Brandon M. Scott
Mayor

WATERFRONT PARTNERSHIP OF BALTIMORE

MEMO: BALTIMORE INNER HARBOR PROMENADE SEA-LEVEL RISE & COASTAL FLOODING CONSIDERATIONS

NOVEMBER 27, 2023

NOVEMBER 27, 2023

This memo was prepared by SCAPE Landscape Architecture based on conversations with the Waterfront Partnership of Baltimore and the City of Baltimore Department of Planning and research performed in September and October, 2023. The memo was prepared in consultation with The City of Baltimore Office of Sustainability, The Water Institute, Climate Adaptation Partners, and Ben Zaitcheck of John Hopkins University. The findings and recommendations herein are based on existing published sea level rise projections and flooding data and do not constitute scientific opinion or include new modeling or analysis. The information in this report is intended to provide context for planning level decisions. It does not endorse, oppose, or take any stance whatsoever on projects or initiatives within the study area.

CONTENTS

1. **PROJECT BACKGROUND AND PURPOSE 5**

2. **CONTEXT: HISTORIC FLOODING & CLIMATE CHANGE 7**
   - TYPES OF FLOODING 8
   - HISTORIC & CURRENT FLOODING 10

3. **SEA-LEVEL RISE CONSIDERATIONS & PROJECTIONS 15**
   - BEST AVAILABLE SCIENCE AND APPLICABLE GUIDANCE 16
   - SUMMARY OF KEY DECISIONS IN IDENTIFYING SEA-LEVEL RISE PROJECTIONS 17
   - PROJECT TYPE, GOALS, AND LOCATION 18
   - PROJECT TIMEFRAME 19
   - EMISSIONS SCENARIO 20
   - SEA-LEVEL RISE PROBABILITY 21
   - UNCERTAINTY & ADAPTATION 22
   - SUMMARY 24

4. **FUTURE COASTAL FLOODING WITH SEA-LEVEL RISE 27**
   - FUTURE FLOOD FREQUENCIES: MINOR, MODERATE, AND MAJOR HIGH TIDE FLOODING 28
   - FUTURE PROJECTED WATER LEVELS 29

