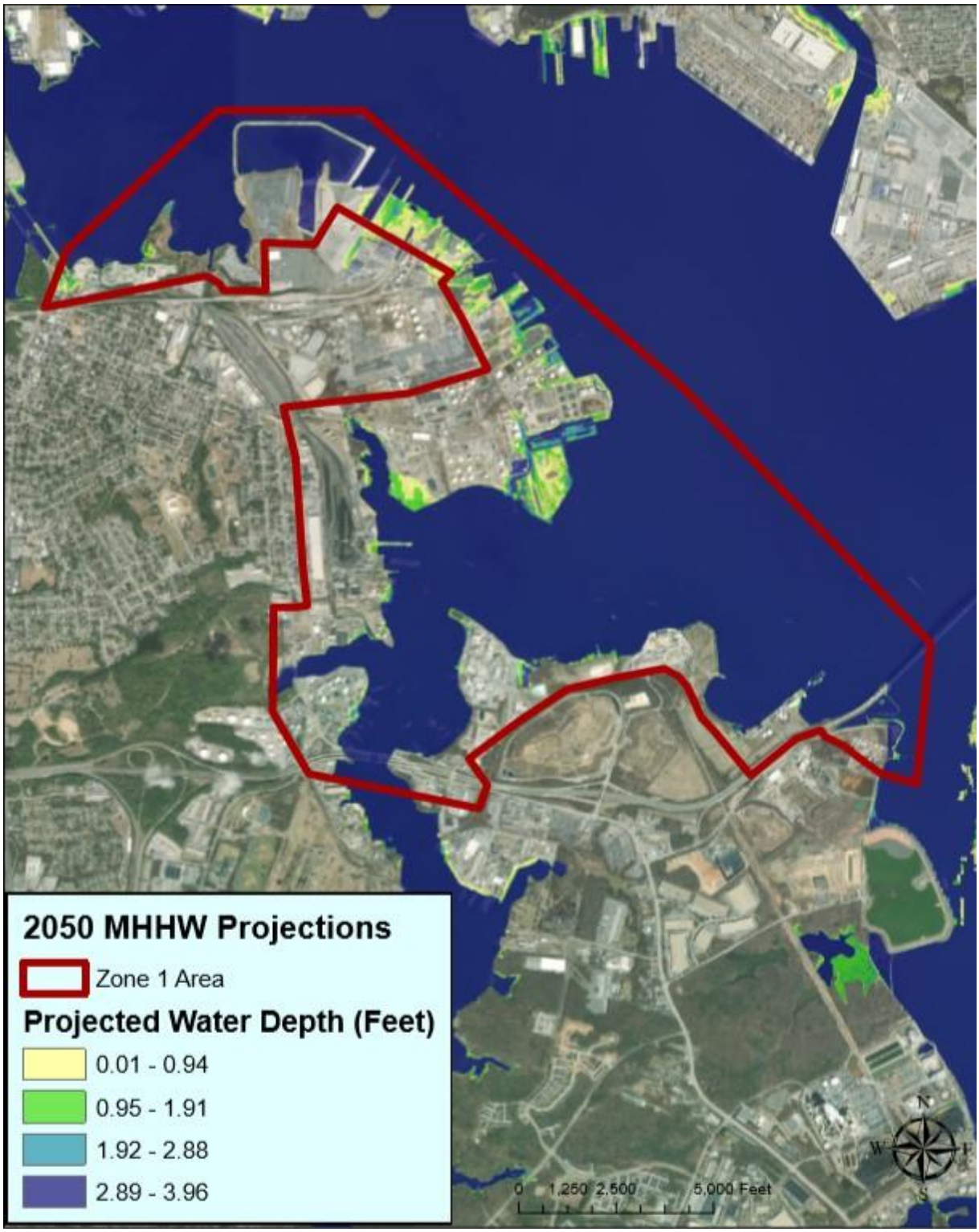


Figure 34: Zone 1 2050 projected water depths

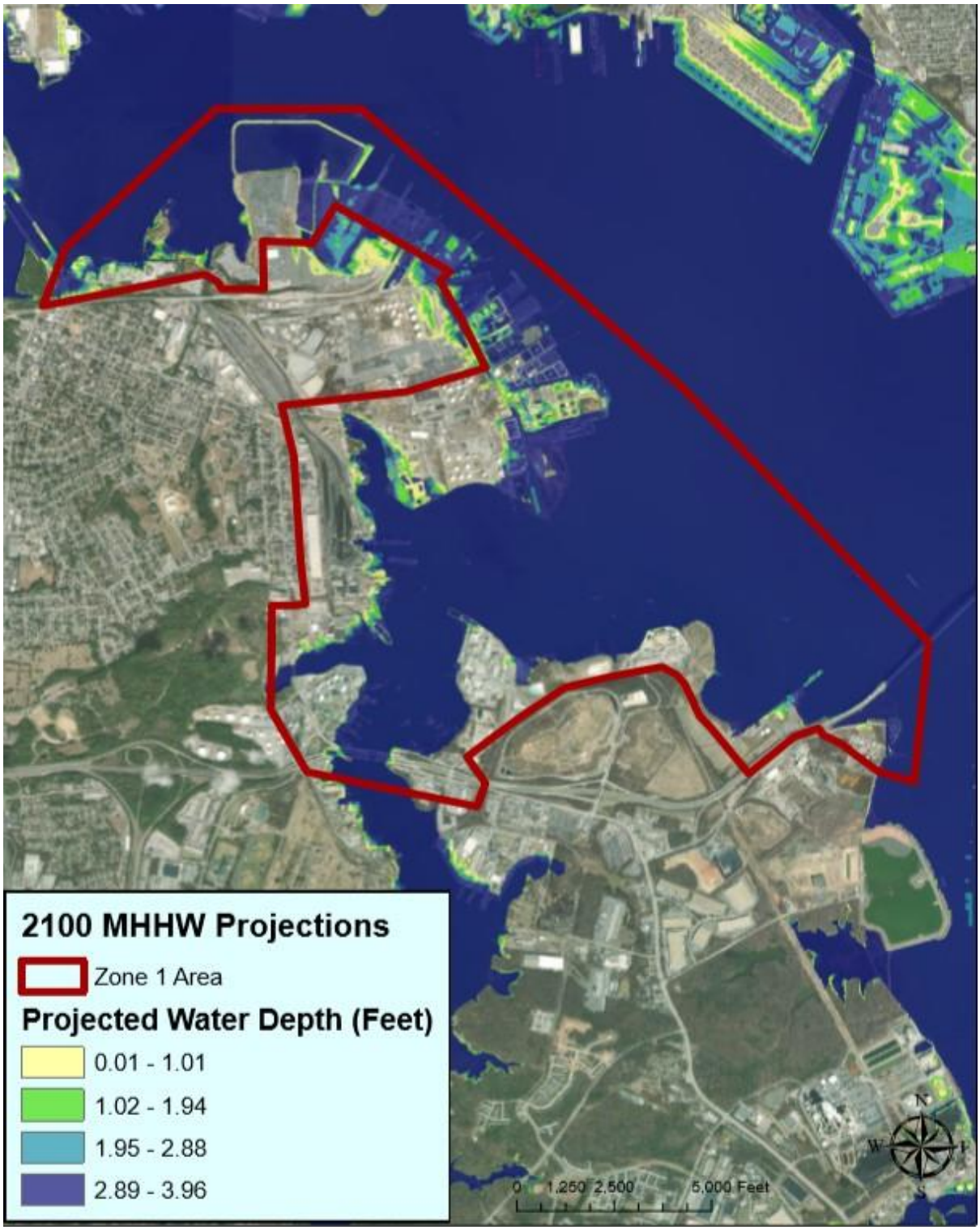


Figure 35: Zone 1 2100 projected water depths

5.2.2 Zone 2 Projections

Based on MDOT modeling, nuisance flooding currently affects an estimated 36 acres of land in Zone 2. Figure 36 illustrates both the range/extent and estimated water depths for current conditions within the zone. MDOT modeling predicts that nuisance flooding will grow to 42 acres in Zone 2 by 2050, and by the year 2100 nuisance flooding will encompass 212 acres in this zone. Figure 37 and Figure 38 provide details on the extent and water depths associated with nuisance flooding in 2050 and 2100, respectively. These modeling predictions are based upon present-day parameters and sea-level rise estimations. Table 14 provides estimated areas within Zone 2 to be affected by nuisance flooding based on model year. An analysis of the ensuing modeling shows that nuisance flooding could potentially impact the Russell Street corridor adjacent to the current Horseshoe Casino, cause problems for a large electrical utility yard, impact local and Greyhound transit operations, increase problems along the Middle Branch Park, Cherry Hill Park, and Harbor Hospital, and begin to affect land in Port Covington without the implementation of successful mitigation strategies. It is important to note that current development plans occurring in the Port Covington, Westport, and Middle Branch areas could change the projected scenarios.

Table 14: Predicted estimations of areas within Zone 2 affected by nuisance flooding based on model years

MODEL YEAR	AREA (ACRES)	OVERALL INCREASE (%)
2015	36	---
2050	42	17%
2100	212	405%

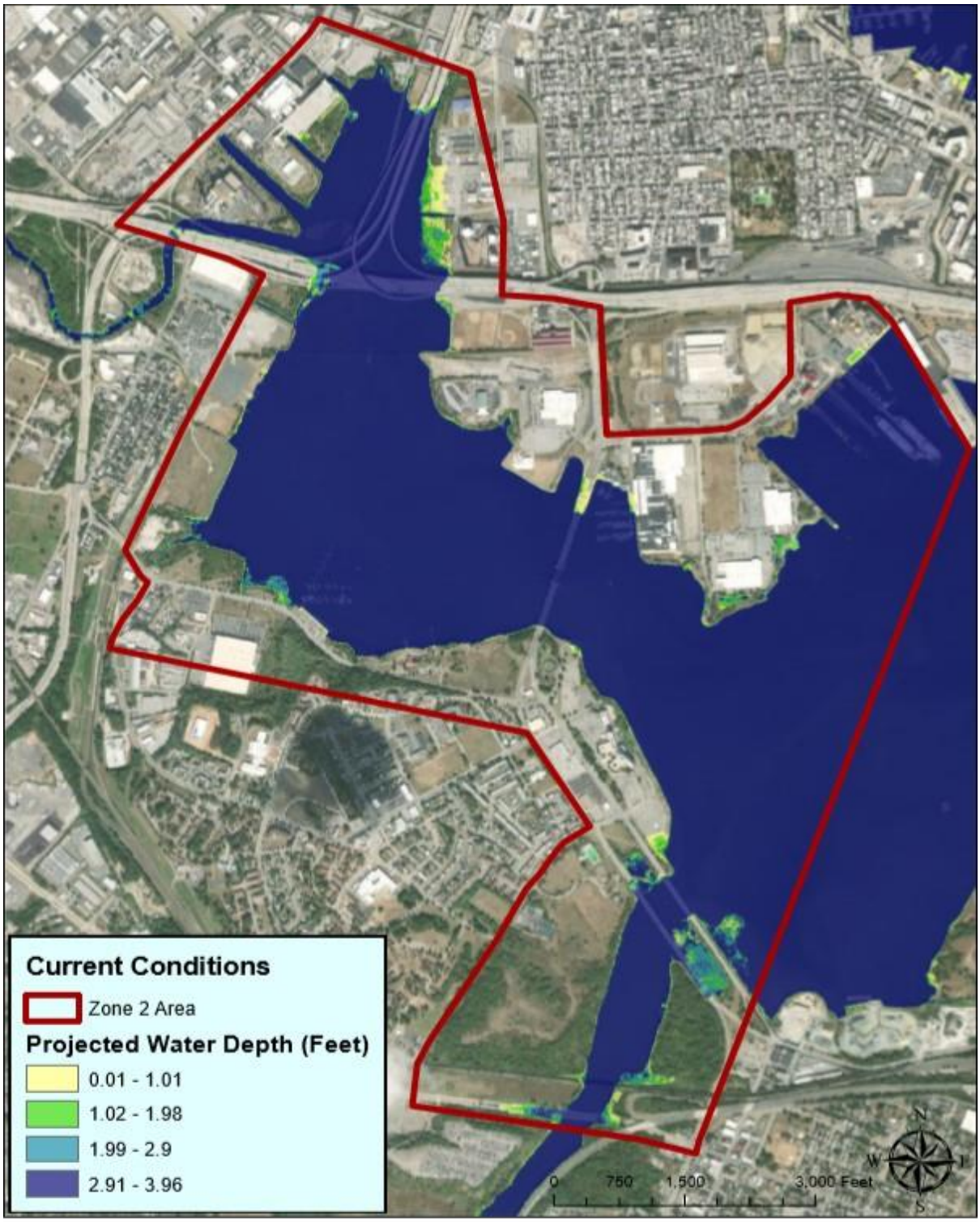


Figure 36: Zone 2 2015 baseline water depths (current conditions)

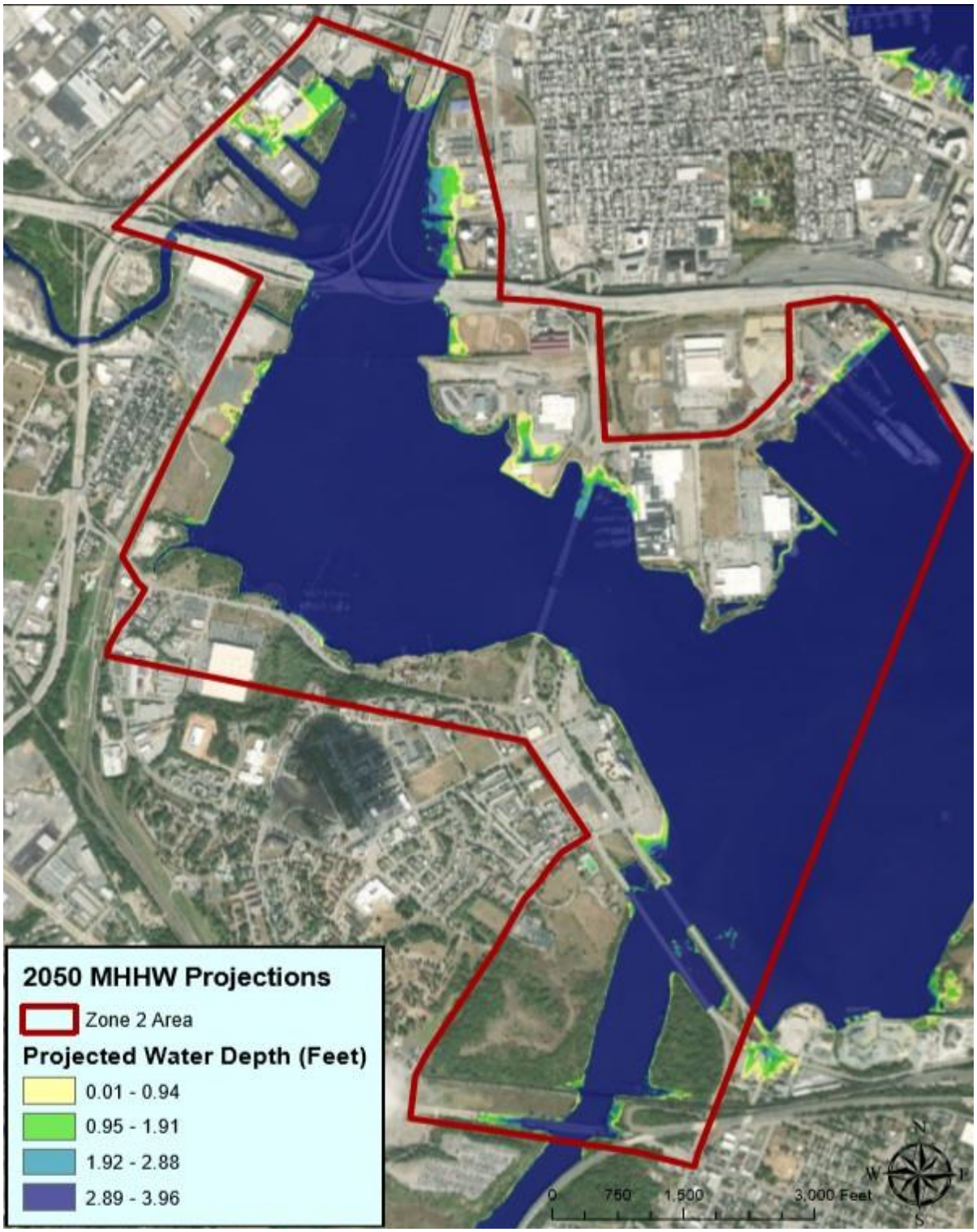


Figure 37: Zone 2 2050 projected water depths

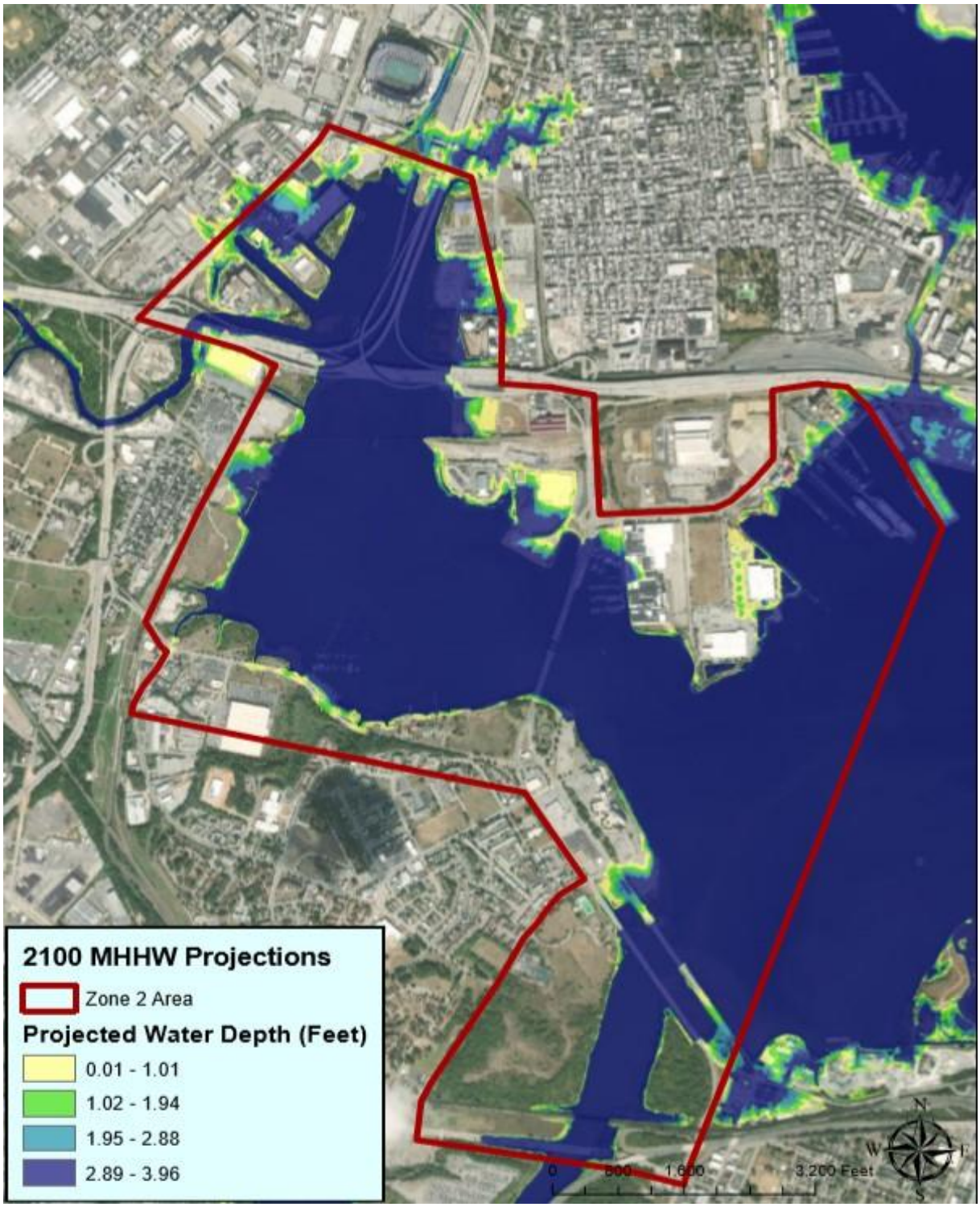


Figure 38: Zone 2 2100 projected water depths

5.2.3 Zone 3 Projections

Based on MDOT modeling, nuisance flooding currently affects an estimated 8 acres of land in Zone 3. Figure 39 illustrates both the range/extent and estimated water depths for current conditions within the zone. As we plan for the future, MDOT modeling predicts that nuisance flooding will grow to 32 acres in Zone 3 by 2050, and by the year 2100 nuisance flooding will encompass 196 acres in this zone. Figure 40 and Figure 41 provide details on the extent and water depths associated with nuisance flooding in 2050 and 2100, respectively. These modeling predictions are based upon present-day parameters and sea-level rise estimations. Table 15 provides estimated areas within Zone 3 to be affected by nuisance flooding based on model year. An analysis of the ensuing modeling shows that significant impacts on the downtown business and tourism district could occur from nuisance flood activity. Currently, promenade, piers, and adjacent properties in the Inner Harbor area are affected, however modeling shows that growing issues in Harbor East and along both the Light and Pratt Street corridors. By 2100, widespread nuisance flooding could affect major portions of the Inner Harbor, Harbor East, downtown business district, City government buildings, and along the Jones Falls corridor without the proper implementation of successful mitigation strategies.

Table 15: Predicted estimations of areas within Zone 3 affected by nuisance flooding based on model years

MODEL YEAR	AREA (ACRES)	OVERALL INCREASE (%)
2015	8	---
2050	32	300%
2100	196	512%

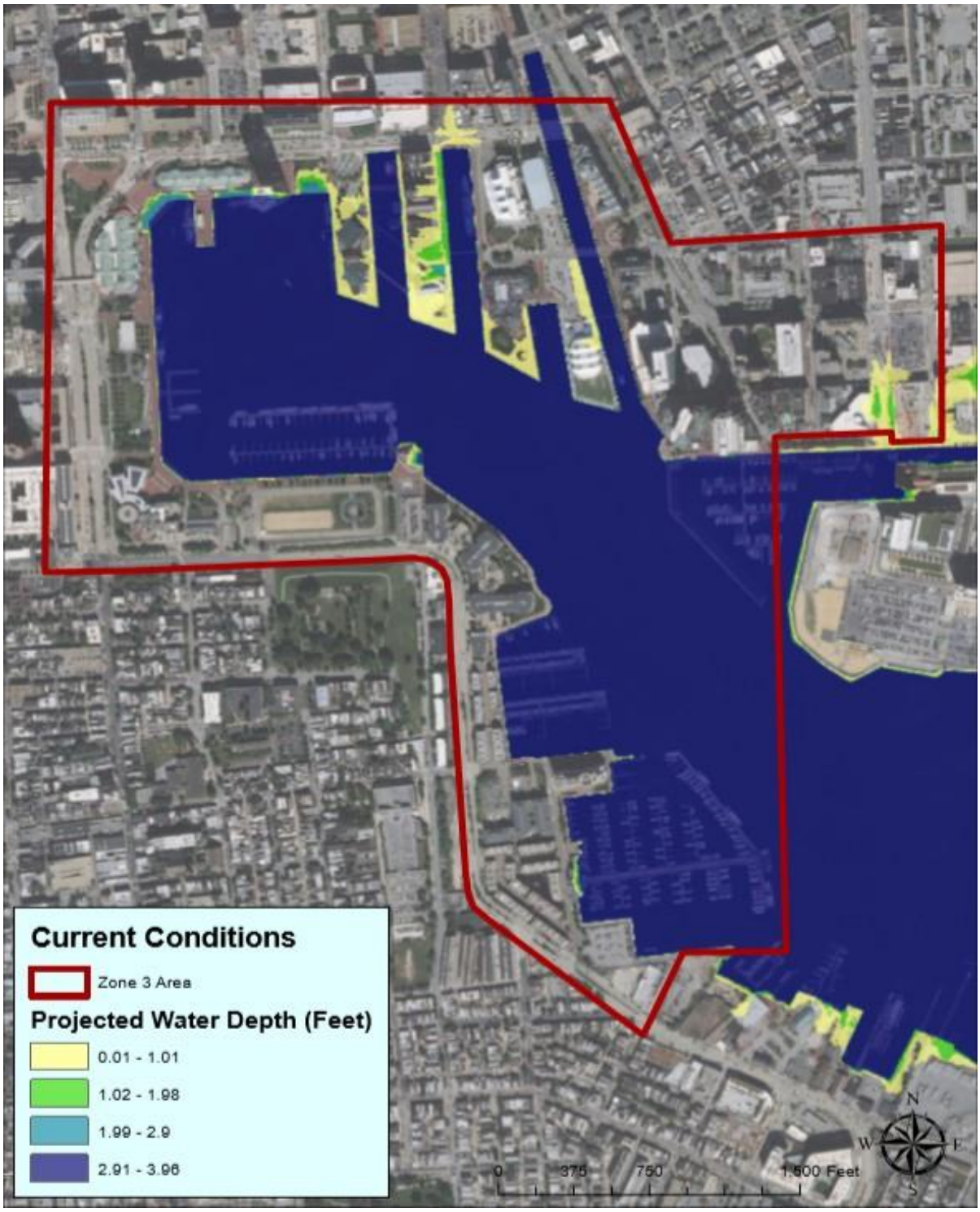


Figure 39: Zone 3 2015 baseline water depths (current conditions)

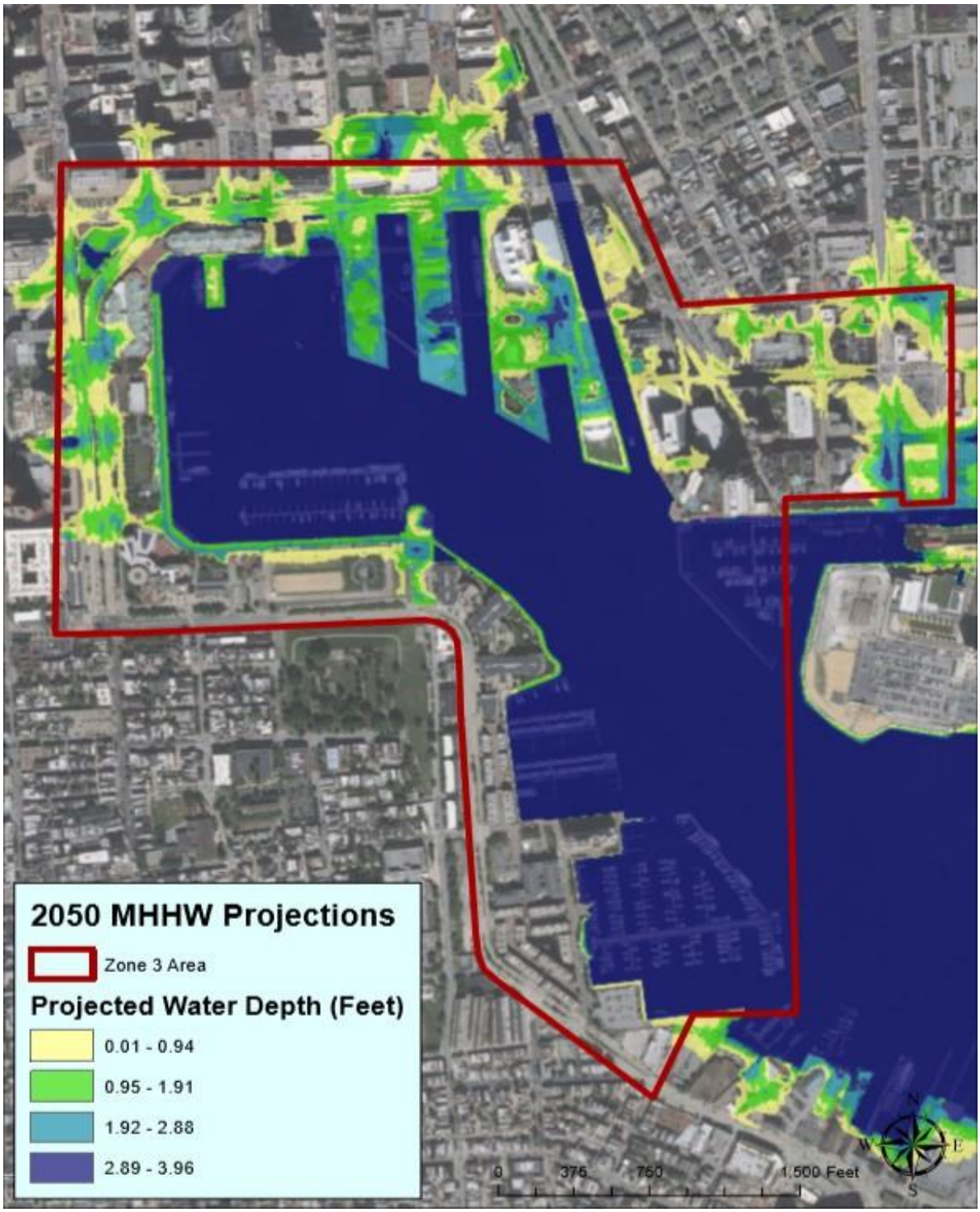


Figure 40: Zone 3 2050 projected water depths

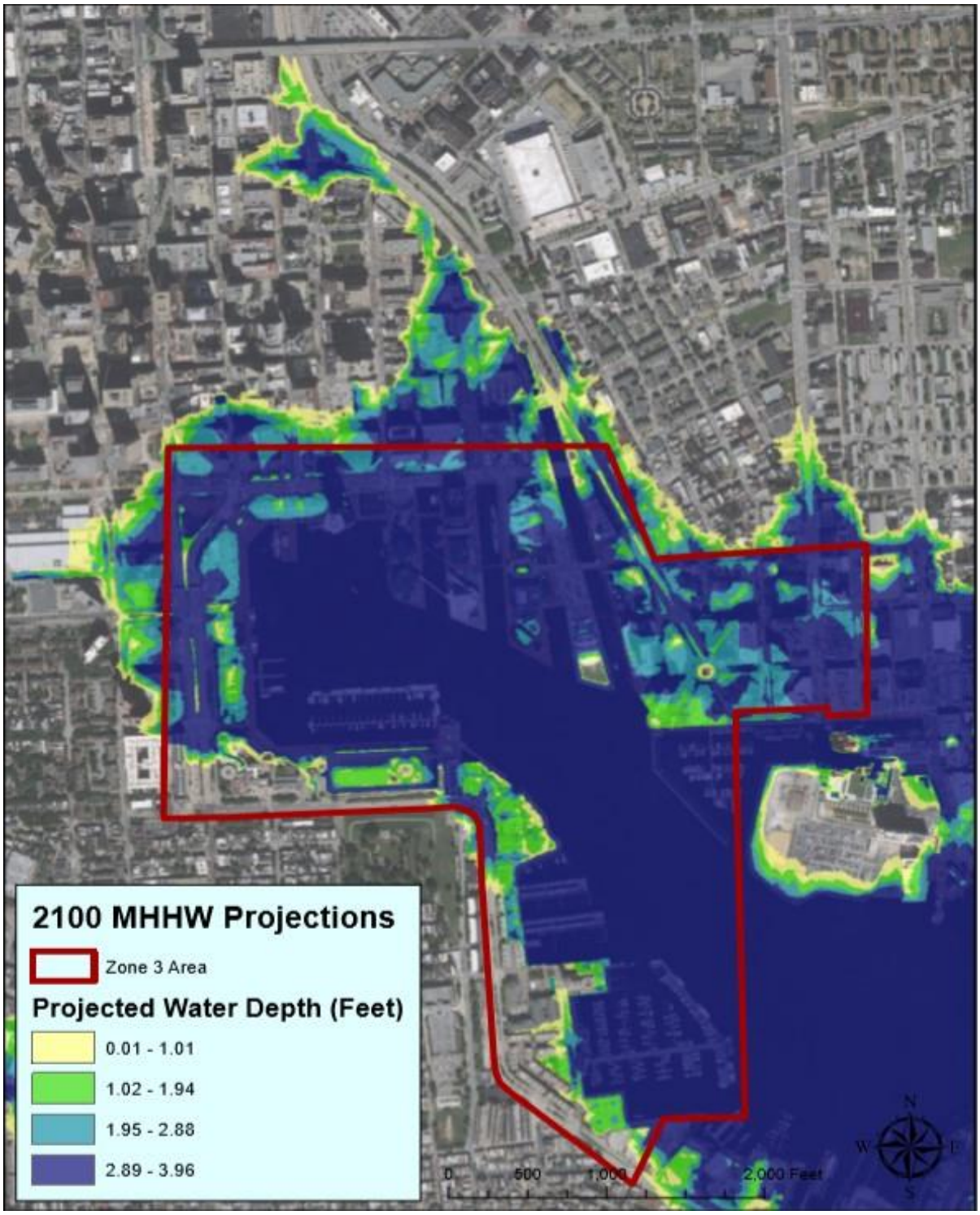


Figure 41: Zone 3 2100 projected water depths

5.2.4 Zone 4 Projections

Based on MDOT modeling, nuisance flooding currently affects an estimated 12 acres of land in Zone 4. Figure 42 illustrates both the range/extent and estimated water depths for current conditions within the zone. MDOT modeling predicts that nuisance flooding will grow to 16 acres in Zone 4 by 2050, and by the year 2100 nuisance flooding will encompass 119 acres in this zone. Figure 43 and Figure 44Figure 41 provide details on the extent and water depths associated with nuisance flooding in 2050 and 2100, respectively. The modeling predictions are based on current conditions and sea-level rise estimations. Table 16 provides estimated areas within Zone 4 to be affected by nuisance flooding based on model year. An analysis of the ensuing modeling shows that the problem of nuisance flooding in Zone 4 continues to grow both in range and water depths until it reaches a point much of Lower Fells Point is inundated by 2100 during nuisance flood events without the proper implementation of successful mitigation strategies.

Table 16: Predicted estimations of areas within Zone 4 affected by nuisance flooding based on model years

MODEL YEAR	AREA (ACRES)	OVERALL INCREASE (%)
2015	12	---
2050	16	33%
2100	119	644%

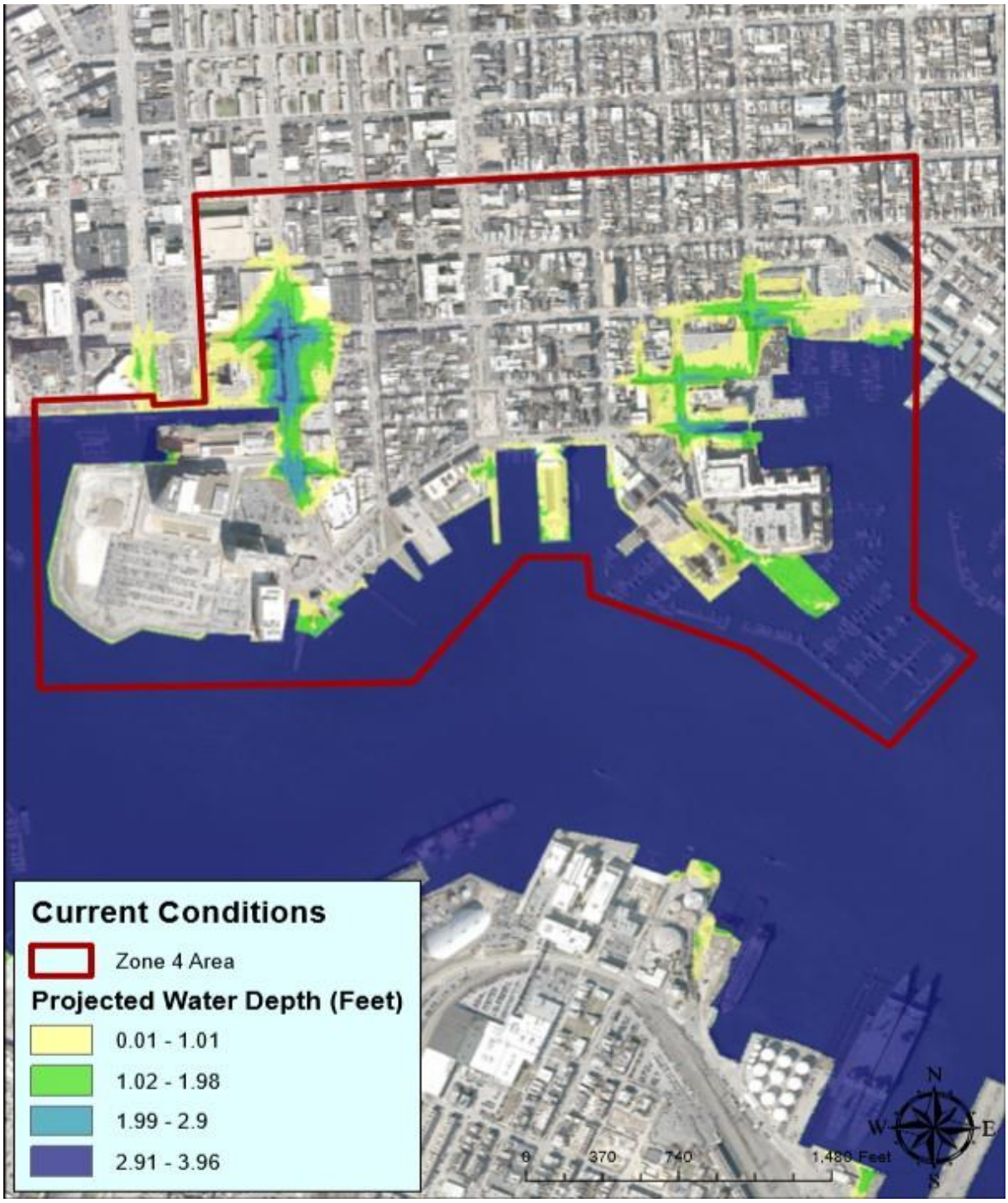


Figure 42: Zone 4 2015 baseline water depths (current conditions)

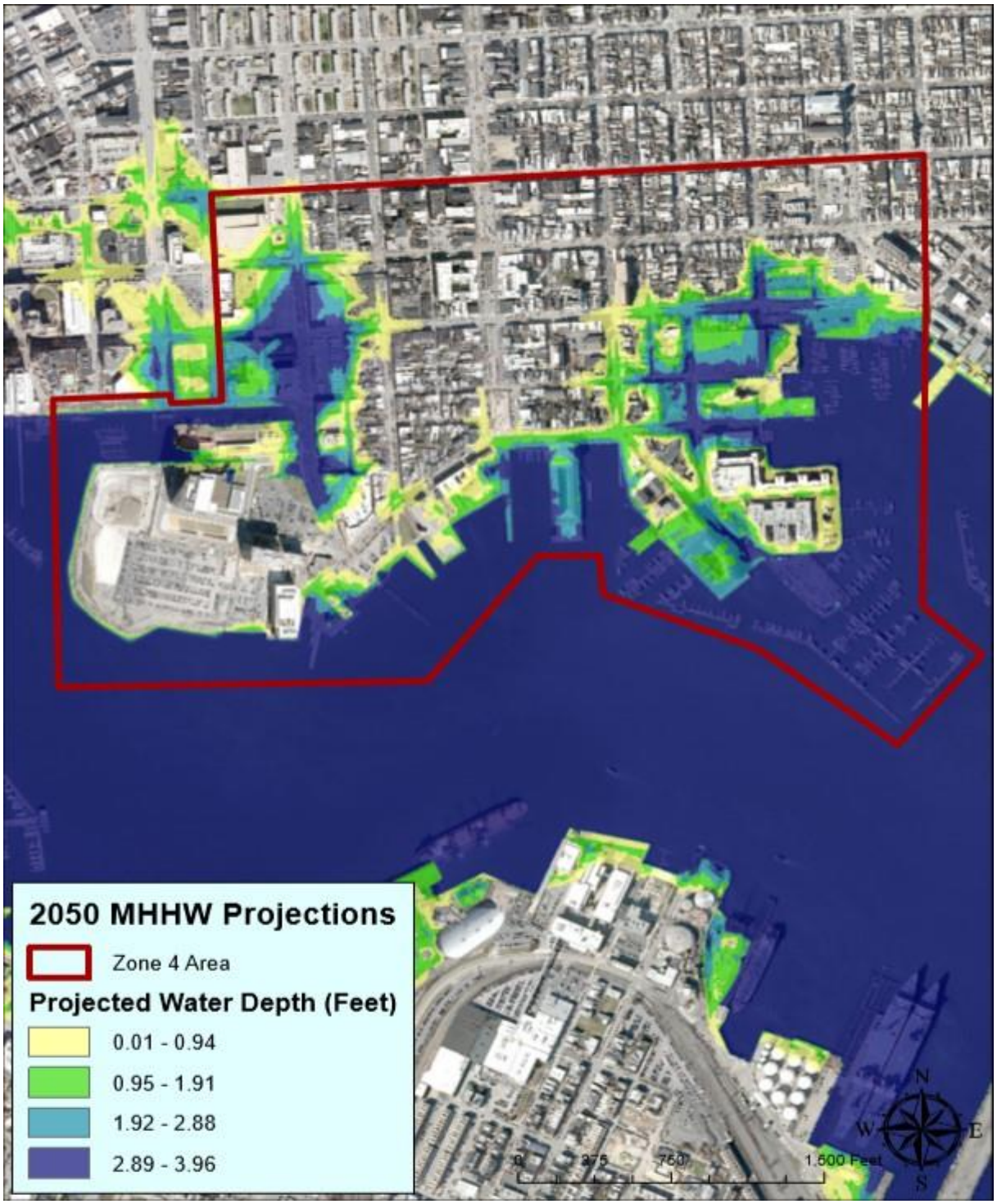


Figure 43: Zone 4 2050 projected water depths

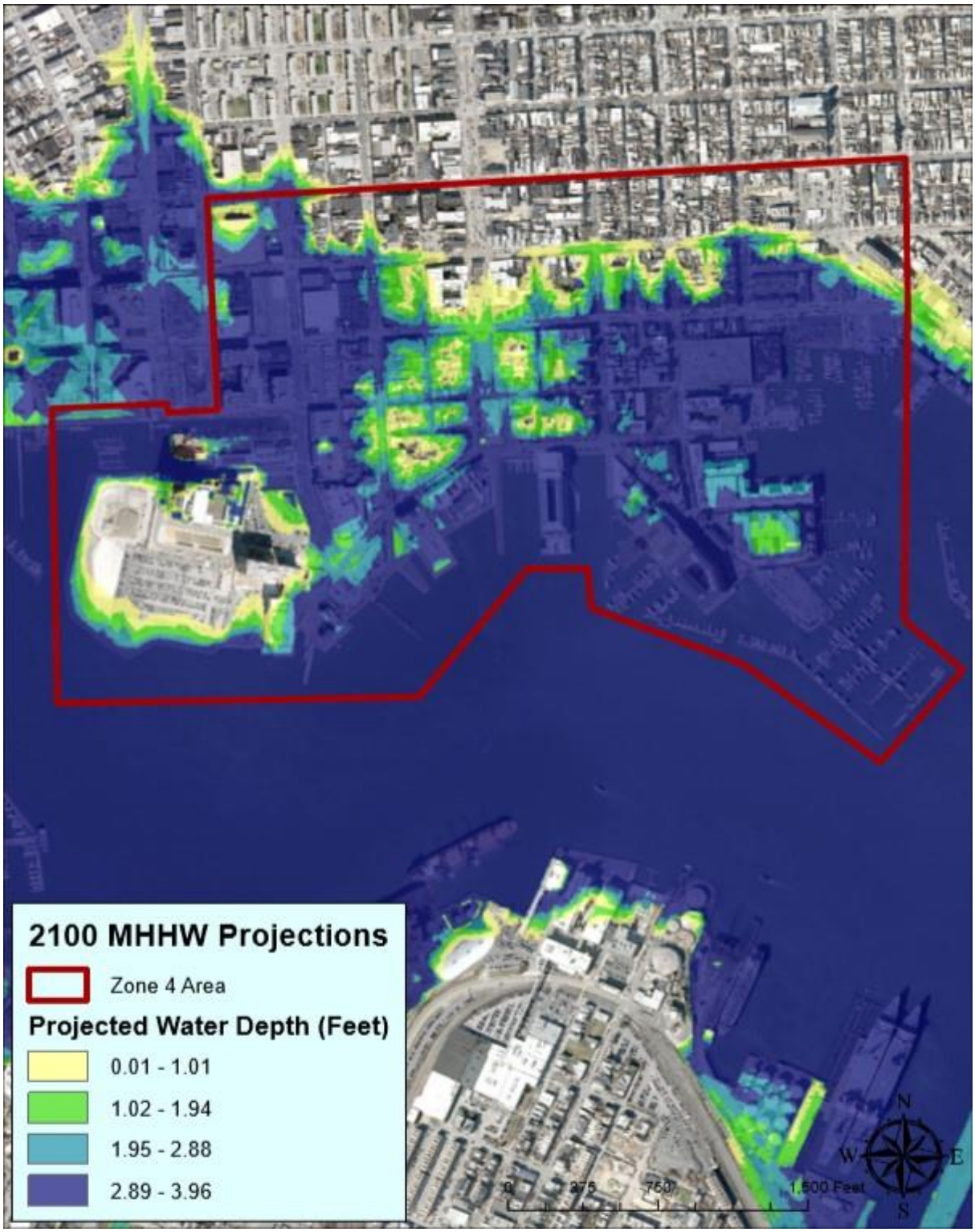


Figure 44: Zone 4 2100 projected water depths

5.2.5 Zone 5 Projections

Based on MDOT modeling, nuisance flooding currently affects an estimated 28 acres of land in Zone 5. Figure 45 illustrates both the range/extent and estimated water depths for current conditions within the zone. As we plan for the future, MDOT modeling predicts that nuisance flooding will grow to 82 acres in Zone 5 by 2050, and by the year 2100 nuisance flooding will encompass 388 acres in this zone. Figure 46 and Figure 47 provide details on the extent and water depths associated with nuisance flooding in 2050 and 2100, respectively. These modeling predictions are based upon present-day parameters and sea-level rise estimations. Table 17 provides estimated areas within Zone 5 to be affected by nuisance flooding based on model year. An analysis of the ensuing modeling shows that with time most shoreline in Zone 5 will eventually become affected by nuisance flooding. Specifically, Port of Baltimore operations, energy infrastructure, and large areas adjacent to the present-day Tide Point complex will see widespread and significant nuisance flood activity without the proper implementation of successful mitigation strategies.