5. **BIBLIOGRAPHY 34**

6. **APPENDICIES 35**

Inner Harbor, October 2023, Source: SCAPE

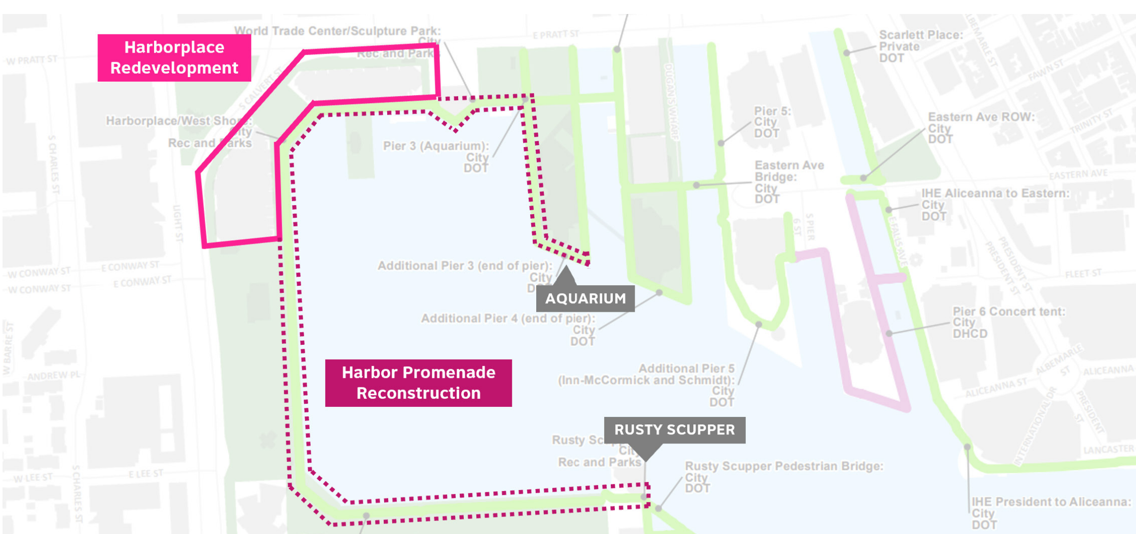
1. PROJECT BACKGROUND AND PURPOSE

As part of the upcoming Harborplace redevelopment, the State of Maryland has committed funding to support the redesign and reconstruction of the Inner Harbor Promenade. Funding for the reconstruction is being provided via the Waterfront Partnership of Baltimore (WPB). The design of the new harbor promenade will be developed by the developer's (MCB) design team with review and oversight by the City of Baltimore. The City's Disaster Preparedness and Planning Project (DP3), first adopted in 2013 and currently being updated, calls for increasing the resilience of waterfront buildings and infrastructure by designing new projects to be resilient to projected sea-level rise, raising bulkhead heights, integrating flood protection systems, enhancing waterfront design guidelines to better mitigate flooding, and strengthening waterfront zoning and permitting. The Baltimore Nuisance Flood Plan of 2020 documents current and projected nuisance flooding in the Inner Harbor, which demonstrates the need for near-term redevelopment to account for projected nuisance flooding and sea level rise.

Understanding the generational opportunity for Baltimore presented by the Harborplace redevelopment and reconstruction of part of the Inner Harbor Promenade, the Waterfront Partnership of Baltimore (WPB) and the Baltimore Department of Planning, Office of Sustainability, identified the need for the design to be resilient to climate change, particularly sea-level rise. WPB, with support from the Department of Planning, engaged a consultant team to better understand the available sea-level rise projections and likely implication of flooding in the Inner Harbor with a focus on high tide flooding and the potential for flooding of the Inner Harbor Promenade. Specifically this memo is intended to:

- Provide an overview of recent coastal flooding trends based on existing available information including city planning documents and NOAA tide gauge data,
- Advise on appropriate available sea-level rise projections to use for analyzing future flood risk to the Inner Harbor Promenade,
- Describe and visualize likely future water levels and flooding with those sea-level rise projections, and
- Engage with City agencies and select stakeholders for input into and to share findings from this analysis of likely sea-level rise and high tide flooding in the Inner Harbor Promenade in order to inform WPB and the City's review and evaluation of the developer team's design proposals.
- This memo summarizes our findings and conclusions.

Resources consulted in this memo are listed in the attached appendices.



SCAPE

Hurricane Isabel, September 2003, Source: Baltimore Sun

2. CONTEXT: HISTORIC FLOODING & CLIMATE CHANGE

This section identifies types of flooding that influence the Inner Harbor, defines the focus of this work on coastal flooding, describes past coastal flood events and trends, and associated high tide flooding thresholds with documented events in the Inner Harbor.

For consistency and to align definitions and understanding of flood types and coastal processes with relevant planning documents and funding sources, terminology and references in this section draw largely on information and reports from the United States National Oceanic and Atmospheric Administration (NOAA) and the State of Maryland. Elevations presented in this section are provided in feet relative to the North Atlantic Vertical Datum of 1988 (NAVD88) for consistency and to enable comparison. Where tidal datums or water levels are used, elevations at the NOAA tide station for Baltimore, MD, Station ID: 8574680, are used unless otherwise noted. Tidal datums are provided for the current tidal epoch which represent values calculated for the period of 1983-2001.

TYPES OF FLOODING

If we think the problem is flooding, that's like saying the problem is "I'm sick;" that is not enough information.

– John Englander on 'Moving to Higher Ground' in Shorewards, American Shoreline Podcast 2021

There are many types of flooding and while we experience most of them similarly, they are caused by different forces and are exacerbated by climate change in different ways. Understanding those forces and how flooding will be impacted by climate change is key to planning and designing measures to mitigate and adapt to flooding. The main types of flooding that are likely to be experienced in and around the Inner Harbor (coastal, rain-induced, and compound) are briefly described below.

Coastal Flooding

Coastal flooding refers to flooding that occurs due to coastal inundation or tidally influenced water occurring above normally dry ground (NOAA Tides & Currents, Coastal Inundation Dashboard). There are two main types of coastal flooding:

- **High Tide Flooding:** High tide flooding is the flooding of low-lying coastal areas by high tides during normal high tides or extreme high tide events (e.g., "king" tides or spring high tides). High tide flooding is frequently referred to as "sunny day flooding" or "nuisance flooding." The City's Nuisance Flood Plan and §3-1001 of the Natural Resource Article of the Maryland Annotated Code define nuisance flooding as "high tide flooding that causes a public inconvenience" (Baltimore City Department of City Planning Office of Sustainability, 2020). As sea levels rise, the time periods when this type of tidal flooding occurs will increase in frequency and duration (Sweet et al. 2018).
- **Coastal Storm Flooding:** Coastal storm flooding is flooding driven by coastal storms like hurricanes. It includes the effects of both storm surge and high waves. Storm surge is "the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide" (NOAA National Ocean Service (n.d.) What is Storm Surge?). Along with storm surge, coastal storms typically bring high winds and waves which drive total water levels even higher. Higher sea-levels due to climate change will raise the elevation of storm surge and waves which in turn causes flooding to travel further inland than in the past, impacting more coastal assets (buildings, landscapes, roadways, etc.) (Reidmiller, D.R. et al. 2018).