Table 17: Predicted estimations of areas within Zone 5 affected by nuisance flooding based on model years

MODEL YEAR	AREA (ACRES)	OVERALL INCREASE (%)
2015	28	---
2050	82	193%
2100	388	373%

Figure 45: Zone 5 2015 baseline water depths (current conditions)

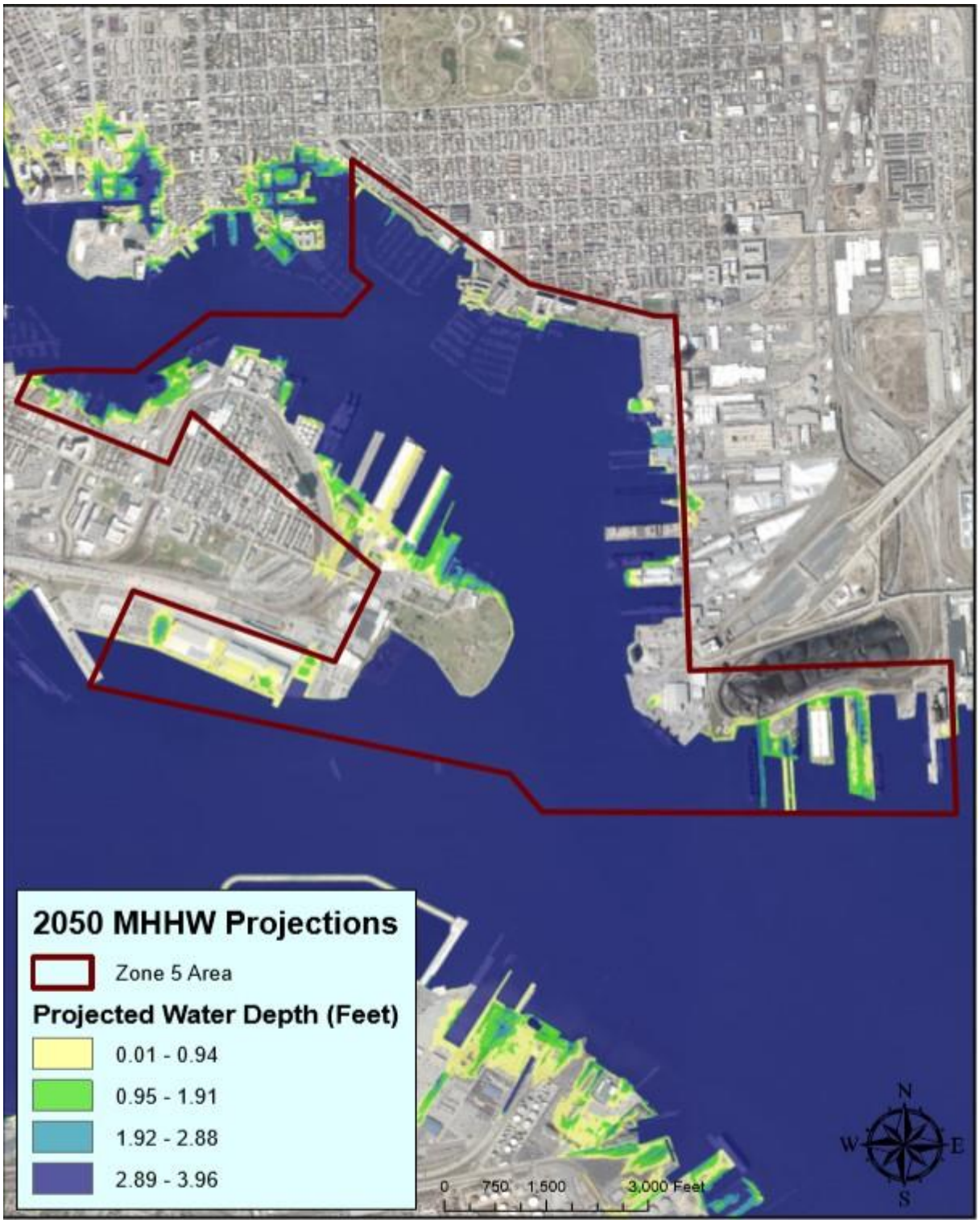


Figure 46: Zone 5 2050 projected water depths

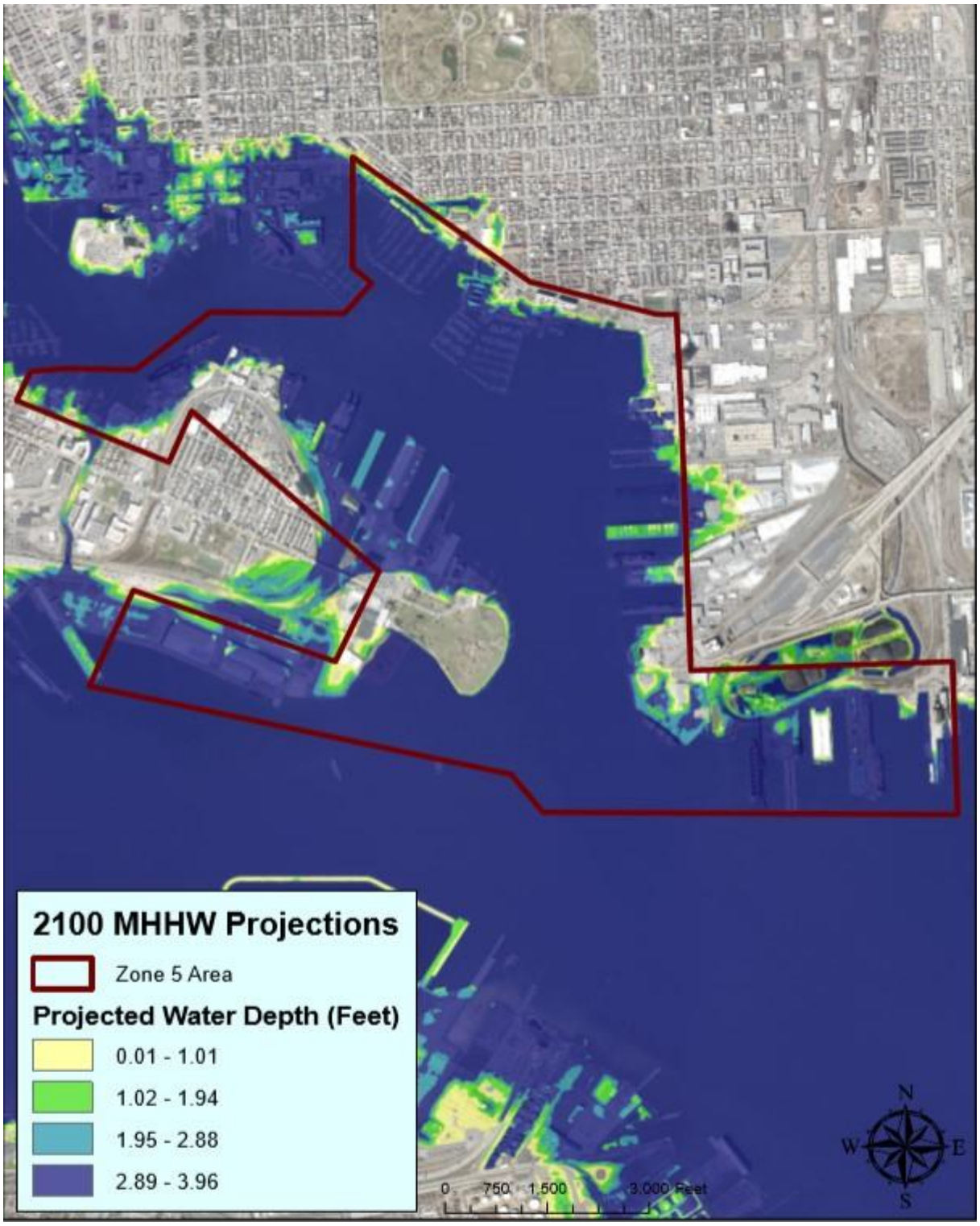


Figure 47: Zone 5 2100 projected water depths

5.2.6 Zone 6 Projections

Based on MDOT modeling, nuisance flooding currently affects an estimated 18 acres of land in Zone 6. Figure 48 illustrates both the range/extent and estimated water depths for current conditions within the zone. As we plan for the future, MDOT modeling predicts that nuisance flooding will grow to 80 acres in Zone 6 by 2050, and by the year 2100 nuisance flooding will encompass 114 acres in this zone. Figure 49 and Figure 50 provide details on the extent and water depths associated with nuisance flooding in 2050 and 2100, respectively. These modeling predictions are based upon present-day parameters and sea-level rise estimations. Table 18 provides estimated areas within Zone 6 to be affected by nuisance flooding based on model year. An analysis of the ensuing modeling shows that shorelines along Colgate Creek will continue to experience growing nuisance flood range and depth problems. Port of Baltimore operations, other critical infrastructure, and eventually residential areas in the St. Helena area will be affected without the proper implementation of successful mitigation strategies.

Table 18: Predicted estimations of areas within Zone 6 affected by nuisance flooding based on model years

MODEL YEAR	AREA (ACRES)	OVERALL INCREASE (%)
2015	18	---
2050	80	344%
2100	114	43%

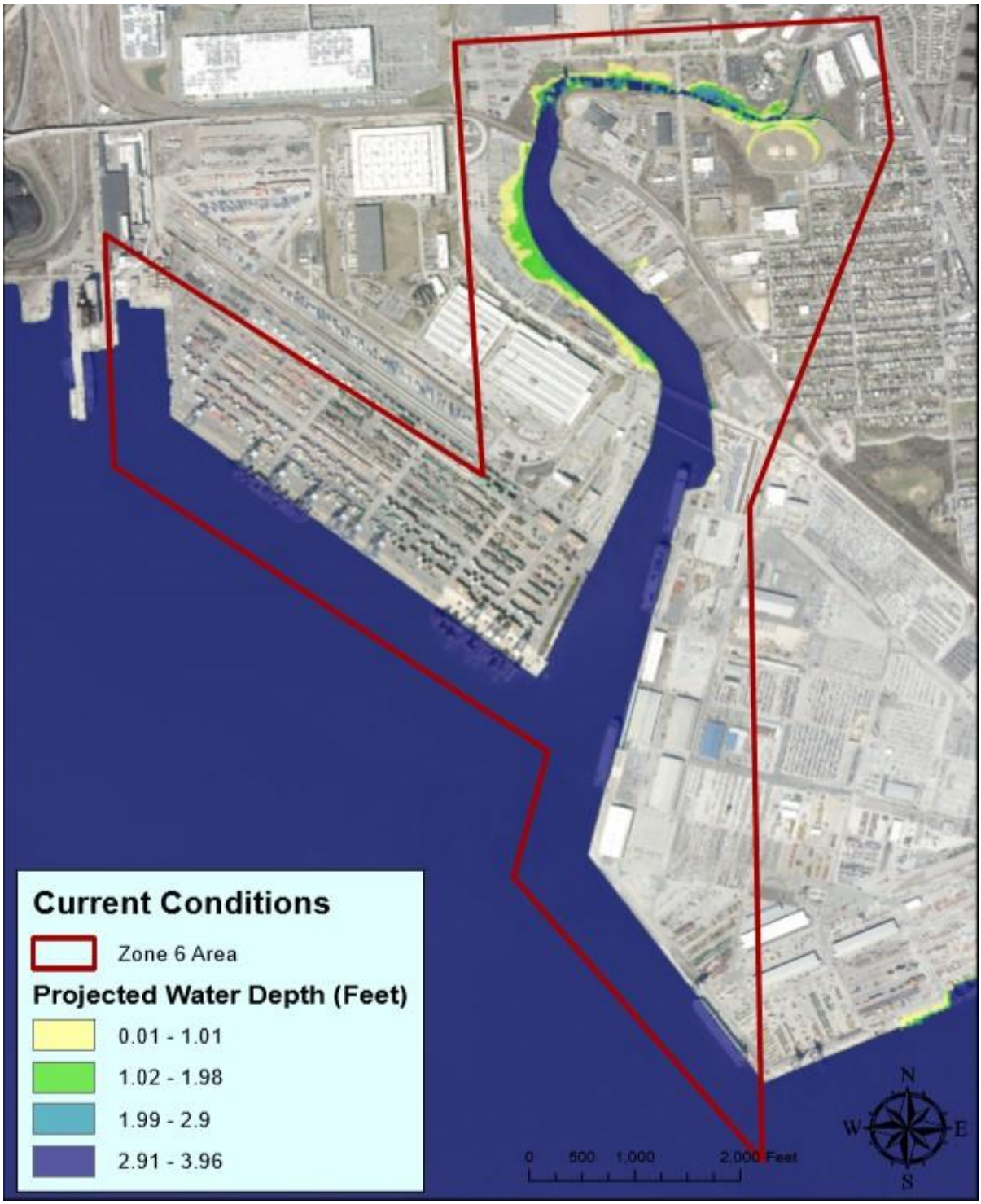


Figure 48: Zone 6 2015 baseline water depths (current conditions)

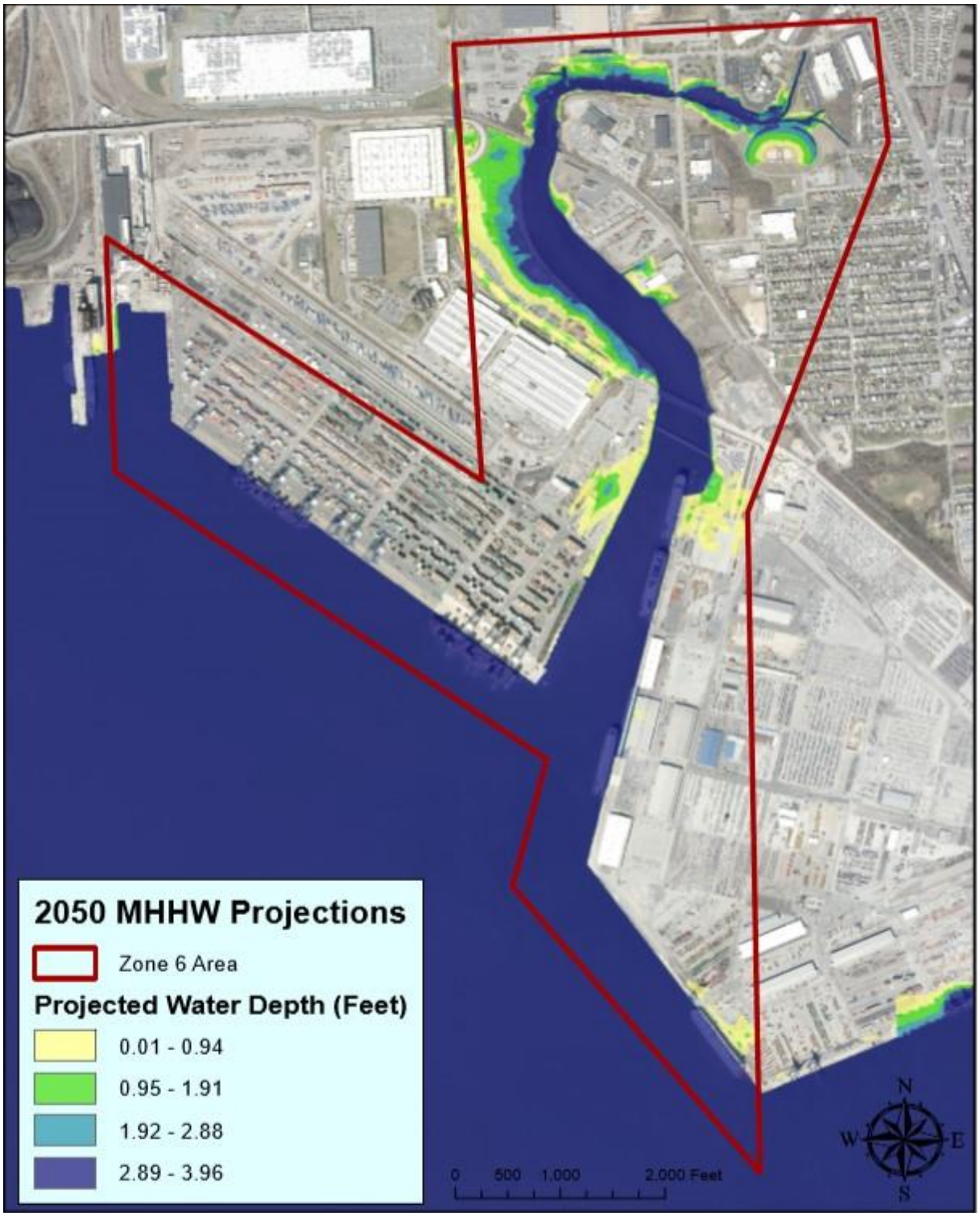


Figure 49: Zone 6 2050 projected water depths

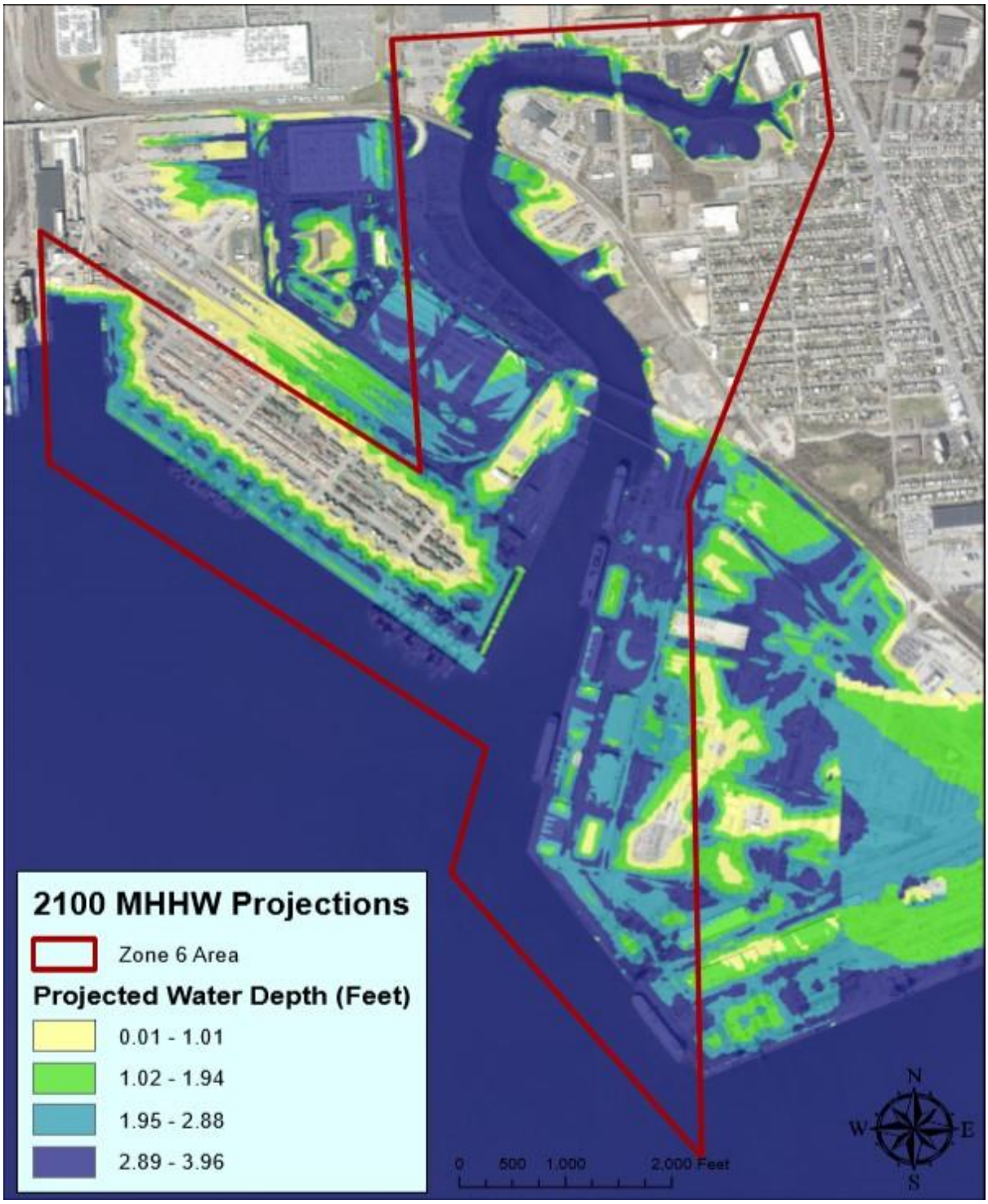


Figure 50: Zone 6 2100 projected water depths

5.3 EQUITY ASSESSMENT

Equity considerations have been assessed to determine whether nuisance flooding imposes negative impacts over minority or underserved communities in Baltimore. Using an "equity lens" acknowledges societal inequities that are long-standing and that have their roots in generations of unfair structural barriers. The methodology used in this mapping analysis is similar to that of other planning initiatives completed by the Baltimore Office of Sustainability (BoS), including the Coastal Adaptation Planning and Implementation in Baltimore City (CAPIR) and the City's DP3.

The analysis has been focused on residential areas located within the nuisance flooding hot-spots, specifically the six zones identified in this plan section. The zones were defined based on location, topographical features, land use and zoning type, frequency of nuisance flooding events based on historical data, and/or vulnerability indexes. Using these nuisance flood zones, additional map layers were identified at the census tract level, allowing for the performance of a more detailed equity analysis. Additional map layers identified for equity considerations in the analysis included:

- Age, specifically 5 & under and 65 & over
- Educational attainment
- Language spoken at home (limited English-speaking households)
- Employment status (civilian: 16 & over unemployed)
- Poverty status (below poverty level)
- Vehicle access (no vehicle available)

The following figures depict each of the equity layers listed above along with the identified nuisance flood zones. Concentration of populations for each of the map layers are shown as percentages by census tract within each zone. **Darker colors indicate a higher population concentration for each equity layer**.