Rain-Induced (Inland) Flooding

Rain-induced flooding is caused by extreme precipitation events. The types of rain-induced flooding that can occur in Baltimore are riverine (fluvial) flooding and stormwater (pluvial) flooding. Rising global average and extreme temperatures due to climate change are resulting in warmer air. As warmer air can result in an increase in atmospheric water vapor, extreme precipitation events are expected to increase with increasing global/regional temperatures. In the region, an increasing trend in the frequency and intensity of extreme precipitation events has already been observed and is projected to continue (Terando et al. 2018).

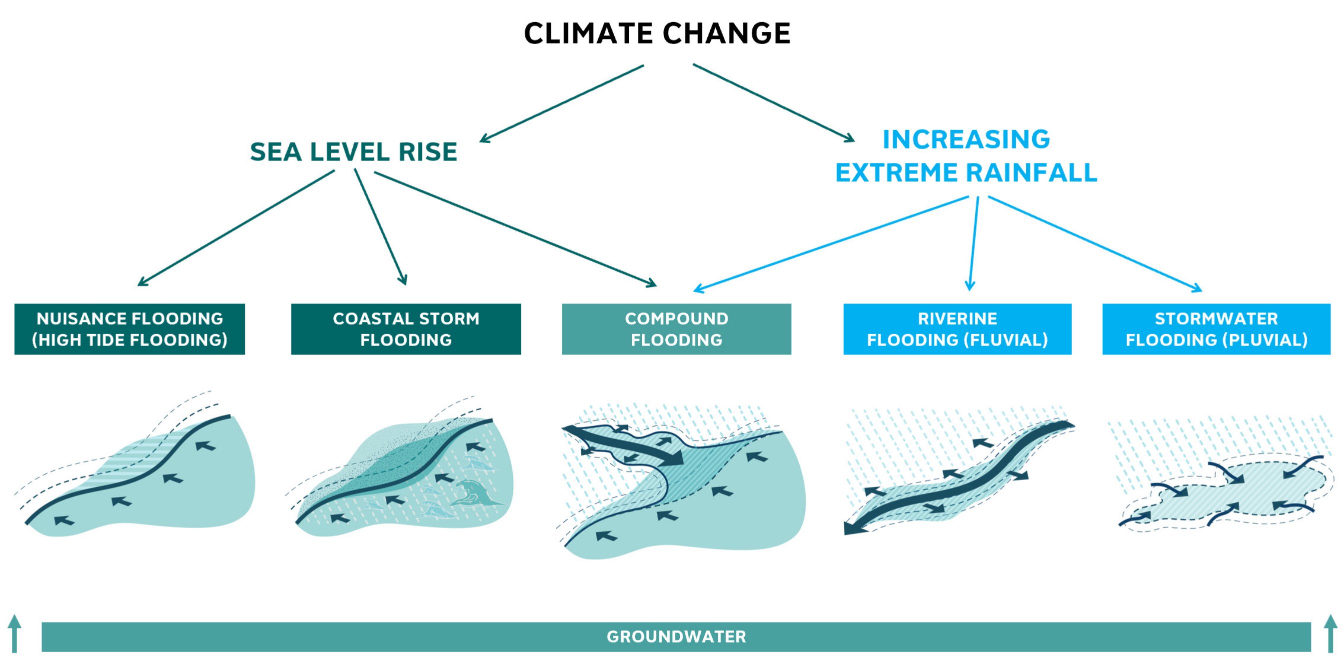
- **Riverine (Fluvial) Flooding:** Riverine flooding, also known as fluvial flooding, is when water in rivers, creeks, or canals overtop their banks. This can happen due to local extreme precipitation. It can also result from precipitation and associated runoff upstream even when it has not rained where the flooding occurs.
- **Stormwater (Pluvial) Flooding:** Stormwater flooding, also known as pluvial flooding, is flooding due to rainwater backing up in areas with poor or undersized drainage. This often happens during extreme precipitation events when drains and pipes cannot adequately drain (Reidmiller, D.R. et al. 2018).