Aggregation of these mapping products, Figure 51 to Figure 57, was completed in an attempt to provide a sense of overall vulnerability in order to guide prioritization for further analysis and investment. The final figure in this series provides a composite score percentage for all equity layers per census tract used in this analysis, Figure 58. **Nuisance flood Zone 1 contains census tracts with the highest population concentration of the combined equity layers**. Specifically, Zone 1 is comprised of four separate census tracts, one of which is shown in red, census tract 250500, which indicates the area of **highest social vulnerability based on this analysis**. The detailed attribute data table used in this analysis has been included in the appendix.

Please note that the "equity layers" developed are not meant to be comprehensive and neither is any weighting done to provide relative levels of importance. However, the concept is worth continuing to develop as other data sets are added.

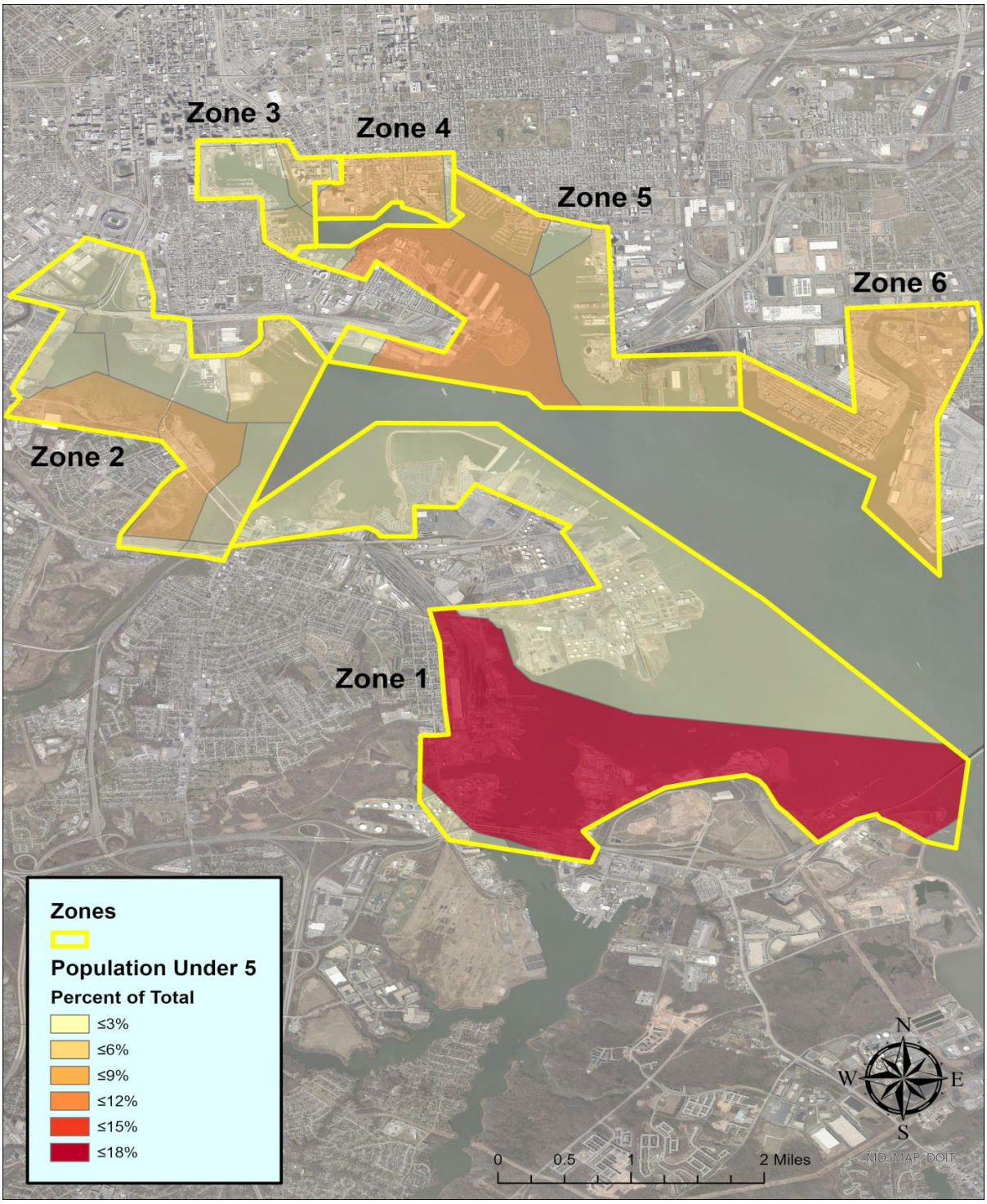


Figure 51: Nuisance Flood Zones and population under 5 years old equity layer

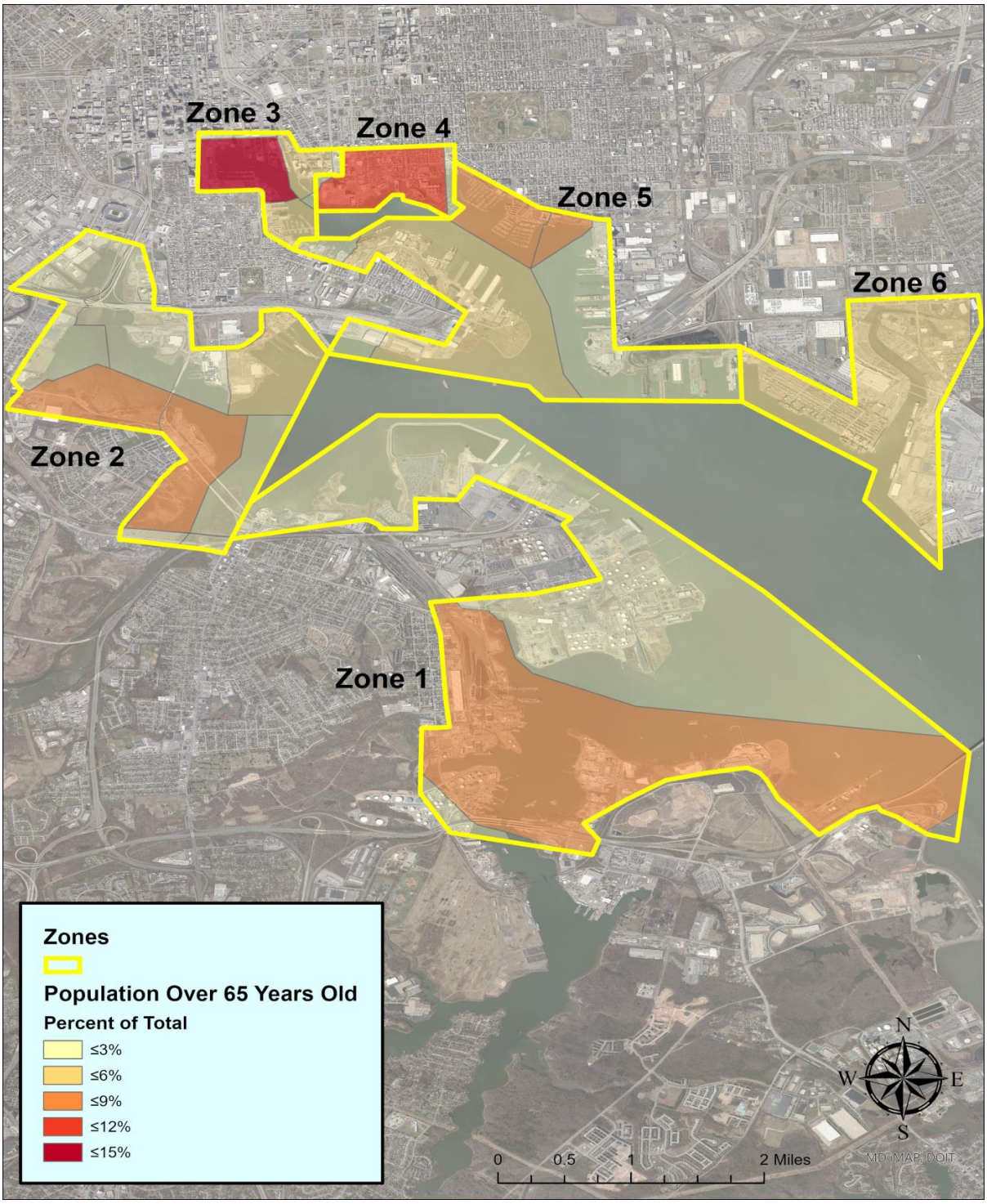


Figure 52: Nuisance Flood Zones and population over 65 years old equity layer

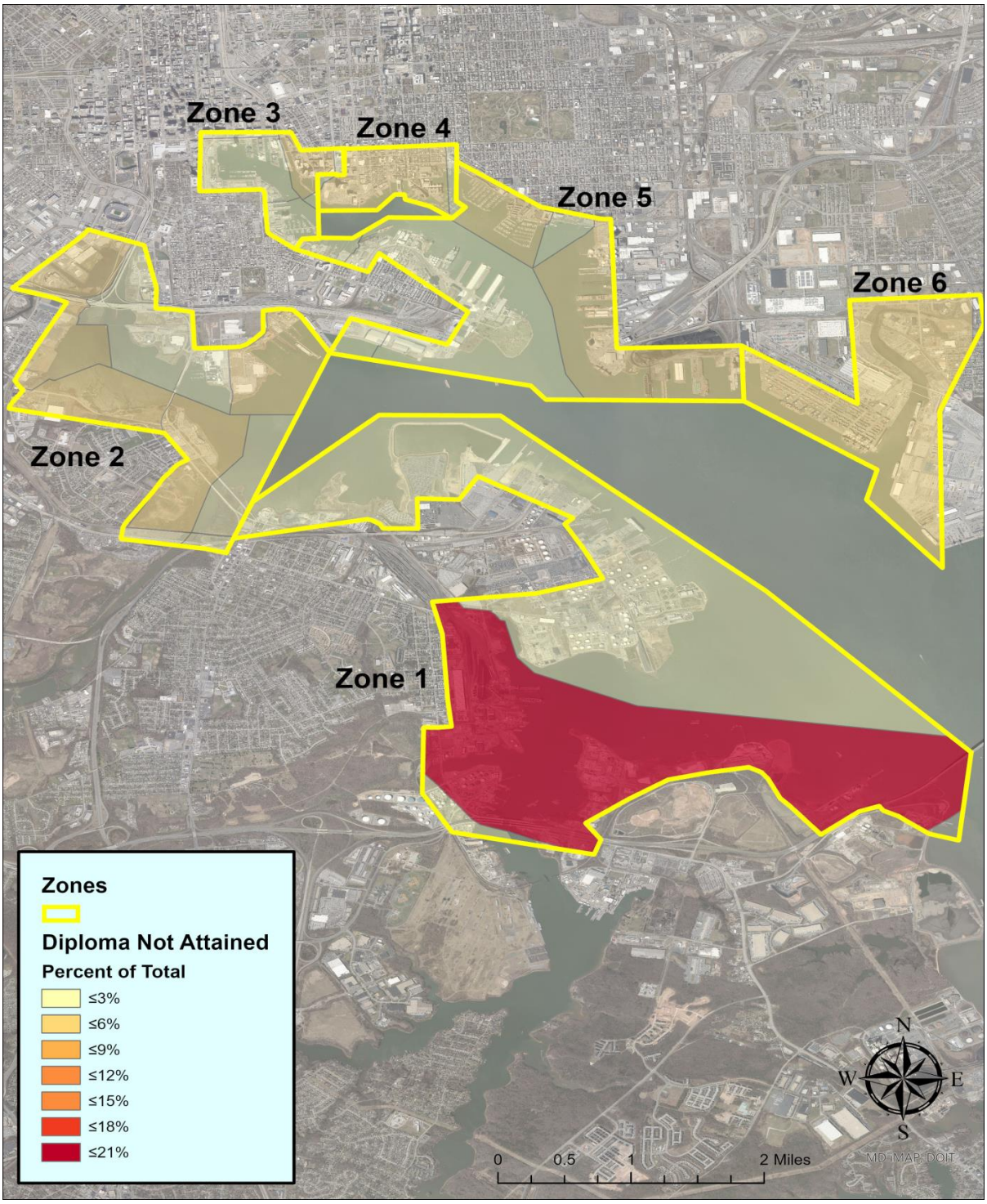


Figure 53: Nuisance Flood Zones and education attainment equity layer

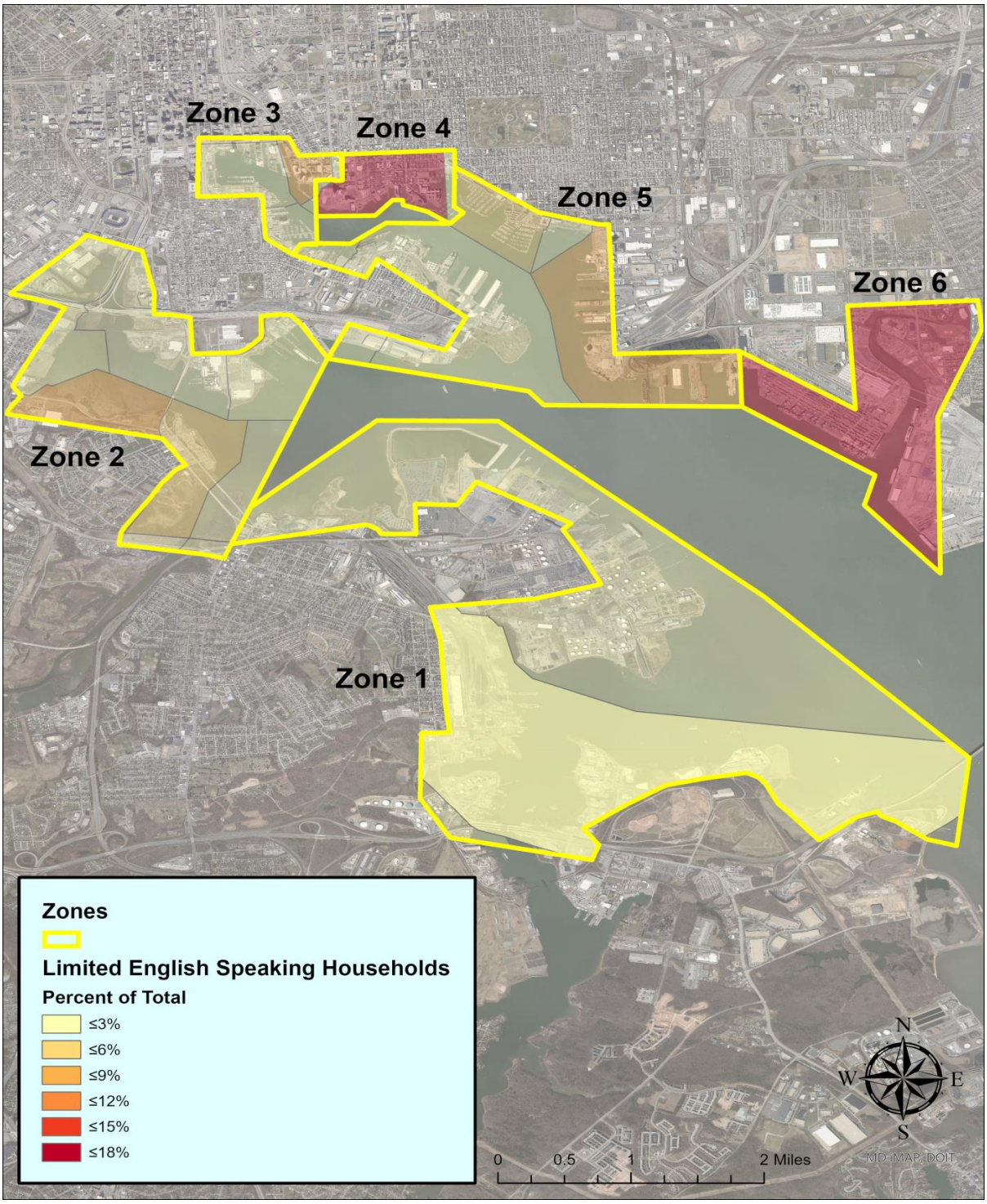


Figure 54: Nuisance Flood Zones and limited English speaking households equity layer

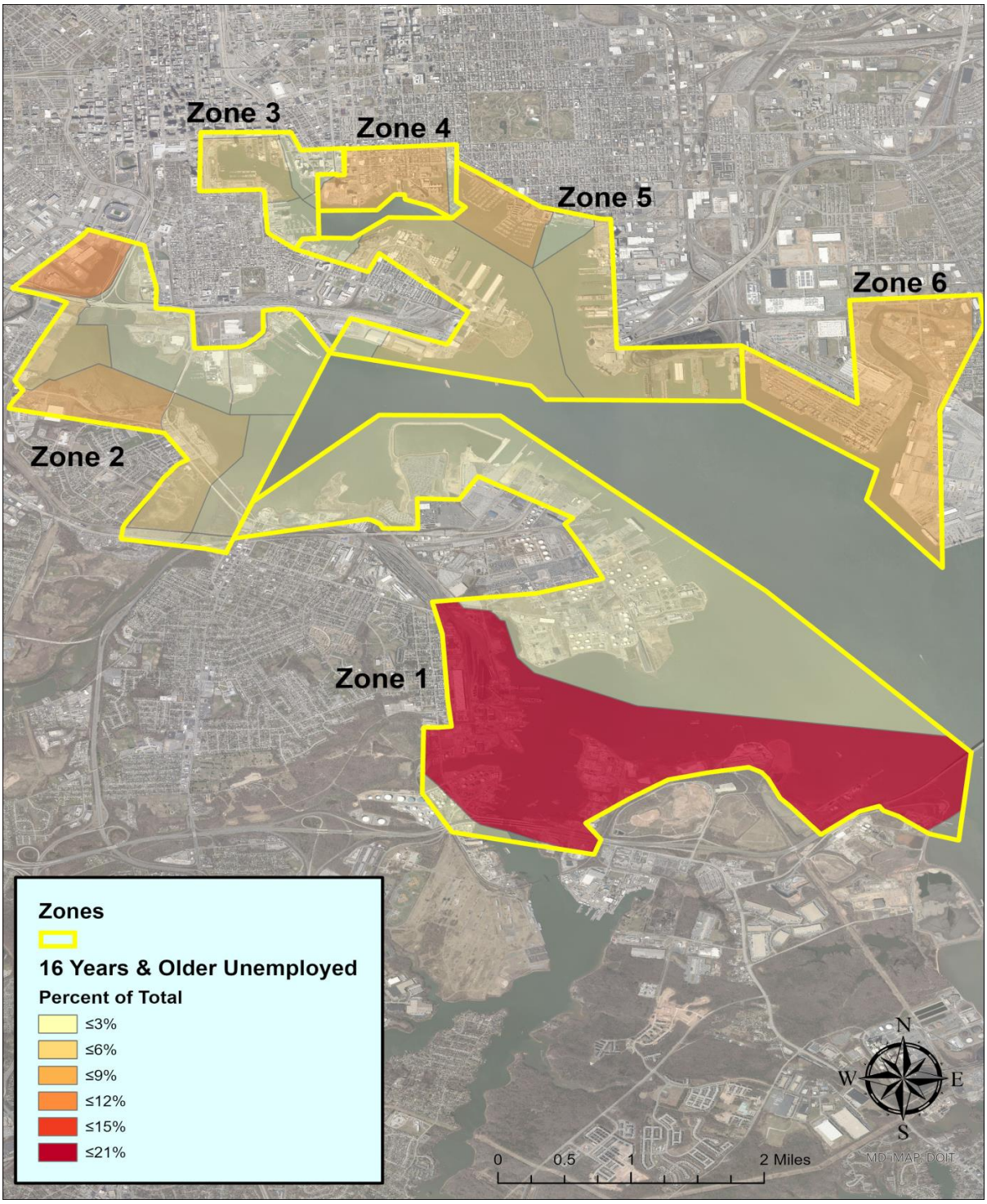


Figure 55: Nuisance Flood Zones and employment equity layer

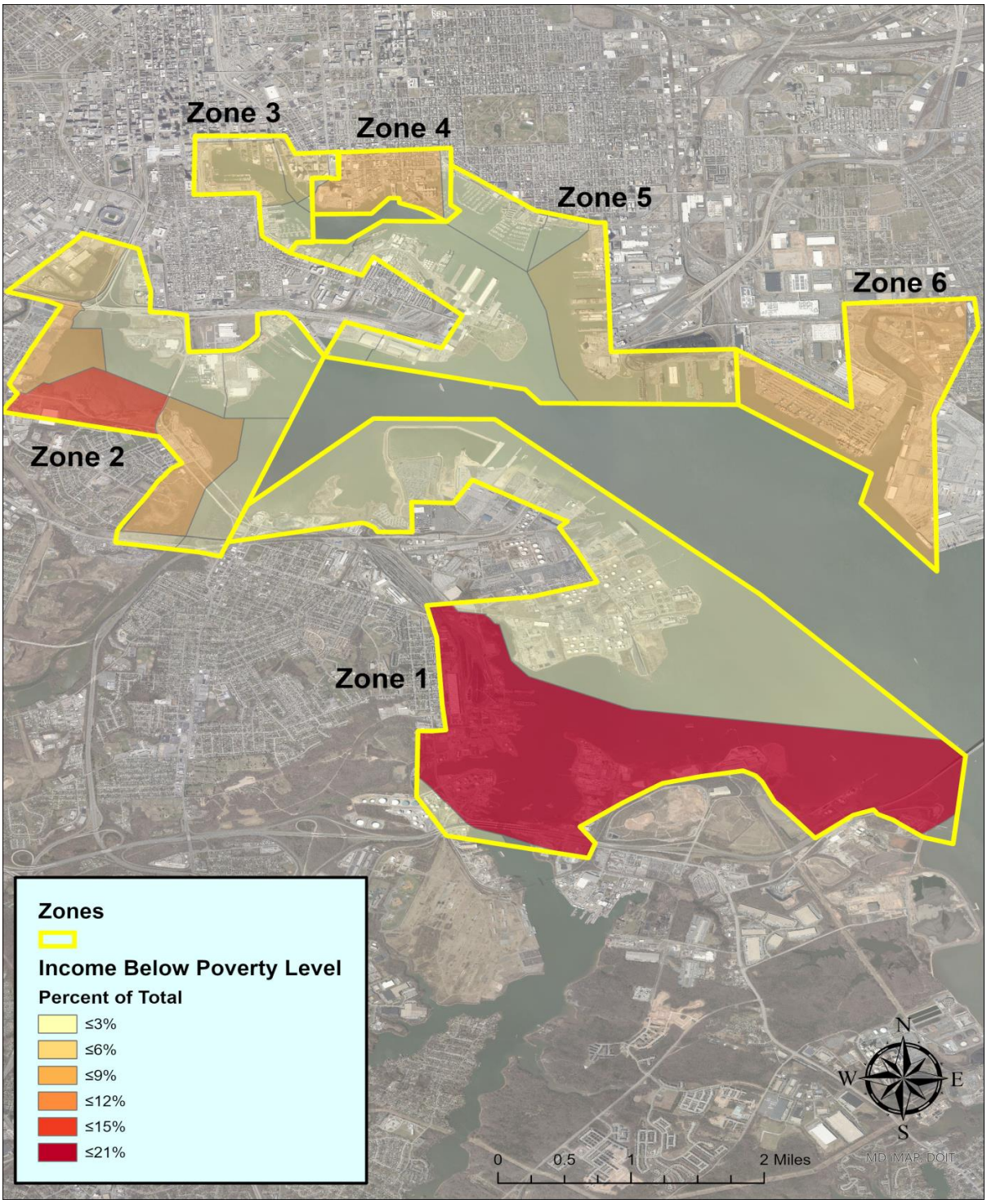


Figure 56: Nuisance Flood Zone and income below poverty level equity layer

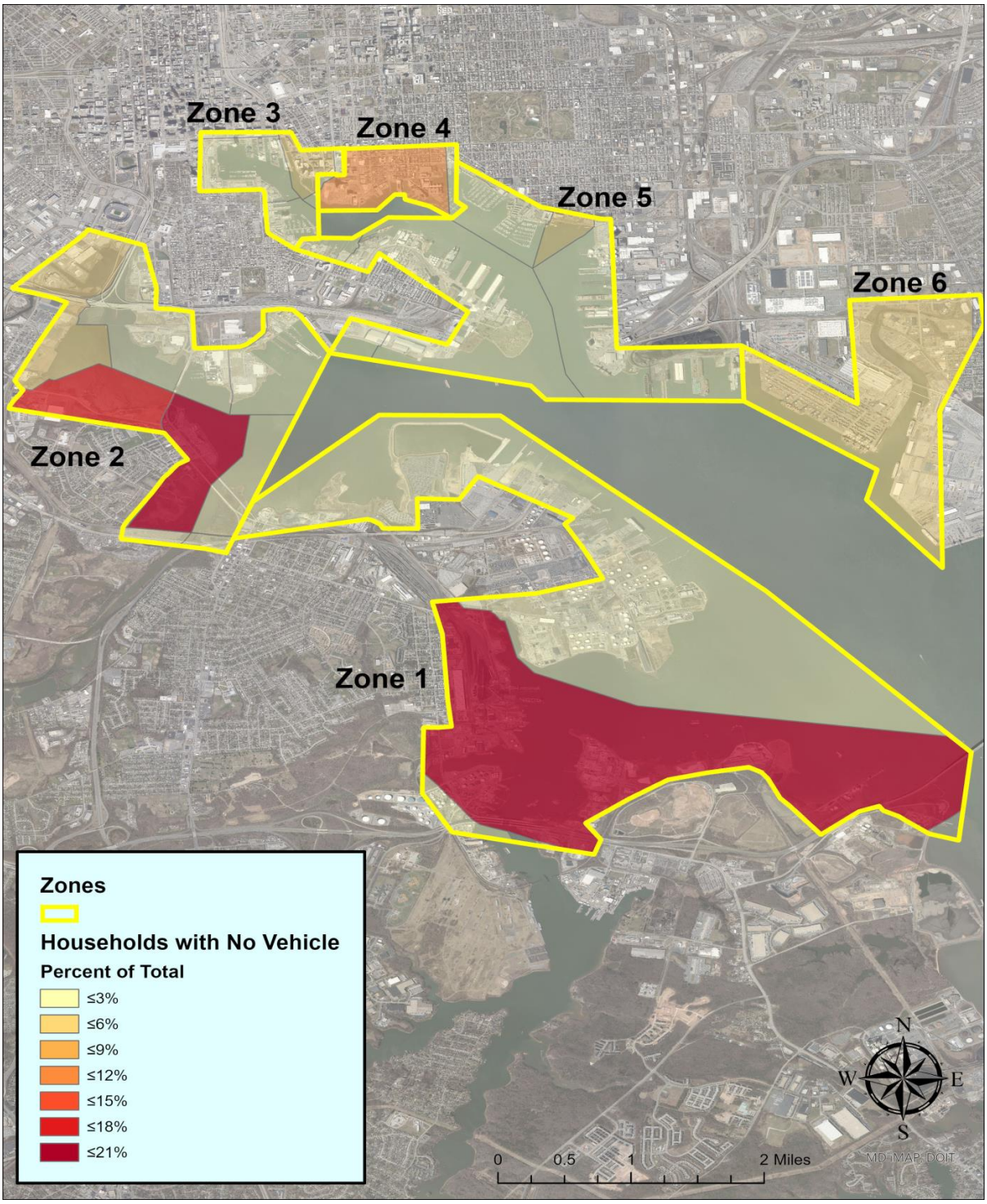


Figure 57: Nuisance Flood Zones and vehicle access equity layer

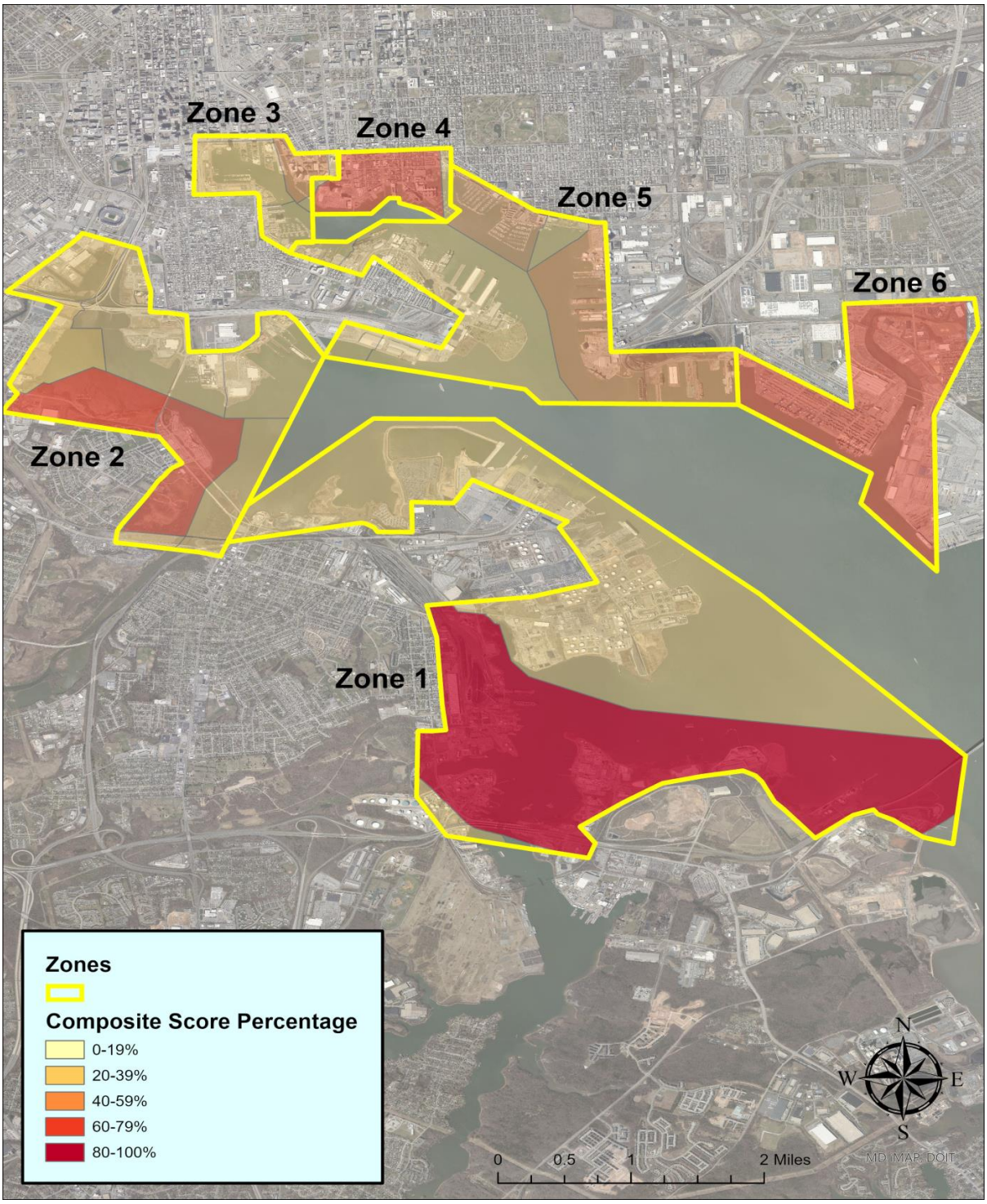


Figure 58: Nuisance Flood Zones and composite score percentage for all equity layers

6 RESPONSE APPROACH

6.1 CURRENT CONDITIONS

In response to nuisance flood events in Baltimore City, specific agency dispatch is dictated by the extent and location of flooding. Protocols and policies are in place to cover both emergency and non-emergency flood activity. For forecasted weather events, the Fire Department (BCFD) and its Office of Emergency Management (OEM), Department of Public Works (DPW), and Department of Transportation (DOT) generally plan for street closures and other strategies depending on the severity and type of upcoming weather. The various agencies are aware of frequently impacted areas in their response zone and adapt to other hazards and locations, as necessary. The Baltimore City Police Department (BCPD) does not have a roll in response to nuisance flooding due to the non-emergency nature of the events. The BCPD is tasked with preserving life and property, and therefore nuisance flooding by itself does not prompt notification and response by the agency.

6.1.1 Weather Awareness

Baltimore City government agencies are notified through the National Weather Service alerts, AccuWeather and other forecast services of impending weather events. The hazards that most often trigger action include intense precipitation, extreme high tides, wind events, hurricanes and tropical storms. Depending on the severity of a single weather event or the combination of multiple events (for instance, wind event in conjunction with extreme high tide) may require proactive road and sidewalk/Promenade closures, transit and pedestrian detours, inlet cleaning, and other mitigation strategies. In many cases, City social media outlets and/or local news agencies are utilized to inform citizens of expected hazard conditions.

6.1.2 Emergency Response to Hazards

Nuisance flooding is defined as minor flooding that produces public inconveniences; however, events preceding or following nuisance flooding in Baltimore City can become life-threatening. When that happens, the City has protocols in place for multi-agency deployment, life saving measures, incident containment, command center coordination, and public health assessments. Post-disaster activities include media advisement, damage assessment, provisions for displaced citizens, and post-incident analysis. The actions and core agencies tasked with emergency response are described in the City of Baltimore Emergency Operations Plan prepared and maintained by the BCFD/OEM.

6.1.3 Non-Emergency Response to Nuisance Flooding

Currently, when nuisance flooding occurs on its own, response action is initiated through the City's 3-1-1 Service when a resident reports the event, and when an extreme weather event is forecasted by BCFD/OEM and DOT.

6.1.3.1 Baltimore City Fire Department

6.1.3.1.1 City's 3-1-1 Service

Upon receiving a nuisance flood report, 3-1-1 customer service agents categorize the event as Flooded Streets, which is one of the 3-1-1 Service's Service Requests Types. The code Flooded Streets service request is created in the Salesforce system which integrates with DPW's Water and Wastewater Bureau 's CityWorks system. The service request triggers agency deployment to investigate the flood report and make an initial assessment. Upon investigation, DPW' s Water and Wastewater Bureau may manage the incident alone, or other City agencies may be requested to perform traffic control, debris clean-up, or other associated problems. When complete, the 3-1-1 Service is updated to confirm whether the incident has been resolved or if it requires further attention.

6.1.3.1.2 Office of Emergency Management

The Office of Emergency Management (OEM) proactively tracks the weather using the National Weather Service and the Contrail OneRAIN systems to guide early response and public notifications regarding flood events, including nuisance

flooding. OEM tracks tide levels using information provided by the National Weather Service, and it tracks City-operated stream gauges located throughout the city. The stream gauge data is also relevant to nuisance flood events, as defined in this plan, because during combined events (tidal/ pluvial and/or riverine flooding), the stormwater that originated in non-tidal areas of the watershed may overwhelm the drainage system and intensify the level and geographic range of nuisance flooding.

Regarding response and coordination, OEM is responsible for notifying other City agencies of upcoming weather and current issues that may require response actions. That includes DOT for street closures and DPW for inlet cleaning. OEM crafts and publishes public messaging via the BMORE ALERT mass notification system, along with other notification methods to ensure that the public is aware of impending weather and possible impacts. The office also dispatches crews for on-site event monitoring as needed.

6.1.3.2 Department of Transportation

DOT utilizes the forecasting service AccuWeather to proactively respond to weather events. The events tracked by the agency that trigger action include intense precipitation/storms and wind events. DOT does not currently track extreme high tide events. BCFD and OEM utilize the National Weather Service alert system to track extreme weather events, which include extreme high tides. OEM notifies DOT when a forecasted event requires street closures.

6.1.3.3 Department of Public Works

6.1.3.3.1 Bureau of Water and Wastewater

The Bureau of Water and Wastewater (BWW) receives notifications and flood response requests from BCFD, through OEM and the 3-1-1 Service. The Bureau dispatches crews to clean stormwater inlets and other stormwater infrastructure in the target areas as needed. The BWW also conducts proactive cleaning of stormwater infrastructure across the city, including inlets and culverts, which happens both on a set schedule and when a large storm is forecasted to impact the city.

6.1.3.3.2 Bureau of Solid Waste

Nuisance flood events often cause the accumulation of waterborne trash on land, which requires action by the Bureau of Solid Waste (BSW). The BSW is responsible for solid waste management in Baltimore, including floating debris. The agency has crews assigned to proactively perform street-sweeping throughout the city, as well as in areas of the promenade that are nuisance flood hot-spots. The BSW also operates trash-skimmers to collect floating debris in areas near Fort McHenry and into the Harbor. Other water-based trash collection systems include a trash intercepting system, Mr. Trash Wheel, located at the mouth of the Jones Falls (a project by the Waterfront Partnership of Baltimore- Healthy Harbor Initiative), and City-managed floating booms (located in the Middle Branch area).

The BSW does not track weather forecasts and they do not get notified by other City agencies of extreme high tide events. However, because the agency proactively cleans the Inner Harbor promenade twice per day, the early morning crews address any accumulated trash over land brought by the high tides. The agency noted that two nuisance flood hot-spots in the Inner Harbor that require regular cleaning is the Amphitheater and the waterfront area near the Science Center, both located in Nuisance Flood Zone 3.

6.2 RECOMMENDATIONS

The list of recommendations below was developed throughout the planning process and includes, if available, recommendations received from the public.

- A process for tracking flooding events across the City, and not just within the regulatory floodplain as defined by FEMA, should be developed by each responding agency. The outputs from such database could be added to the process of nuisance flood events tracking.
- Public comments received during the public comment period indicate the need for the expansion of the study area to the entire geographic range of the city. The public comments received reflects the need for assessing

other flooding sources, including pluvial/urban and riverine flooding that happens outside of the regulatory floodplain as defined by FEMA. Additional funding should be allocated to support the work and/or grant funding should be pursued.

- Those areas identified as priorities for additional signage, especially those identified for the installation of signage with flashing warning lights, staff should identify “triggers’ for light usage based on weather warnings and notifications.
- Educate DPW, DOT and BCFD staff on the expected increase in nuisance flood incidents within Baltimore City, based on current projections and geographic range hot-spot areas. The action will help the agencies prepare for increasing response demands and develop plans to address the growing problem more efficiently.
- Increased weather monitoring, as it specifically relates to coastal flood hazards, watches, and warnings.
- Seek help from DPW, DOT and BCFD with data collection as the agencies respond to nuisance flood events. This could include data on water depths observed, amount of debris collected, specific location information, and assets affected. The data could be used to inform the selection of mitigation strategies for specific hot-spots.
- Seek a partnership with DPW/SWB and educate the crews that perform proactive street cleaning along the promenade to report nuisance flood events through the MyCoast application. The partnership would enable the City to have accurate records of all ranges of nuisance flood events and help validate and further refine the tide elevation thresholds that cause nuisance flooding in the city.
- Increase the level of inter-agency communication to optimize and improve the response to nuisance flood events.

7 IMPACTS AND MITIGATION STRATEGIES

7.1 IMPACTS

Nuisance flooding, although represented by minor events, has the potential to incur a variety of negative impacts over communities located near the waterfront**.** Due to the **expected increase in the frequency of occurrence and the range of areas impacted by nuisance flooding** over the next decades, it is important that local jurisdictions understand the types of impacts that can be expected, and the mitigation strategies that should be considered.

7.1.1 Public Health Risks and Safety

Floods at any depth may threaten public health and safety. Ponded flood water of any depth can provide habitat for mosquitos and other disease vectors. Flood waters, especially sewage systems surcharges may contain bacteria and contaminants such as toxic chemicals or wastes that may cause illness, especially in children. The contaminated runoff may dilute water bodies and so extend the impacts well beyond urban areas.

Even a **shallow layer of water can transmit electrical shock** from downed power lines or bad electrical wiring. Public health and safety risks increase with increases in water depth. Fast-moving flood water is dangerous based on the potential to be hit by debris or be swept away.

Marine wildlife can also pose a safety hazard during nuisance flood events. Although the potential for inland migration of hazardous marine wildlife is currently low, it is expected to increase as the events become more severe with higher water elevations. This potential hazard emphasizes the importance of public awareness regarding flood waters, and the many dangers associated with flooding.

7.1.2 Property Damage

Property damage from flooding includes impacts to structures, contents and utilities, and is strongly correlated with flood depths, especially when water elevations rise above the first finished floor. Although nuisance flooding is associated with flood heights below finished floor elevations, commercial buildings are often constructed with doorways at ground level, and thus, building contents are exposed to flooding when flood levels overtop street curbs. Residences with first floor elevations on grade are similarly vulnerable to building content damage. Given that street curbs typically rise 10–12 inches above the roadway, this height is representative of the upper limit on flooding from a damage perspective.

7.1.3 Homeowners and Businesses

Homeowners and businesses tend to bear a large portion of repair costs due to nuisance flooding, since these events usually do not trigger government assistance. Small Business Administration loans are also not available to those affected by a nuisance flood event that is not declared a disaster. In addition, damages from flooding might not exceed the deductible on a flood insurance policy. From the perspective of a single homeowner or business owner, even a small-scale flooding that causes damage to property or contents can be a notable event. Owners bear the cost of uninsured repairs and may face lower resale prices of their assets. Policies under the National Flood Insurance Program (NFIP) do not cover a broad range of damages including vehicles, landscaping, septic systems, business interruption, and a range of assets located in basements. Reoccurring flooding can especially be problematic for NFIP policyholders since four claims in excess of $5,000 can lead to a “severe repetitive loss property” classification.

Additionally, **businesses located near the waterfront can suffer revenue losses** when flooded streets, sidewalks or parking lots keep customers from reaching their establishments.

7.2 MITIGATION STRATEGIES

The planning process is just as important as the plan itself. **Risk-based decision-making guides communities to become more sustainable and disaster-resistant by focusing efforts on hazards and disaster-prone areas, and by identifying appropriate mitigation actions**. As such, the 2018 DP3 acts as the foundation for Baltimore's long-term strategy to reduce disaster impacts and damage. 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.

Following identification of affected critical assets and the significance that nuisance flooding will continue to present for the City of Baltimore, it is evident that **mitigation strategies, new ideas, and future planning must be developed and implemented**. Nuisance flooding will affect infrastructure, communities, cultural and historical components, transit routes, and many other aspects of city life. In concurrence with Baltimore's DP3 plan, several mitigation strategies are already in progress and being planned. This plan attempts to identify the pertinent mitigation approaches listed in the DP3; and explore new ideas, technologies and plans being utilized by other jurisdictions affected by nuisance flooding.

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 both short and long-range policies and actions that can be implemented to reduce the magnitude of current risks and future losses. The City's hazard mitigation strategies and actions should also enable Baltimore City to increase its overall resilience to the hazards it faces. In Baltimore City, resilience is defined as the ability to anticipate, accommodate, and positively adapt to or thrive amidst changing climate conditions or hazard events and enhance quality of life, reliable systems, economic vitality, and conservation of resources for present and future generations.

Although this plan strictly focuses on minor coastal flooding and coastal hazard response, many other broad and comprehensive planning actions included in DP3 supplement and support actions to manage nuisance flooding. These strategies include protection and resiliency enhancement of infrastructure systems in the energy, communication, wastewater/water, and transportation sectors, integrating climate change factors into design and maintenance plans, developing hazard adaptation plans for critical facilities, and strengthen partnerships and coordination plans with private stakeholders, surrounding governments, and NGOs. And while all strategies and actions developed in DP3 are critical, the sections that follow illustrate actions being implemented to specifically address nuisance flooding in Baltimore City. The strategies were divided into four sectors to include infrastructure, buildings, natural systems, and public services. The complete list of strategies can be found in Appendix 5-1 of the DP3.

7.3 STAKEHOLDERS

The strategies and actions listed below were carefully chosen from the DP3 due to their potential to mitigate nuisance flooding specifically. The City agencies responsible for the implementation of the mitigation strategies included in this section are DOT, BCFD, DOP and DPW. The strategies were divided by agency, or offices within an agency, and listed in a survey to enable the preparation of a status report on each item. A summary of responses including suggestions for strategy refinement, if available, are included below as provided by the responding agency.

7.4 INFRASTRUCTURE STRATEGIES

7.4.1 Transportation

Goals: Integrate climate change into transportation design, building, and maintenance; Identify additional alternative routes and modes for effective transport and evacuation efforts during emergency situations.