Compound Flooding

Compound flooding is when different types of flooding occur at the same time. An example of compound flooding is when heavy rain falls during a coastal storm, resulting in flooding from both coastal storm surge and waves as well as from riverine or stormwater flooding. Many places in Baltimore, particularly along tidal rivers and creeks, are vulnerable to compound flooding. However, estimating the likelihood of this type of flooding is the most difficult due to the complexity of predicting flooding from multiple sources of water occurring at the same time.

Flood risk to the Inner Harbor Promenade: Focus on coastal flooding

In low-lying waterfront areas like the Inner Harbor, we tend to experience all these types of flooding. However, the focus of this study is coastal flooding and the impact of sea-level rise on coastal flooding. We are particularly interested in high frequency coastal flood events (high tide flooding or nuisance flooding), while also considering lower frequency, higher intensity coastal flooding driven by hurricanes and other coastal storms. While coastal flooding is most likely to directly impact the Inner Harbor Promenade, it will be important in planning and design of the larger Inner Harbor waterfront area to think about all types of flooding and incorporate considerations of fluvial and pluvial flooding, including increasingly intense and erratic rain events and compound flooding resulting from the combination of these.



HISTORIC & CURRENT FLOODING

High tide (nuisance) flooding occurs when sea-level rise combines with local factors to push water levels above the normal high tide mark. Changes in prevailing winds, shifts in ocean currents, and strong tidal forces (which occur during full or new moon) can cause high tide flooding, inundating streets even on sunny days.

– NOAA National Ocean Service. What is High Tide Flooding? https://oceanservice.noaa.gov/facts/high-tide-flooding.html

High tide flooding, also referred to in Baltimore and Maryland as "Nuisance Flooding" is a past, current, and growing threat in many low-lying coastal areas across the city as documented in the City's 2020 Nuisance Flood Plan and reiterated in the City's forthcoming *2023 Disaster Preparedness and Planning Project (DP3)* Plan. As part of the Nuisance Flood Plan, the City is tracking flooding events reported through the MyCoast Maryland app and 311 reports, which will be validated and compiled for reporting to the state.

NOAA's National Ocean Services (NOS) classifies high tide flooding into three categories: Minor, Moderate, and Major high tide flooding, which are defined as (NOAA Ocean Service, What is High Tide Flooding?):

- Minor high tide flooding is when water levels reach 1.8 feet (0.55 meters) above average high tide. This minor flooding is mostly disruptive, causing stormwater backups and road closures.
- Moderate high tide flooding is 2.8 feet (0.85 meters) above average high tide. This can cause more disruption and can damage homes and businesses.
- Major flooding is flooding 3.9 feet (1.20 meters) above average high tide. Floods of this severity are quite destructive, may lead to evacuations, and often require repairs to infrastructure and property.

The actual levels of these thresholds above average high tide vary somewhat by geography. In order to compare inundation impacts over large geographic areas, each NOAA tide station has a separate minor flood threshold based on the analysis performed in NOAA Technical Report NOS CO-OPS 086 - Patterns and Projections of High Tide Flooding (Sweet et al. 2018). These NOS minor flood thresholds are derived using a correlation that was found between the National Weather Service (NWS) minor flood thresholds and the mean difference between high and low tide at that location. In some instances the NOS minor flood threshold may be lower or higher than the NWS minor flood threshold. Since the NOS thresholds are more consistent across geographical areas, these levels are used when examining historic water level data to determine the number of past flooding events.

The minor, moderate, and major high tide flooding thresholds for the Baltimore tide station (station ID 8574680) are noted in the graphic in this section. These thresholds are particularly discernable in the Baltimore Inner Harbor as the threshold for "minor" high tide flooding at 2.5 ft NAVD88 (1.7 feet above MHHW) is just higher than the lowest areas of the promenade and "major" high tide flooding at 4.7 ft NAVD88 (2.7 feet above MHHW) is close to the higher elevations along the waterfront promenade (which generally range between 4.5 and 5.5 ft NAVD88). Note that excludes the upper promenade where building entrances to Harborplace are located, which is significantly higher (8-8.5 ft NAVD88).

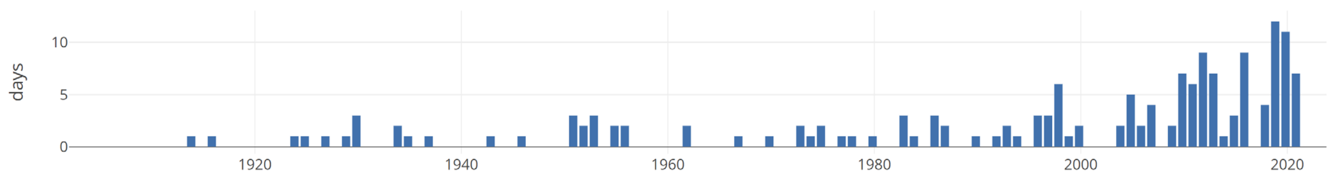
*Elevations are measured from NAVD88, or the North American Vertical Datum of 1988, which is a vertical datum used for elevations in North America. It was established by the National Geodetic Survey (NGS) of the United States government as the official vertical datum for the United States, Canada, and Mexico.

Increasing Frequency of High Tide Flooding

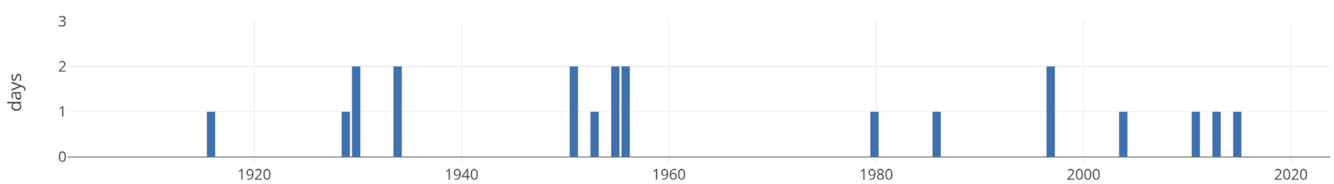
Anecdotal experience tells us that high tide flooding is a not uncommon event on the Inner Harbor, and a look at tide gauge data from NOAA over the last century confirms that these events are occurring more frequently on average in recent years than they have in the past. The graphs below, generated through National Aeronautics and Space Administration (NASA) Sea Level Change Team's Flood Analysis Tool (NASA and University of Hawaii, Flooding Analysis Tool) summarize the number of days per year that readings at the Baltimore tide gauge have exceeded each threshold for the years of available data (1920-2022). Plotting the number of flood days annually exceeding the “minor” high tide flooding threshold of 2.5 ft NAVD88 (1.71 ft MHHW tidal datum) clearly shows this threshold being exceed at least once a year almost every year since the early 2000s and the number of times it is exceeded being greater than three in most years and multiple times exceeding 5, even 10 times a year, occurrences that never happened prior to 1998.Historic patterns are harder to discern from the plots of moderate and major high tide flooding due to the lower number of overall events; however, as seas continue to rise, research demonstrates increases in both moderate and major flooding are expected with high confidence (see Section 4).

Flooding from coastal storm events

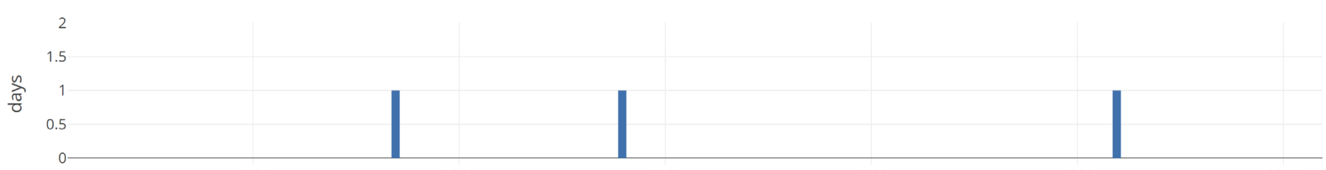
Infrequent, intense storms such as hurricanes or superstorms including tropical and extratropical events can cause high levels of water coupled with rainfall and wind driven damage. These water levels are often used to set design standards because while they are infrequent the damage from them can be catastrophic. Scientific consensus is that in the future there are likely to be more of the greater intensity storms. This will serve as another source of flood risk coupled with even higher seas exacerbating the already intense surge.



Annual Flood Days (1900-2022) above the Minor High Tide Flooding Threshold (1.71 ft MHHW; 2.5 NAVD888)



Annual Flood Days (1900-2022) above the Moderate High Tide Flooding Threshold (2.69 ft MHHW; 3.5 NAVD888)



Annual Flood Days (1900-2022) above the Major High Tide Flooding Threshold (3.90 ft’ MHHW; 4.7 NAVD888)

What Do High Tide Flood Events Look Like?