- Determine the coastal storm vulnerability and complete an exposure assessment of City transportation assets. (DP3 Ref. IN-7)
- Improve stormwater management, operations and maintenance for stream flooding that erodes bridge supports. (DP3 Ref. IN-7)

- Research utilizing existing and new rating systems for all new infrastructure and road projects. (DP3 Ref. IN-7)
- Identify, investigate, and incorporate Best Management Practices related to transportation design, construction and maintenance. (DP3 Ref. IN-7)
- Require that backup solar-powered streetlights and signals be integrated along evacuation routes and high-traffic areas. (DP3 Ref. IN-7)
- Educate the public on the dangers of driving through flooded roads. (DP3 Ref. IN-8)

Stakeholder Updates: Improvements to stormwater management, operations and maintenance for stream flooding are ongoing. The Department of Transportation follows the policy of the Maryland State Administration and performs post flood inspections after flooding is experienced at the susceptible bridge locations. The Bridge Engineering Section is moving away from the traditional practice of designing the storm water management facilities for its projects to the minimum standards necessary to obtain the permit for the Maryland Department of the Environment. The City is now designing to the level of water that are being experienced and recorded on local flood gauges. (DP3 Ref. IN-7)

Outreach materials, such as, "Turn Around, Don't Drown" have been distributed as part of the Frederick Avenue outreach initiative. (DP3 Ref. IN-8)

Suggestions for Refining Strategies: Cease the practice of designing the storm water management facilities for its projects to the minimum standards necessary to obtain the permit for the Maryland Department of the Environment. It doesn't work and always results in claims from the contractors. (DP3 Ref. IN-7)

7.4.2 Stormwater

Goals: Enhance and expand stormwater infrastructure and systems; Modify urban landscaping requirements and increase permeable services to reduce stormwater runoff; Evaluate and support DPW's stream maintenance program; Support and increase coordination and information sharing across jurisdictions to better enable mitigation of cross-water impacts of the regions' watersheds.

- Implement the requirements of Baltimore's MS4 (separate stormwater and sewer system) permit. (DP3 Ref. IN-16)
- Prioritize storm drain upgrades and replacement in areas with reoccurring flooding. (DP3 Ref. IN-16)
- Install backflow-prevention devices or other appropriate technology along waterfront to reduce flood risk. (DP3 Ref. IN-16)
- Preserve and protect natural drainage corridors. (DP3 Ref. IN-16)
- Review and revise storm drain design on a continuous basis, to accommodate projected changes in intense rainfall. (DP3 Ref. IN-16)
- Pursue grants for Flood Control measures to alleviate flooding in the most flood prone areas when and where feasible. (DP3 Ref. IN-16)
- Support existing stormwater requirements and continue to evaluate and improve Best Management Practices. (DP3 Ref. IN-17)
- Encourage urban landscaping requirements and permeable surfaces into community-managed open spaces. (DP3 Ref. IN-17)
- Utilize water conservation elements such as green roofs, rain gardens, cisterns, and bioswales on residential, commercial, industrial, and City-owned properties to capture stormwater. (DP3 Ref. IN-17)
- Encourage permeable paving on low-use pathways. (DP3 Ref. IN-17)
- Pursue grants for Floodplain Storage and Diversion projects to alleviate flooding in the most flood prone areas when and where feasible. (DP3 Ref. IN-17)
- Review and improve status of standing maintenance requirements. (DP3 Ref. IN-18)

- Ensure adequate funding is in place to support stream maintenance. (DP3 Ref. IN-18)
- Identify opportunities where stream restoration efforts will offset maintenance costs. (DP3 Ref. IN-18)
- Identify interdependencies and benefits of stream maintenance with other transportation programs. (DP3 Ref. IN-18)
- Conduct regular maintenance of streams and stormwater quality facilities: clear streams, prioritize dredging, increase inspection and cleaning of culverts and storm drains. (DP3 Ref. IN-18)
- 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). (DP3 Ref. IN-19)

Stakeholder Updates: The Office of Emergency Management (OEM), along with other city agencies, are pursuing grants for mitigation in various flood prone areas in the City. (DP3 Ref. IN-16).

Hydrology and hydraulics (H&H) study for the Frederick Avenue corridor is scheduled to be completed by 2021. (DP3 Ref. IN-17)

The encouragement of urban landscaping requirements and permeable surfaces into community-managed open spaces is ongoing. The action is sponsored by the Critical Area Management Program offset-fee grants and DPW grants for impervious surface removal, rain garden installation, etc. (DP3 Ref. IN-17).

7.4.3 Communication Systems

Goal: Evaluate and improve the resiliency of communication systems that are in place for hazard events.

- Identify best practices for the installation and management of floodproofing for all communication infrastructure at risk of water damage. (DP3 Ref. IN-6)

7.4.4 Waterfront

Goals: Alter transportation systems in flood-prone areas in order to effectively manage stormwater; Enhance the resiliency of the City's waterfront to better adapt to impacts from hazard events and climate change.

- 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. (DP3 Ref. IN-9)
- Raise streets in identified flood-prone areas as they are redeveloped. (DP3 Ref. IN-9)
- Encourage development of Green Streets in flood-prone areas and throughout the City. (DP3 Ref. IN-9)
- Encourage use of permeable pavement in non-critical areas–low-use roadways, sidewalks, parking lots and alleys where soils permit proper drainage. (DP3 Ref. IN-9)
- Add pumps or other mitigation alternatives to streets as they are redeveloped (if needed). (DP3 Ref. IN-9)
- Assess need for new culvert capacity and identify where upgrades are needed. (DP3 Ref. IN-9)
- Conduct an in-depth analysis of the impacts of drain fields that feed the harbor. (DP3 Ref. IN-9)
- Expand and reinforce existing stormwater education programs. (DP3 Ref. IN-9)
- Design and implement floodgates and barriers in transportation tunnels. (DP3 Ref. IN-9)
- Encourage Federal and State Government to design and install floodgates and barriers at vulnerable transportation tunnels. (DP3 Ref. IN-9)
- Upgrade existing floodgate hardware and mechanisms to control rise rate of water into all city tunnels. (DP3 Ref. IN-9)
- Raise bulkhead height along shoreline areas most at risk. (DP3 Ref. IN-12)

- Encourage the development of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures. (DP3 Ref. IN-12)
- Review and enhance coastal area design guidelines to better mitigate the impacts of flooding. (DP3 Ref. IN-12)
- Enhance and strengthen waterfront zoning and permitting. (DP3 Ref. IN-12)

Stakeholder Updates: The encouragement the of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures is ongoing. Two examples include the Middle Branch Plan and Frederick Avenue Stormwater Mitigation efforts. (DP3 Ref. IN-12)

The review and enhancement of coastal area design guidelines to better mitigate the impacts of flooding is ongoing. The CAMP Manual 2020 update prevents new bulkheads from being built, for example.

The enhancement and strengthening of waterfront zoning and permitting is ongoing. The Department of Planning is working on a revision of Article 7 Natural Resources Code Division I (floodplain requirements). The revision will include waterfront areas that are located within the regulatory floodplain. (DP3 Ref. IN-12)

Suggestions for Refining Strategies: "Encouraging" is not an action, green infrastructure integration should be included as a codified required. (DP3 Ref. IN-12)

7.4.5 Solid Waste Management

Goal: Reevaluate and support a comprehensive debris management plan for hazard events

- Expand and integrate existing programs to reduce or intercept debris before it gets into the streams and harbor.
- Investigate, develop and promote solid waste management actions for disposing of waste debris removal before a hazard event.

7.4.6 Wastewater

Goal: 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. (DP3 Ref. IN-13)
- Develop and adopt increased level of protection for construction, redevelopment, and design of all water and wastewater facilities that incorporate future climate projections. (DP3 Ref. IN-13)
- Establish protocols and ensure effective operations and security for wastewater treatment plants when facilities are overwhelmed during large storm events. (DP3 Ref. IN-13)
- Increase stormwater recharge areas and quantity management to prevent flooding from overflows. (DP3 Ref. IN-13)
- Conduct a risk assessment of the City's current water and sewer systems to identify age, condition of infrastructure, capacity, weaknesses and areas for priority upgrades. (DP3 Ref. IN-13)
- Conduct and utilize a detailed risk assessment to determine vulnerability of the sewage treatment plant to prevent overflows from extreme storm events. (DP3 Ref. IN-13)

- 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. (DP3 Ref. IN-13)

7.4.7 Policy and Government Decision Making

Goals: Encourage the integration of climate change and natural hazards into private and State planning documents, systems, operations, and maintenance; Develop City policy which requires new city government capital improvement projects to incorporate hazard mitigation principles

- Incorporate consideration of hazards and climate adaptation efforts into all plans, systems, operations, and maintenance. (DP3 Ref. IN-21)
- Ensure Red Line planning incorporates adaptation strategies (if resurrected). (DP3 Ref. IN-21)
- Ensure hazard scenarios, utilized in vulnerability assessments, are at a minimum 25% greater in intensity and impact than historical record events to date. (DP3 Ref. IN-21)
- Develop guidelines for hospital, health care facilities and other institutional entities. (e.g. Universities) (DP3 Ref. IN-21)
- Partner with regional air quality institutions to integrate air quality measures and messaging into City climate change policy efforts. (DP3 Ref. IN-21)
- Discourage new public projects in hazard-prone areas such as floodplains or the coastal high hazard areas. (DP3 Ref. IN-22)
- Utilize hazard mitigation design requirements that exceed minimum standards for critical facilities. (DP3 Ref. IN-22)
- Use comprehensive infrastructure assessments to identify infrastructure in need of replacement and prioritize funding for those projects. (DP3 Ref. IN-22)

Stakeholder Updates: The consideration of hazards and climate adaptation efforts into all plans, systems, operations, and maintenance is an ongoing effort. For instance, in the development of the new Less Waste, Better Baltimore Plan, hazard planning was integrated so as to suggest increased capacity for the landfill in case of disaster. (DP3 Ref. IN-21)

The use of comprehensive infrastructure assessments to identify infrastructure in need of replacement and prioritize funding for those projects is ongoing. System for improved asset management and prioritization of infrastructure needs/CIP funding allocation has recently begun. (DP3 Ref. IN-22)

Suggestions for Refining Strategies: More clearly strengthen requirements for the Capital Improvements Program (CIP) for other agencies to include climate and adaptation as justifications for their projects and funding requests. (DP3 Ref. IN-21)

7.4.8 Energy

Goal: Protect and enhance the resiliency and redundancy of electricity systems

- Identify, harden, and water seal critical infrastructure relative to pump stations, treatment plants, electrical, heating, and ventilation facilities within the floodplain. (DP3 Ref. IN-1)
- Evaluate the City of Baltimore's utility distribution system and identify "underground utility districts" using BGE's May 2013 short-term reliability improvement plan. (DP3 Ref. IN-1)
- Determine low-lying substation vulnerability and outline options for adaptation and mitigation. (DP3 Ref. IN-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. (DP3 Ref. IN-1)

7.4.9 Liquid Gas

Goal: Protect and manage liquefied natural gas sites and City fueling stations before and during hazard events

- Adopt building code that requires anchoring of 50-gallon storage tanks or larger. (DP3 Ref. IN-4)
- Support the Maryland Public Service Commission's effort to accelerate replacement of aging natural gas infrastructure, which will harden the system against flooding. (DP3 Ref. IN-4)

Stakeholder Updates: In flood hazard areas, tanks must be installed at or above the elevation required by the Floodplain Management Code (Natural Resources Code - Article 7) or as otherwise allowed by the Floodplain Management Code. (DP3 Ref. IN-4)

7.5 BUILDING STRATEGIES

7.5.1 City Codes and Design Guidelines

Goals: Develop and implement hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.; Enhance City building codes that regulate building within a floodplain or near the waterfront; Strengthen City zoning, floodplain, and construction codes, to integrate anticipated changes in climate; Update list of flood-prone and repetitive loss buildings to consider for acquisition.

- Conduct educational outreach for city-owned, residential, commercial, and industrial buildings about proper storage and disposal of hazardous materials and heating oil. (DP3 Ref. B-1)
- Require hazardous materials stored in city-owned, residential, commercial, and industrial buildings within the floodplain to be elevated a minimum of 3 feet above the freeboard. (DP3 Ref. B-1)
- Require new critical facilities to be designed with redundant operating systems. (DP3 Ref. B-1)
- Require pre-wiring for generators at all facilities designated critical to agency operations and hazard response. (DP3 Ref. B-1)
- Develop stricter flood regulations for critical facilities 6. Coordinate delivery of fuel and/or access to fuel for critical facility emergency generators. (DP3 Ref. B-1)
- Design new projects to be resilient to a mid-century sea-level rise projection and adaptable to longer term impacts. (DP3 Ref. B-2)
- Incorporate climate change and coastal hazard considerations into building codes by increasing freeboard requirements to 2 feet as buildings are redeveloped and renovated. (DP3 Ref. B-2)
- Continue to regulate to the existing tidal floodplain as adopted on February 2, 2012 (DP3 Ref. B-2)
- Incorporate outfall elevation regulations. (DP3 Ref. B-2)
- Develop and share construction Best Practices for development within floodplains. (DP3 Ref. B-2)
- Train all code enforcement and building inspectors about floodproofing techniques and the local floodplain ordinance. (DP3 Ref. B-2)
- Encourage green roof installations to include vegetative and reflective technologies for all new commercial, industrial, multifamily, and city-owned development. (DP3 Ref. B-2)
- Review zoning code and strengthen language (where necessary) in order to better protect citizens and increase resiliency in buildings. (DP3 Ref. B-3)
- Review and amend existing building and floodplain regulations to require more flood-resistant new and existing structures when located in the floodplain. (DP3 Ref. B-3)

- Utilize open space category in zoning code to protect sensitive areas (stormwater sites, steep slopes, floodways, etc.). (DP3 Ref. B-3)
- Review and increase Flood Protection Elevation (Base Flood Elevation + Freeboard) standards to the highest available State, Federal or local elevation level. (DP3 Ref. B-3)
- Evaluate and update stormwater management regulations to avoid increases in downstream flooding. (DP3 Ref. B-3)
- Adopt design requirements that include wet and dry floodproofing techniques. (DP3 Ref. B-3)
- Review and consider adoption of the International Green Construction code. (DP3 Ref. B-3)
- Continue to acquire property (including repetitive loss properties) in the Special Flood Hazard Areas, where feasible and appropriate. (DP3 Ref. B-4)
- Prioritize Hazard Mitigation Assistance funding for mitigation of repetitive loss properties and severe repetitive loss properties. (DP3 Ref. B-4)
- Develop a creative financing program for flood resiliency in industrial buildings. (DP3 Ref. B-4)
- Pursue grants to acquire flood prone properties when and where feasible. (DP3 Ref. B-4)

Stakeholder Updates: The requirement for hazardous materials stored in city-owned, residential, commercial, and industrial buildings within the floodplain to be elevated a minimum of 3 feet above the freeboard has not been drafted or implemented, as yet. Note: The current requirement is consistent with ASCE 24, which mandates a 2 FT of freeboard over the 0.2% annual chance of flood elevation for tidal areas. (DP3 Ref. B-1)

The Incorporation of climate change and coastal hazard considerations into building codes by increasing freeboard requirements to 2 feet as buildings are redeveloped and renovated has been completed. The freeboard requirement for coastal high hazard areas and coastal resilience areas (1% and 0.2% annual chance of flood areas) is 2 FT above the 0.2% annual chance of flood elevation. (DP3 Ref. B-2)

Continue to regulate to the existing tidal floodplain delineation as adopted on February 2, 2012 has been completed. (DP3 Ref. B-2)

The review and amendment of existing building and floodplain regulations to require more flood-resistant new and existing structures when located in the floodplain has been completed. The Baltimore City Building, Fire and Related Codes have been updated on May 18, 2020 and include the latest updates to the Article 7 Natural Resources Code (floodplain requirements). (DP3 Ref. B-3)

The utilization of open space category in zoning code to protect sensitive areas (stormwater sites, steep slopes, floodways, etc.) is ongoing. Regarding the protection of stormwater management (SWM) facilities, Article 7 Natural Resources Code requires that SWM facilities sites be placed under conservation easements or similar instrument to protect the areas from being redeveloped. The Zoning Code section that addresses the Critical Area Management Program requires that open space where mitigation plantings have been installed must be placed under a conservation easement or similar legal instrument to preserve the area in perpetuity. (DP3 Ref. B-3)

The review and increasing of Flood Protection Elevation (Base Flood Elevation + Freeboard) standards to the highest available State, Federal or local elevation level has been completed. (DP3 Ref. B-3)

The adoption of design requirements that include wet and dry floodproofing techniques has been completed. (DP3 Ref. B-3)

The adoption of the International Green Construction code has been completed. The International Green Construction code is included and required under the Building, Fire and Related Codes of Baltimore City. (DP3 Ref. B-3)

7.5.2 Structural

Goal: Retrofit existing buildings in the designated flood areas to increase resiliency.

- Target and encourage flood resiliency retrofits for buildings in the designated SFHAs. (DP3 Ref. B-7)
- Prioritize retrofitting and increasing resiliency of Public Housing units in the designated SFHA and other high-risk areas. (DP3 Ref. B-7)
- 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. (DP3 Ref. B-7)
- Pursue grants to elevate flood prone properties when and where feasible. (DP3 Ref. B-7)
- Pursue grants for dry flood proofing of Commercial and Historic structures in the most flood prone areas when and where feasible. (DP3 Ref. B-7)

Stakeholder Updates: The education of 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 is ongoing. This is completed through the floodplain review permit review process. (DP3 Ref. B-7)

7.5.3 Non-Structural

Goal: Use HAZMUS-MH computer modeling to determine losses generated by coastal storms.

- Utilize engineering studies and cost-benefit analyses to identify additional mitigation needs and actions. (DP3 Ref. B-10)
- Evaluate various building design enhancements to reduce losses generated by earthquakes, floods, and storm surge. (DP3 Ref. B-10)

7.6 NATURAL SYSTEMS STRATEGIES

7.6.1 Urban Parks and Forests

Goals: Utilize green corridors and parks to help protect surrounding communities from the impacts of hazard events; Create an interconnected network of green spaces to support biodiversity and watershed-based water quality management; Expand, protect, and restore riparian areas in the city; Preserve and create new coastal buffer efforts and support creating more wetlands and soft shoreline along coastal areas.

- Evaluate green corridors and parks for possible improvements for floodplain management. (DP3 Ref. NS-1)
- Increase the resiliency of park facilities and buildings. (DP3 Ref. NS-1)
- Utilize the Baltimore Green Network Plan to increase green spaces in areas where there is available vacant land to reduce the heat island effect and provide other benefits. (DP3 Ref. NS-3)
- Convert vacant land and row houses into meaningful and connected open space. (DP3 Ref. NS-3)
- Complete a habitat analysis and plan for the City. (DP3 Ref. NS-3)
- Create a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation. (DP3 Ref. NS-3)
- Certify Baltimore as a Community Wildlife Habitat through the National Wildlife Foundation. (NWF) (DP3 Ref. NS-3)
- Evaluate current regulations regarding stream buffers and floodplains and modify them (if appropriate) to assure they adequately protect perennial stream corridors. (DP3 Ref. NS-4)
- Integrate natural buffer requirements, such as wetlands and soft shorelines, into new development or redevelopment. (DP3 Ref. NS-5)

- 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. (DP3 Ref. NS-5)
- Identify and evaluate areas in the Critical Area buffer to prioritize ecological buffer restoration efforts. (DP3 Ref. NS-5)

Stakeholder Updates: The evaluation of green corridors and parks for possible improvements for floodplain management is ongoing. Many stream restoration projects by DPW are happening in Parks as a co-benefit to the MS4 permit requirements, but more could still be done to a better extent specifically for floodplain management. (DP3 Ref. NS-1)

The utilization of the Baltimore Green Network Plan to increase green spaces in areas where there is available vacant land to reduce the heat island effect and provide other benefits is ongoing. Both Racheal Wilson and Cab Calloway parks are well underway. (DP3 Ref. NS-3)

The conversion of vacant land and row houses into meaningful and connected open space is ongoing. (DP3 Ref. NS-3)

The creation of a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation has not been started, as yet. However, Green Network does this to some extent and the MS4 identifies some priorities but needs to be coordinated with the Sustainability Plan. This collaborative, interagency effort needs to be initiated. (DP3 Ref. NS-3)

The integration of natural buffer requirements, such as wetlands and soft shorelines, into new development or redevelopment is ongoing. The maintenance of soft shorelines is required from projects located on sites that currently have green/soft shorelines. The requirements if put forth through the Critical Area Management Program Manual 2020 Edition, which is authorized by the Baltimore City Zoning Code. (DP3 Ref. NS-5)

The identification and evaluation of areas in the Critical Area buffer for prioritization of ecological buffer restoration efforts is ongoing. The maintenance of soft shorelines is required from projects located on sites that currently have green/soft shorelines. The requirements if put forth through the Critical Area Management Program Manual 2020 Edition, which is authorized by the Baltimore City Zoning Code. (DP3 Ref. NS-5)

7.6.2 Water Supply and Management

Goals: Integrate climate change and natural hazards planning into small watershed action plans (SWAPs); Conduct detailed ongoing analysis of climate information, trends in storm events and hydrology.

- Review existing watershed management plans and identify future actions to address climate impacts. (DP3 Ref. NS-7)
- Expand the use of climate information (e.g. seasonal forecasts) in water resources planning and management. (DP3 Ref. NS-8)
- Research and actively monitor trends in storm events, stream flow and other conditions affecting hydrology and water. (DP3 Ref. NS-8)
- Update flood maps to reflect changing risk associated with climate change. (DP3 Ref. NS-8)
- Continuously improve and enhance flood vulnerability data. (DP3 Ref. NS-8)

7.7 PUBLIC SERVICES STRATEGIES

7.7.1 Emergency Preparedness and Response

Goals: 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); Develop a Hazard Awareness Program; 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

- 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, response and recovery. (DP3 Ref. PS-1)
- Continue to identify and improve coordination with Key Partners. Develop strong working relationships with local experts to provide technical assistance to refine and improve city government emergency preparation. (DP3 Ref. PS-1)
- Review and improve specific response plans contained in the EOP and related ESFs that relate to extreme weather events. (DP3 Ref. PS-1)
- Ensure equipment purchases and communication systems are compatible across agencies and jurisdictions. (DP3 Ref. PS-1)
- Ensure all animal rescue and care shelters located within the floodplain are provided the support to apply for and obtain funds to relocate. (DP3 Ref. PS-1)
- Create a standardized early warning system for members of the public and educate them on actions they should take when alarm sounds. (DP3 Ref. PS-2)
- Hold climate specific seminars, in partnership with MDH2E and MHA, for hospital emergency and sustainability managers. (DP3 Ref. PS-2)
- Prior to a hazard event, identify lead contacts serving vulnerable populations and coordinate actions to maximize safety and information sharing. (DP3 Ref. PS-3)
- Develop a community group coordination plan and implementation guide. (DP3 Ref. PS-3)
- Identify and evaluate plans already in place and work to improve utilization of community-based leaders to assist in preparedness and response. (DP3 Ref. PS-3)
- Develop training and guidance documents for Resiliency Hub Leaders that detail the scope of services (include checklists and instructions for opening, running, and closing). (DP3 Ref. PS-3)
- Increase number of Resiliency Hubs. (DP3 Ref. PS-3)
- Initiate community resiliency planning, outreach, and support. (DP3 Ref. PS-3)
- Develop guidelines to include proactive resilience planning into plan development process. (DP3 Ref. PS-4)

Stakeholder Updates: The coordination of 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, response and recovery is ongoing. A great recent example of this level of interagency coordination is our integrated outreach to communities during the pandemic. Another great example was a combined canvassing effort in SW Baltimore on Frederick Avenue in July with OEM, BCFD, BCHD, and DOP. (DP3 Ref. PS-1)

The initiation of community resiliency planning, outreach, and support is ongoing. A grant from the Pew Charitable Trusts from 2019-2020 enabled us to hire consultants and build out our community resiliency planning outreach and support, particularly of Resiliency Hubs, by hosting a scenario-based training workshop in October 2019. Crisis/hazard support for communities and community organizations has been ongoing throughout the pandemic. (DP3 Ref. PS-3)

Suggestions for Refining Strategies: Add clarity to community group coordination plan and implementation guide and suggestions for moving forward. (DP3 Ref. PS-3).

7.7.2 Education and Outreach

Goals: Conduct climate, resiliency, and emergency planning education and outreach; Improve awareness and education about the importance of flood insurance and preparation for Baltimore residents.

- Incorporate environmental health and climate change into curriculum at schools, universities and health care facilities (DP3 Ref. PS-8).
- Create curriculum for hospitals to teach communities about climate change as part of hospital community benefits programs (DP3 Ref. PS-8).
- Create an educational program centered on flood hazards, coastal construction practices and evacuation procedures.
- Encourage owners of properties to purchase flood insurance, and improve policyholder awareness at time of sale or renewal (DP3 Ref. PS-9).
- Identify programs and grants that assist citizens in purchasing flood insurance and making floodproofing changes (DP3 Ref. PS-9).
- . Develop an annual newsletter to inform and remind owners of property in the floodplain about flood insurance and floodproofing activities they should undertake (DP3 Ref. PS-9).
- Require a flood disclosure form and distribution of floodplain awareness educational information as part of lease agreements for commercial/residential properties, and ensure distribution as tenants change (DP3 Ref. PS-9).

Suggestions for Refining Strategies: Clarify who the target audience for the creation of educational program centered on flood hazards, coastal construction practices and evacuation procedures - for whom? Developers? Residents? Children? How is this different from general outreach? (DP3 Ref. PS-2)

7.7.3 Health

Goal: Protect Baltimore residents from the effects of hazard events and plan for more frequent hazard instances

- When and where feasible pursue grants to complete any project eligible under FEMAs Hazard Mitigation Unified Guidance and its addendum that will contribute to the reduction of hazardous conditions in the city (DP3 Ref. PS-7)

7.8 ADDITIONAL MITIGATION APPROACHES

In addition to the mitigation strategies listed above, it is essential to consider new technologies and approaches being developed to address future flooding hazards of coastal cities. By exploring those options, Baltimore can increase its ability to find the right solutions to address nuisance flooding that maximize resiliency and cost/benefit factors. The sections below illustrate goals, concepts, and approaches being used by jurisdictions attempting to tackle the impending issue of seal-level rise and nuisance flooding.

7.8.1 Jurisdictional Influences

7.8.1.1 Charleston, SC

Charleston has developed a flood and nuisance flood plan that focuses on upgrading the storage capacity of their stormwater system. The aim is to manage stormwater run-off and channel it in a way that alleviates system overflows. Pumps, tanks, and tunnels are being utilized to mitigate stormwater and sewage system overflows. Other strategies being employed in Charleston include elevating seawalls, homes, and streets; elevating new construction structures, purchasing repetitive loss properties; changing building codes, increasing effectiveness of backflow prevention valves (a diagram of the technology can be seen on Figure 59); installing water pumps and flood gates; and finding ways to reduce runoff by implementing the construction of green roofs and cisterns. Charleston has developed a regional collaboration of stakeholders to address flooding problems, and the partnership is expected to drastically improve their chances of being successful in their flood resilience goals.

7.8.1.2 Washington, DC

There are many similarities between Charleston's approach and Washington's Anacostia River Tunnel project. DC Water has completed construction on one stormwater tunnel with a storage capacity of 100 million gallons to capture stormwater and sewage runoff prior to it flowing into the Anacostia River, a Potomac River tributary. Another tunnel with a capacity of 90 million gallons is also in the works. In addition to storage and flood mitigation goals, this system also the ability to filter over 225 million gallons of water per day prior to river discharge, thus improving ecosystem health and water quality in the watershed.

7.8.1.3 Norfolk, VA

Norfolk has been identified as one of the most vulnerable areas affected by nuisance flooding on the east coast. Strategies have been developed in Norfolk to steer new development away from flood zones. New building codes and zoning plans have been instituted for this effort. Additionally, Norfolk has developed plans to restore and create wetland and natural shoreline buffers, install flood walls and tide gates, create man-made berms along the coast, raise roads, and strategically install pump stations to manage stormwater. Like Charleston, Norfolk is taking a holistic approach in dealing with nuisance flooding and has built critical public-private relationships to ensure the implementation of effective solutions to nuisance flooding.

7.8.1.4 Netherlands

When it comes to flood control and sea-level rise, the Dutch have been global leaders in innovation and advancement. Due to historic land formation, topography and proximity to water, the Dutch have battled changing sea-levels for centuries. Mitigation projects in the area range from small-scale land repurposing to mega engineering projects such as the Maeslantkering, a set of swinging doors that completely closes off the waterway connecting the Rhine River with the North Sea. Other methods and strategies employed by the Dutch in response to rising seas include replenishing/growing

natural and artificial shorelines through natural tidal action, topographical land surface adjustments, surge barriers, water squares/plazas, sea gates, decreasing impervious areas, constructing diversion channels, and repurposing areas such as recreational land and parking structures to act as dikes and storage locations when water levels rise.

7.8.2 Additional Mitigation Strategies

7.8.2.1 New or Improved Technologies

New technologies and approaches are being developed in response to rising sea-levels and future flood concerns. The following list provides innovations and new concepts will help control and abate nuisance flooding.

- Analyzing channel dredging for large ships and its correlating effects on hydrodynamic tidal flows within harbors. This includes studying the effects of dredging activity on underwater topographical features in addition to how this activity alters water flow and drag and determining whether dredging activity and land displacement effects tidal flows and increases or decreases nuisance flooding within a harbor area.
- Water diversion products including water gates, tidal gates, water inflatable protectors, quick dams, and modular barriers (Figure 60).
- Backflow preventer technology including flap gates, check valves, and other backflow prevention devices installed at outfall locations (Figure 59).
- New technologies for tidal monitoring, forecasting, and communication/alert systems.
- Installation of sirens/tone systems, pole signs, lights and other alert measures within communities that frequently experience nuisance flooding (Figure 61).
- Internet of Things (IoT) water level sensors for data collection and alerts systems (currently undergoing pilot program in Virginia's Hampton Roads region).
- Development of regional and community groups to specifically address future nuisance flood issues.
- New advancements in wetland enhancement/restoration, bank stabilization, buffer zones, sedimentation reduction, and water channel restoration/clean-out.

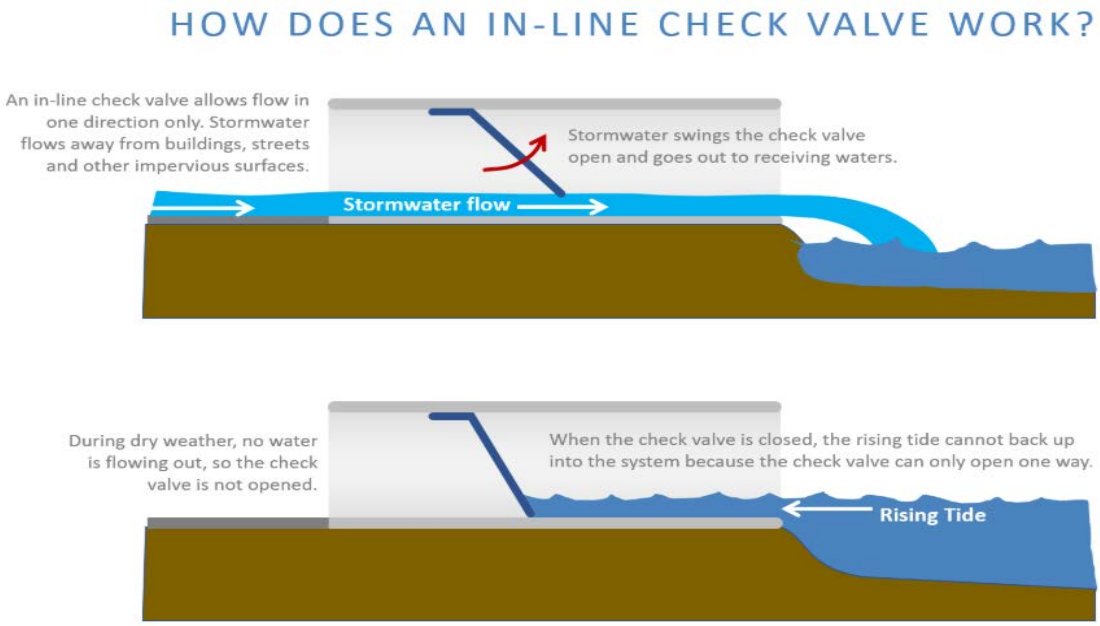


Figure 59: Graphic depiction of backflow preventer technology at stormwater outfall site (Image Source: City of Charelston, SC)

Figure 60: Automatic sea wall technology (Image Source: The Flood Company, Flood Control International)

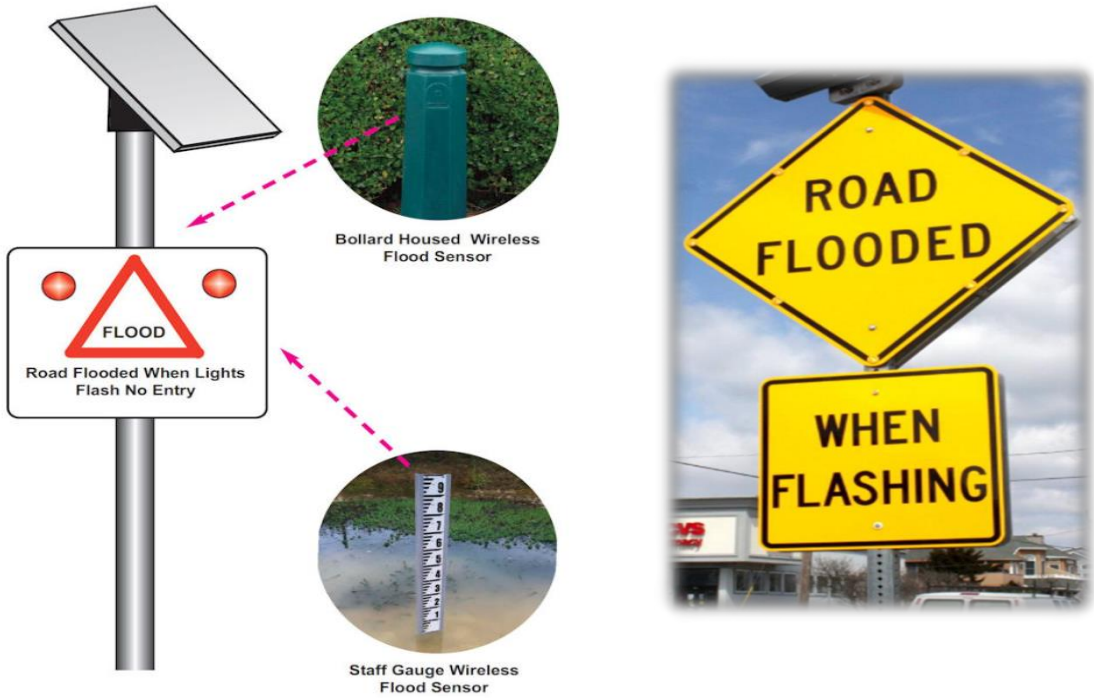


Figure 61: Automated flood warning sign with depth sensor gauge (Image Source: Radio Data Network, Cape May County Herald)

7.8.2.2 Land Acquisition

Coastal land acquisition is an additional technique that can be utilized for nuisance flood mitigation. Although this approach can be costly for local municipalities, and in some cases, it may raise questions on individual property rights, there are instances where this mitigation action can prove productive and advantageous. The process involves the identification of open space parcels affected by flooding, repetitive loss properties, and other flood-prone areas. Once prioritization and cost/benefit analysis of property acquisition and land management is completed, acquisition of land is carried out if terms are agreeable. This process is most beneficial when large areas of open land can be identified for mitigation purposes. This process has recently been undertaken in Howard County, MD where several properties were acquired to prevent future repetitive flood damage and personal injury in lower Ellicott City. After several studies were completed, including cost-benefit analyses and hydrographical studies, public input was received, and settlement terms for properties were achieved. In total, 10 properties were acquired for various intents, and a flood master plan is currently under multi-level review for implementation to further address flooding in the town.

To address cost issues, Federal legislation was passed in 1993, following the Great Flood of 1993 on the Mississippi River, to include additional funding for long-term hazard mitigation measures, including the acquisition of land. FEMA's Hazard Mitigation Grant Program (HMGP) provides funding for these measures, and requires a benefit-cost analysis for each project proposal. Other FEMA programs available for flood mitigation include Pre-Disaster Mitigation Program (PDM) and the Flood Mitigation Assistance Grant Program (FMA). There are many other Federal grant programs available for disaster mitigation, and additionally, many individual states and local organizations provide grant funding for flood mitigation projects. These programs can be utilized to help offset some of the costs of land acquisition and other strategy implementation.

7.8.2.3 Open Space Management

One project that identifies open space for mitigation purposes is underway in Baltimore City, and upon completion will prove beneficial in fighting nuisance flooding in Zone 2 and beyond. In 2019, Baltimore City began the process of seeking

plans to revitalize and develop an 11-mile tract of land within Middle Branch area. The project could prove invaluable to surrounding underserved communities, City tourism, and to mitigate nuisance flooding in the area. For more information on the flood mitigation benefits of the Middle Branch project, see Appendix 1.

Figure 62: Rendering of Middle Branch Master Plan

7.9 RECOMMENDATIONS

The list of recommendations below was developed throughout the planning process and includes, if available, recommendations received from the public.

- The nuisance flooding hot-spots should be ranked to create a priority list of areas for mitigation projects. The ranking should consider events frequency and severity, and equity status of impacted areas.
- The mitigation strategies included in the plan should be assessed and selected to address nuisance flooding in the six nuisance flood zones and hot-spots. The section requires cost-benefit analysis, feasibility studies, among other efforts.
- A No-Action Alternative Analysis should be developed for each Nuisance Flood Zone that considers and quantifies the economic and equity impacts for the areas.
- The requirements that apply to FEMA's regulatory floodplain, as defined by Article 7 of the Baltimore City Code of Natural Resources, should be considered to also regulate new construction and substantial improvement located in the nuisance flood zones.
- Specific mitigation strategies and tools should be identified for each Nuisance Flood Zones, including cost/benefit analysis for each strategy (or cluster of strategies).
- The mitigation strategies identified through the analysis for each Nuisance Flood Zones should be considered by responding agencies (DPW, DOT, BCFD/OEM) and infrastructure projects that provide co-benefits to abate nuisance flooding should be prioritized by the Capital Improvement Program (CIP) selection process.
- Nuisance flooding should be added as a consideration of asset management tools used by DOP, DOT and DPW.
- The mitigation strategies adopted from Baltimore's DP3 Emergency Preparedness Plan should be reevaluated by each responsible agency during the next plan update to determine the overall progress of each strategy and requirements necessary to move forward.

- During the collaborative process of mitigation strategy reevaluation, each agency should explore and discuss new technologies available that may be utilized to further address nuisance flooding. This could include technologies illustrated in Section 7.8 Additional Mitigation Approaches.
- City-wide property analysis, along with land acquisition and open space grants should be considered to address nuisance flooding. A determination of how the Middle Branch Development project could further address nuisance flooding could also be beneficial.
- Exploring the feasibility of installing and monitoring local tide gauges within each nuisance flooding zone could prove beneficial for future assessment and planning.
- A comprehensive shoreline analysis could assist in determining future planning needs.
- Maintaining open lines of dialogue and feedback with plan stakeholders could help in continual monitoring and future planning.
- Continued public education campaigns on nuisance flooding delivered via newsletters, social media, and other formats should be utilized in order to provide updates for citizens and businesses, as well as to seek feedback regarding new mitigation approaches.
- Develop regional partnerships with neighboring jurisdictions and State agencies to discuss new strategies, technologies, and ideas to address nuisance flooding collectively.
- Pursue State and Federal funding to implement mitigation strategies and identify local funding that could be used as match when needed.
- Develop in-house modeling or seek out additional modeling data for future plan updates.

8 EVENT TRACKING AND CATALOGING

Although **nuisance flooding has been a persistent problem in Baltimore City for many years**, it is treated as minor flooding regarding the response and tracking methods utilized by City agencies, which is appropriate in view of the current impact levels. However, as explained on Section 3 Sea-level Rise Projections and Regional Trends, **nuisance flooding occurrences are expected to increase in frequency and severity over the next decades with rising sea-levels and changing weather patterns**. For that reason, one important outcome of this plan is the development of a method to identify and catalog nuisance flood events from 2020 to 2025.

Regarding the cataloguing of events, the Baltimore City Department of Planning, through its Office of Sustainability, is responsible for the logging of events into the tracking the database and maintenance of the system. The action, however, is highly dependent on inter-agency coordination, as a portion of the data necessary for the cataloguing of a nuisance flood event originates in different City departments. The process suggested in this plan for the identification and tracking of nuisance flood events from 2020 to 2025 should be revised and modified in the next plan update to correct shortcomings that may be identified during this timeframe.

8.1 PROCESS FOR EVENT IDENTIFICATION

The data sources utilized to track the occurrence of nuisance flooding in Baltimore City include the 3-1-1 Service the MyCoast application. During the process trial period (2020 to 2025), the data will be collected from each source on a trimestral base, which will require data analysis, validation and cataloguing performed four times per year. The data retrieval from all sources will be performed on a synchronized schedule in order to streamline the process.

8.1.1 Parameters for Event Validation

The flooding occurrence data received from each source will be validated based on two primary parameters: location of the event and tide height data.

8.1.1.1 Location of Flood Event

The first step to validate a flood event as nuisance flooding is the assessment of the location where the event was observed. This is an important step since the 3-1-1 Service and the information provided by other City agencies will include flood events observed in areas outside of the tidal range, and that are caused by other sources not encompassed by this plan like riverine and pluvial flooding. Events that happen 2,000 feet away from the coastline are classified as having a high potential for nuisance flooding, pending the assessment of the second identification parameter, tide height data. The 2,000-foot buffer was defined because it represents the mid-point between the extent of the current nuisance flood hot-spots (1,500 feet) and the forecasted geographic range of hot-spots in 2050 (2,500 feet). The utilization of a conservative buffer that goes beyond the current impacted areas assures the assessment of a wide range of flood events and decreases the likelihood that a nuisance flood event located outside of a current hot-spot is excluded from the analysis. The buffer width should be reassessed during the next plan update and revised as needed.

8.1.1.2 Tide Height Data

The first and most important parameter for event identification is tide height data since the current characterization of nuisance flooding in Baltimore City necessarily includes a tidal event. Tide height information is retrieved from NOAA's webpage Tides and Currents. In order to classify a flood event as nuisance flood, the observed tide height during the day of the event must have been 3.0 feet or greater. A tide height of 3.0 feet is categorized by NOAA as having the potential for minor tidal flooding in Baltimore City, which is an accurate number for very minor nuisance flooding based on field observations.

8.1.2 Data Sources

8.1.2.1 3-1-1 Service

The 3-1-1 Service connects Baltimore citizens, businesses and visitors with a vast array of city services, programs and information. Either by a live agent-assisted phone call or through the self-service web or mobile portal, 3-1-1 allows customers to report a problem, request a service, check the status of a previously submitted service request, and obtain information regarding City programs or events. Constituents may call 3-1-1 to file non-emergency police reports. The Flooded Streets code is the Service Request Type generated by the system to address a nuisance flood event; however, the same code is also triggered for flooding that happens due to pluvial or riverine sources. The steps taken on Section 8.1.1 Parameters for Event Validation must be followed in order to flag the nuisance flood events reported to 3-1-1 during the reporting timeframe. The data reports will be requested from the 3-1-1 Service by DOP on a quarterly basis. Upon event validation, the selected nuisance flood occurrences will be cataloged following the steps outlines on Section 8.2 Method for Event Cataloging.

8.1.2.2 MyCoast Application

MyCoast is a social media application used to document nuisance flooding and flooding after storms. The National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) developed the application. NOAA and NWS partner with State agencies to tailor the application to suit the needs of the partnering agency. In Maryland, the Department of Natural Resources (DNR) is the sponsoring partner.

The application is downloaded onto a mobile device. Users take photographs of nuisance flooding and submit them through the MyCoast application. These submissions are called "reports." The application captures the time and location of the photograph, as well as the weather and tidal conditions. The information is recorded by the application and the data can be downloaded to inform decisions on how to address nuisance flooding.

The Department of Planning, though its Office of Sustainability, will be the local administrator of the MyCoast application. The local administrator will be responsible for downloading reports from the application. The data collected from the application will be utilized to track the occurrence of nuisance flood events and support the development of mitigation policies and actions for areas impacted by nuisance flooding. The MyCoast report data can be used to:

- Confirm and identify new locations of nuisance flooding.
- Define the hazard (depth, duration, area covered by flooding).
- Further refine the thresholds for when nuisance flooding will occur (in conjunction with tide data).
- Identify locations where residents/businesses should receive messages through Bmore Alert about potential (when high tides are predicted to be above or at the flooding threshold) nuisance flooding, suggesting they use alternate routes, turn around: don't drown, and other safety messaging.
- Quantify the impact of hidden losses due to nuisance flooding and additional data gathered by the City (e.g. overcrowding on alternate streets causing traffic incident, the flooding itself causing traffic incidents, businesses are experiencing a loss in sales coinciding with high tides).
- Develop mitigation strategies and policies to reduce nuisance flooding.

Duplication of instances of nuisance flooding cataloged with the 3-1-1 Service will serve to reinforce where nuisance flooding happens and may provide additional information on the duration of the flood if multiple instances of reporting occur throughout the day. The data collected from the 3-1-1 Service will be included with the MyCoast report data to provide a more robust dataset for analysis.

8.1.2.2.1 Public Outreach Campaign for the MyCoast Application

MyCoast will be publicized as part of a vigorous social media outreach campaign to City employees, citizens, businesses, agencies and organizations that have a presence downtown. The information will also be shared on the Office of

Sustainability and Department of Planning's monthly newsletters. Additionally, virtual training on using the application will be provided as part of the campaign, including webinars and videos, and other relevant available resources. City employees will be encouraged to utilize the application on their work cell phones and to serendipitously capture occurrences of nuisance flooding that they observe as they move about the City while conducting City business. Citizens, businesses, and nonprofit partners will be encouraged to use the application as part of the solution for making our neighborhoods safer and drier. Proper branding will be part of the campaign to distinguish nuisance flooding from other City flood mitigation initiatives.

8.2 PROCESS FOR EVENT CATALOGING

The validated data outputs from the 3-1-1 Service, in addition to the reports obtained from the MyCoast application will be consolidated in an internal data repository of nuisance flood events. The consolidation of data points will enable data analysis to validate known nuisance flood hot-spots, identify new hot-spots, and rank areas for mitigation projects based on frequency and severity of event occurrence and equity vulnerability. The consolidation of the data is also important to facilitate inter-jurisdictional and statewide data sharing to enable the assessment of nuisance flooding trends.

8.2.1 Software and Methodology

Excel is the software selected as the data repository tool, and the spreadsheet will be known as the Nuisance Flood Tracking Sheet. The Department of Planning, through its Office of Sustainability, will be responsible for data collection, validation and insertion of data into the Nuisance Flood Tracking Sheet. The spreadsheet will list the following information:

- Event date and time.
- Event location: address of central point of event with street, zip code, and neighborhood information. The full address will be provided when available.
- Nuisance Flood Zone number.
- Tide height information.
- General weather information. The spreadsheet will include a binary question related to the following weather conditions:
    - Precipitation
    - Strong winds
    - Other weather events (tropical storms, hurricanes, etc.)
- Depth of flooding (when available).

The data collection from the identified sources and updates to the Nuisance Flood Tracking Sheet will be performed on a quarterly basis.

8.3 RECOMMENDATIONS

The list of recommendations below was developed throughout the planning process and includes, if available, recommendations received from the public.

- An automated system to collect reports from the 3-1-1 Service and MyCoast application should be developed.
- A system to gather nuisance flooding information from the responding agencies should put in place, and a central contact staff in each agency should be identified.
- Continue to implement the strategies and actions from the DP3 that were specifically identified for their potential to mitigate nuisance flooding.
- Schedule an annual City agency coordination work session targeting those agencies responsible for the implementation of nuisance flood mitigation strategies. Evaluate event tracking data prepared by the Office of Sustainability, using the Nuisance Flood Tracking Sheet.

- Validate tide gauge data and nuisance flood event threshold(s). Currently, the observed tide height during the day of the event must have been 3.0 feet or greater, to classify as a nuisance flood event (a tide height of 3.0 feet is categorized by NOAA as having the potential for minor tidal flooding in Baltimore City).
- Educating staff within the various City agencies on the definition, causes, and effects of nuisance flooding would provide clarification and the necessary background information required for accurate post-incident recording.
- Invest on a continuous public education campaigns from 2020 to 2025; including social media, newsletters and other media; to inform the public of the importance of utilizing the MyCoast application to record and document nuisance flooding.
- Public comments received during the public comment period indicate the need for the expansion of the study area to the entire geographic range of the city. The public comments received reflects the need to track and assess other flooding sources, including pluvial/urban and riverine flooding that happens outside of the regulatory floodplain as defined by FEMA. Additional funding should be allocated to support the work and/or grant funding should be pursued.

GLOSSARY OF TERMS

10% Flood Event- The term 10-year flood event is used in an attempt to simplify the definition of a flood that statistically has a 10-percent chance of occurring in any given year. It is a likelihood, not a guarantee, as 10-year event might happen once, twice, several times, or not at all during a 10-year period. (USDA, 2020)
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/programs/?cid=nrcs142p2_020752
https://www.dsd.gov.hk/EN/Files/flood_prevention/FAQ_Glossary02.pdf

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.

Backflow Prevention- process through which directional flaps or barriers are utilized within a stormwater outfall pipe to prevent water from flowing back into the drainage system/outfall pipe; source of backflow is usually from a larger body of water that has become flooded or has increased in depth due to a variety of causes

Baseline- minimum or starting point used for comparisons or calculations

Bulkhead- retaining wall barrier utilized to separate water from land

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 long-term change in global or regional climate patterns attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

Community Rating System (CRS)- voluntary incentive program that recognizes and encourages floodplain management activities that exceed National Flood Insurance Protection (NFIP) requirements

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- The assets, systems, and networks, whether physical or virtual, so vital that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.

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.

Declination cycle- angular movements and positioning of the moon in relation to the Earth's Equator

Feedback Loop- the process within a system where output effects are utilized as input elements for another part of the system; reactions can be both positive and negative

Fetch- area of water over which wind blows

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.

Floodplain- Any land area, including watercourse, susceptible to partial or complete inundation by water from any source.

Geographic Information Systems (GIS)- technological framework utilized to capture, record, analyze, and display spatial and geographic data

Global Mean Sea-level (GMSL)- globally averaged sea surface height anomalies measured over a specific period and defined within specific parameters

Greenhouse Gas (GHG)- atmospheric gases and aerosols that capture and absorb heat and contribute to the greenhouse gas effect

Greenhouse Gas Effect- natural warming process that occurs when Earth's atmospheric gases capture and store the sun's heat energy

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 Mitigation- Any sustained action taken to reduce or eliminate long-term risks to people and their property from hazards and their effects.

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, overpasses, railways, rail yards, dep

Intergovernmental Panel on Climate Change (IPCC)- intergovernmental agency within the United Nations that analyzes and presents scientific data related to climate change

Land Subsidence- gradual settling or sinking of Earth's surface

Levee- an embankment constructed to prevent the overflow of water

Mean Higher High Water (MHHW)- average of the higher high water height recorded each tidal day for a period of time

Mean Sea-level (MSL)-average sea surface level measured between levels of high and low water levels recorded over a period of time

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 Weather Service- 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.

Nuisance Flood- (AKA: "sunny day floods") flood event that is not necessarily linked to high precipitation amounts, but lead to public inconveniences and closures, usually stemming from high tide cycles and other factors

Ocean Circulation- large scale movement of ocean waters; Can be defined as wind-driven surface circulation, or deep water circulation driven by water density (salinity and temperature based factors)

Outfall- storm water system discharge point

Perigean Tide- higher than usual tide cycles in accordance with moon and Earth proximity that result in strong gravitational effects and movements on tidal wave action

Planning- The act or process of making or carrying out plans; the establishment of goals, policies and procedures for a social or economic unit.

Relative Sea-level (RSL)- sea surface level as measured in relation to a land-based reference

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

Revetment- sloping structure, usually constructed of stone, concrete, or other material, to protect shoreline embankments from erosion, storm surge, and wave action

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

Seawall- retaining wall barrier utilized to separate water from land, in addition to providing shoreline protection from erosion and wave action

Sea-level Rise- rate if increase of sea surface levels as measured over a specific period of time

Sustainability- (Baltimore City definition)- Improving the quality of human life while balancing the need for environmental protection, societal progress, and economic growth so as to maintain the balance between meeting the needs of people today without diminishing the ecosystems upon which future generations rely.

Thermal Expansion (ocean)- augmentation of seawater volume caused by an increase in water temperature

Tidal Gauge- device utilized to measure the vertical change in sea-level

Vertical Land Motion- change in land elevation that can be causes by several factors such as tectonic plate shift, earthquakes, groundwater withdrawal, soil compaction, etc...

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.

Wetland Buffer- naturally vegetated setback area between a body of water and land that can help protect shoreline erosion and water quality.

ACRONYMS

ACS	American Community Survey
BCFD	Baltimore City Fire Department
BCPD	Baltimore City Police Department
BGE	Baltimore Gas & Electric
BoS	Baltimore Office of Sustainability
CAPIR	*2018 Coastal Adaptation Planning and Implementation Report*
CHAP	Commission for Historical and Architectural Preservation
CIP	Capital Improvement Program
CISA	United States Cybersecurity and Infrastructure Agency
CRS	Community Rating System
DGS	Department of General Services
DNR	Department of Natural Resources
DOP	Department of Planning
DOT	Department of Transportation
DP3	Disaster Preparedness and Planning Project
DPW	Department of Public Works
EOP	Emergency Operations Plan
ESF	Emergency Support Functions
FEMA	Federal Emergency Management Agency
FMA	Flood Mitigation Assistance Grant Program
GIS	Geographical Information Systems
GHG	greenhouse gases
GMSL	global mean sea level
HAZMUS-MH	geographically information systems based natural hazard analysis tool (MH-multi-hazard)
HMGP	Hazard Mitigation Grant Program
IPCC	Intergovernmental Panel on Climate Change
MDE	Maryland Department of the Environment

MDH2E	Maryland Hospitals for a Healthy Environment
MDOT	Maryland Department of Transportation
MHA	Maryland Hospital Association
MHHW	mean higher high water
MS4	Municipal Separate Storm Sewer Systems
MSL	mean sea level
NAVD88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OEM	Office of Emergency Management
PDM	Pre-Disaster Mitigation Program
RCP	Representative Concentration Pathways
RSL	relative sea level
SFHA	Special Flood Hazard Areas
SHA	State Highway Administration
SLOSH	Sea, Lake, and Overland Surges from Hurricanes (modeling program)
SWAP	small watershed action plans
USACE	United States Army Corps of Engineers
UMCES	University of Maryland Center for Environmental Science
USDA	United States Department of Agriculture
USGS	United States Geological Survey

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Lisa McNeilly	Director of Sustainability	Baltimore Office of Sustainability
Bruna Attila	Coastal Resources Planner	Baltimore Office of Sustainability
Douglas Summers	Nuisance Flood Plan Intern	Baltimore Office of Sustainability
Jennifer Sparenberg	Lead Environmental Specialist	Maryland Environmental Service
Mark James	Project Manager	Michael Baker International
Virginia Smith	Project Manager	Smith Planning & Design
Michele King	GIS Mapping Specialist	Smith Planning & Design

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DISCLAIMER

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A. MIDDLE BRANCH DEVELOPMENT PROJECT

Middle Branch Development Project

The City of Baltimore has begun the planning process to develop a phased, multi-year plan to construct and upgrade an 11-mile waterfront property along the Patapsco River in South Baltimore. This includes areas located in Middle Branch Park, to include the communities of Westport, Cherry Hill, and Ridgely's Cove. This project has the potential to bring significant benefits to low-income areas, add to Baltimore's world-class tourism destination status, and provide environmental restoration and flood mitigation to a large area of waterfront.

Park Features

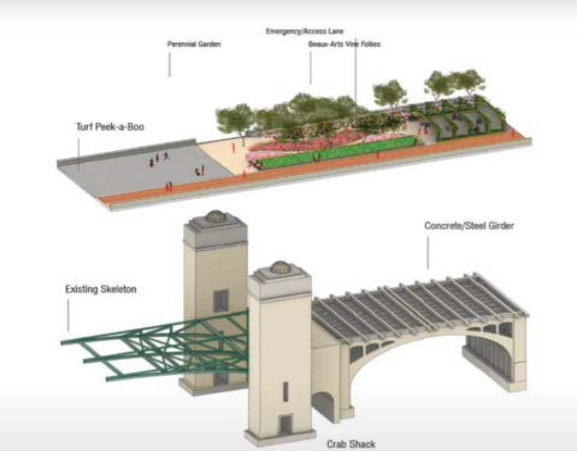
- Reconnect communities to the waterfront, expand public access, and create a green boulevard
- Establish world class park district with recreational opportunities such as kayak, bike, and hiking trails
- Improve cultural and ecological assets and experiences
- Community-driven development and investment
- Free and affordable recreation with tie-in to other regional trail systems

Environmental Benefits

- Major wetland and marsh restoration and creation (240+ acres)
- Open space flood mitigation
- Increase area biodiversity
- Provide habitat for existing and new species, especially shorebirds
- Improvement of water quality
- Repurpose urban infrastructure that has reached its lifespan
- Reinforce natural hydrodynamic channel flows
- Redistribute and reframe Patapsco River ecology

Hanover Street Bridge

As with New York's High Line Park, the Hanover Street Bridge has the potential to be reimagined as Baltimore's new and iconic linear greenway park. The bridge, constructed in 1916 is due for rehabilitation or replacement for vehicular traffic due to age and structural deficiency, however with the creation of a new, and some say cheaper bridge, the Hanover Street Bridge can remain a monument in Baltimore City while transitioning into its new purpose, all with minimal structural upgrades required. The views offered would be unparalleled and the potential for space both on the surface and below the bridge are endless.



B. METHODOLOGY FOR EQUITY ASSESSMENT

The methodology used in this mapping analysis is similar to that of other planning initiatives completed by the Baltimore Office of Sustainability, including the Coastal Adaptation Planning and Implementation in Baltimore City (CAPIR) and the City of Baltimore's All Hazard Mitigation Plan (DP3). To begin the process of analyzing minority or underserved communities impacted by nuisance flooding, potential vulnerable populations were identified. The *2018 Coastal Adaptation Planning and Implementation Report (CAPIR)* focused on using GIS-based information and analysis to support the effort to prioritize communities for resilience plans as part of the 2018 DP3 update. Part of the CAPIR work effort was to identify and map layers related to vulnerable populations (**census tract level**), such as:

- Age, specifically areas with larger populations (by percent) of young (under 5) and elderly (over 65) residents
- Non-English-speaking populations
- Vehicle access (without vehicle access)
- Poverty (below poverty level)

For the *2020 Baltimore City Nuisance Flood Plan*, areas were cross-checked with **census tracts data**. The parameters assessed to categorize a community as minority or underserved included:

- Age (5 & under/65 & over)
- Educational Attainment
- Language Spoken at Home (very little English)
- Employment Status (Civilian: 16 & Over Unemployed)
- Poverty Status (Below Poverty Level)
- Vehicles Available (No Vehicle Available)

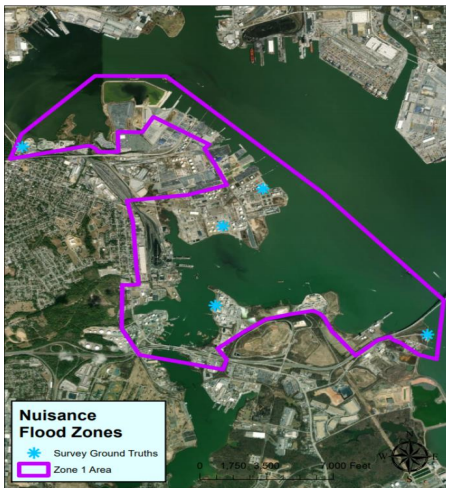
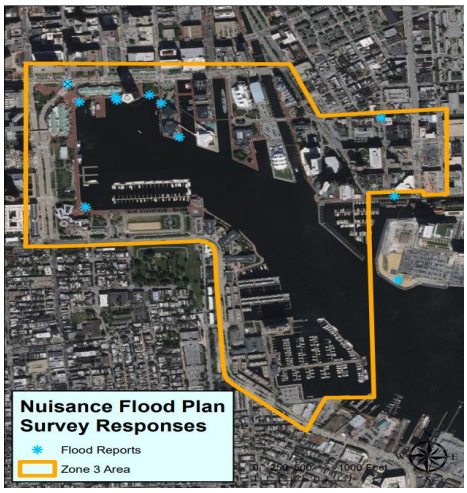
Data available at the census tract level coupled with nuisance flood zones provided a basis for the analysis. U.S. Census data and geodatabases bring together geography from the 2018 TIGER/Line Shapefiles and data from the 2014-2018 American Community Survey (ACS) 5-year estimates as shown on maps in Section 5.3 Equity Considerations and the tables below.

Census tracts do not align perfectly with nuisance flood zones, and therefore the percent of census track area within each of the designated nuisance flood zones was calculated. This calculated percentage of census tract area within each nuisance flood zone was used to determine the percentage rate applied to each equity parameter.

Scoring for each parameter and composite score are as follows:

Identifier	Zones	Census Tract	Census Track Acreage	Zone Acreage	% of Zone in Tract	Equity Parameters																														Vulnerability Analysis Results	
						Tract Total	Zone Total	Under 5 %	Score	Tract Total	Zone Total	Over 65 %	Score	Tract Total	Zone Total	Diploma Not Attainment %	Score	Tract Total	Zone Total	Limited English %	Score	Tract Total	Zone Total	16 Years & Older Unemployed %	Score	Tract Total	Zone Total	Income Below Poverty Level %	Score	Tract Total	Zone Total	Households with No Vehicle %	Score	Composite Score Totals	Composite Score Percentage
1	Zone 1	250500	3123.7	1768.5	0.57	509	290	18%	5	376	213	9%	3	977	553	30%	5	0	0	3%	1	259	147	21%	5	1249	707	21%	5	190	108	21%	5	29	83%
2		250600	3771.5	2248.4	0.60	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	7	20%
3		750203	752.1	30.6	0.04	54	2	3%	1	205	8	3%	1	181	7	3%	1	5	0	3%	1	55	2	3%	1	88	4	3%	1	18	1	3%	1	7	20%
4		751102	2297.5	20.8	0.01	211	2	3%	1	683	6	3%	1	381	3	3%	1	22	0	3%	1	57	1	3%	1	478	4	3%	1	10	0	3%	1	7	20%
5	Zone 2	210100	365.8	129.7	0.35	124	43	3%	1	159	56	3%	1	279	99	6%	2	0	0	3%	1	206	73	12%	4	433	154	6%	2	76	27	6%	2	13	37%
6		230300	500.1	347.3	0.69	13	9	3%	1	99	69	3%	1	27	19	3%	1	5	3	3%	1	12	8	3%	1	120	83	3%	1	0	0	3%	1	7	20%
7		240400	536.3	221.3	0.41	195	80	6%	2	202	83	6%	2	217	90	6%	2	0	0	3%	1	42	17	3%	1	55	23	3%	1	15	6	3%	1	10	29%
8		250203	317.5	242.6	0.76	190	145	9%	3	238	182	9%	3	216	165	9%	3	21	16	9%	3	45	34	6%	2	377	288	9%	3	133	102	21%	5	22	63%
9		250205	575.9	24.8	0.04	267	11	3%	1	240	10	3%	1	523	23	3%	1	82	4	3%	1	232	10	3%	1	828	36	3%	1	141	6	3%	1	7	20%
10		250207	320.7	196.3	0.61	224	137	9%	3	257	157	9%	3	241	148	9%	3	44	27	12%	4	102	62	9%	3	700	428	15%	5	152	93	18%	5	26	74%
11		250301	544	141.6	0.26	193	50	3%	1	213	55	3%	1	349	91	6%	2	18	5	3%	1	146	38	6%	2	931	242	9%	3	74	19	6%	2	12	34%
12		250401	299.7	20.5	0.07	278	19	3%	1	319	22	9%	3	722	49	3%	1	37	3	3%	1	181	12	3%	1	935	64	3%	1	35	2	3%	1	9	26%
13		250600	3771.5	155.9	0.04	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	0	0	3%	1	7	20%

Identifier	Zones	Census Tract	Census Track Acreage	Zone Acreage	% of Zone in Tract	Equity Parameters																												Vulnerability Analysis Results	
						Tract Total	Zone Total	Under 5 %	Score	Tract Total	Zone Total	Over 65 %	Score	Tract Total	Zone Total	Diploma Not Attainment %	Score	Tract Total	Zone Total	Limited English %	Score	Tract Total	Zone Total	16 Years & Older Unemployed %	Score	Tract Total	Zone Total	Income Below Poverty Level %	Score	Tract Total	Zone Total	Households with No Vehicle %	Score	Composite Score Totals	Composite Score Percentage
14		020300	258.7	11.8	0.05	180	8	3%	1	317	14	3%	1	136	6	3%	1	82	4	3%	1	56	3	3%	1	359	16	3%	1	75	3	3%	1	7	20%
15		030200	147.2	59	0.40	199	80	6%	2	236	95	6%	2	202	81	6%	2	59	24	12%	4	42	17	3%	1	520	208	6%	2	57	23	6%	2	15	43%
16	Zone 3	040100	294.7	12.6	0.04	227	10	3%	1	105	4	3%	1	28	1	3%	1	188	8	6%	2	65	3	3%	1	870	37	3%	1	289	12	3%	1	8	23%
17		220100	356.5	146.3	0.41	57	23	3%	1	791	325	15%	5	116	48	3%	1	0	0	3%	1	81	33	6%	2	449	184	6%	2	13	5	3%	1	13	37%
18		240200	184.6	59.1	0.32	231	74	6%	2	388	124	6%	2	53	17	3%	1	8	3	3%	1	55	18	3%	1	75	24	3%	1	8	3	3%	1	9	26%
19		010400	230.4	20.8	0.09	150	14	3%	1	276	25	3%	1	87	8	3%	1	11	1	3%	1	81	7	3%	1	143	13	3%	1	0	0	3%	1	7	20%
20	Zone 4	020300	258.7	204.8	0.79	180	142	9%	3	317	251	12%	4	136	108	6%	2	82	65	30%	5	56	44	9%	3	359	284	9%	3	75	59	12%	4	24	69%
21		030200	147.2	4.2	0.03	199	6	3%	1	236	7	3%	1	202	6	3%	1	59	2	3%	1	42	1	3%	1	520	15	3%	1	57	2	3%	1	7	20%
22		010100	133.8	49.8	0.37	118	44	3%	1	406	151	9%	3	121	45	3%	1	0	0	3%	1	10	4	3%	1	124	46	3%	1	60	22	6%	2	10	29%
23		010400	230.4	161.3	0.70	150	105	9%	3	276	193	9%	3	87	61	6%	2	11	8	6%	2	81	57	9%	3	143	100	3%	1	0	0	3%	1	15	43%
24	Zone 5	240100	1046.5	628.9	0.60	266	160	12%	4	190	114	6%	2	82	49	3%	1	0	0	3%	1	42	25	6%	2	135	81	3%	1	23	14	3%	1	12	34%
25		240200	184.6	34	0.18	231	43	3%	1	388	71	3%	1	53	10	3%	1	8	1	3%	1	55	10	3%	1	75	14	3%	1	8	1	3%	1	7	20%
26		240400	536.3	44.6	0.08	195	16	3%	1	202	17	3%	1	217	18	3%	1	0	0	3%	1	42	3	3%	1	55	5	3%	1	15	1	3%	1	7	20%
27		260605	4241.5	493.6	0.12	628	73	6%	2	584	68	3%	1	694	81	6%	2	181	21	12%	4	231	27	6%	2	1395	162	6%	2	85	10	3%	1	14	40%
28	Zone 6	260605	4241.5	835.6	0.20	628	124	9%	3	584	115	6%	2	694	137	9%	3	181	36	30%	5	231	46	9%	3	1395	275	9%	3	85	17	6%	2	21	60%

C. SUMMARY OF SURVEY & PUBLIC COMMENT RESULTS

The maps below were produced with data provided by public input and survey responses during the public comment period. A total of 55 survey responses and 23 comments were made to the draft Nuisance flood Plan from July to September 2020. The pertinent responses and information are included below and were addressed in the plan.