Visualizing and calibrating these thresholds to lived experiences can be difficult and a challenge to stakeholders trying to understand impacts. As a part of this analysis, we identified two recent flood events that reached water levels similar to the minor and moderate high tide flooding thresholds to help visualize the impact of these events: Flooding on April 05, 2020 reached approximately 2.6 ft NAVD88 just over the minor high tide threshold while flooding on October 29th & 30th reached almost 4.1 ft NAVD88, midway between the moderate (3.5 ft NAVD88) and major (4.7 ft NAVD88) high tide flooding thresholds for the Harbor. These and other similar events may be useful for the WPB and the City to use as reference points for studying and understanding the impacts of future high tide flood events as events like these increase in frequency.

MINOR FLOODING (>2.5 NAVD88)

in 2020: 10 days

In 2021: 5 days

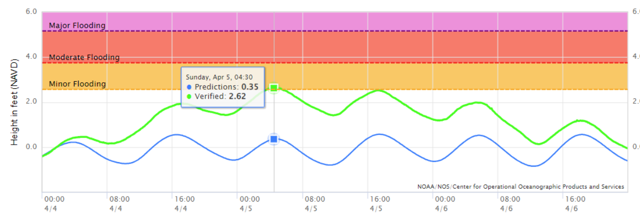
Anticipated days per year

by 2050: 246 (224-269)

by 2080: 354 (349-358)

by 2100: 365 (daily)

Source: NOAA COOPs, Days above 1.71 MHHW



April 5, 2020

MODERATE FLOODING (>3.5 NAVD88)

in 2020: 0 days

In 2021: 2 days

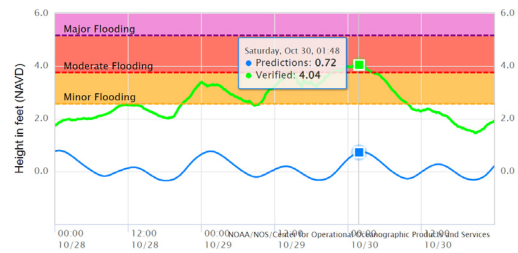
Anticipated days per year

by 2050: 36 (24-51)

by 2080: 275 (255-291)

by 2100: 356 (353-360)

Source: NOAA COOPs, Days above 1.71 MHHW



October 29-30, 2021


F.N.B.
R
RENAISSANCE
IT'SUGAR

3. SEA-LEVEL RISE CONSIDERATIONS & PROJECTIONS

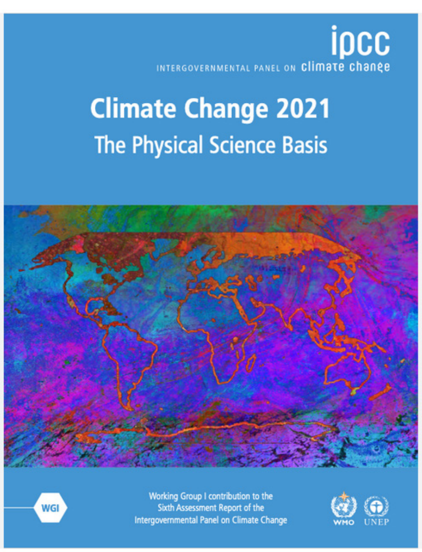
This section describes sources the WPB and the City of Baltimore can use in identifying applicable sea-level rise projections as well as laying out the key decision points that WPB, the City, and stakeholders will need to discuss and make decisions on in selecting a target sea-level rise range. This section provides preliminary recommendations for selecting a sea-level rise scenario(s) from the available Maryland-specific projections based on input received through this process.

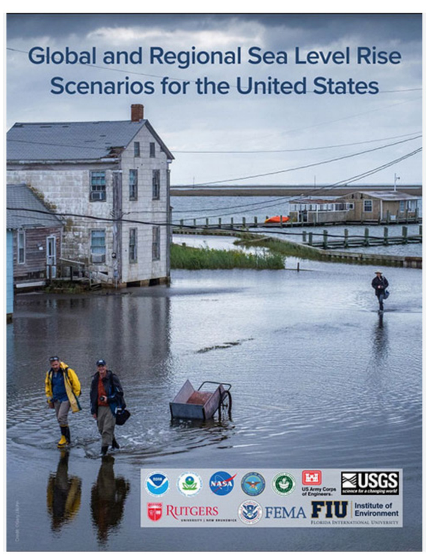
BEST AVAILABLE SCIENCE AND APPLICABLE GUIDANCE

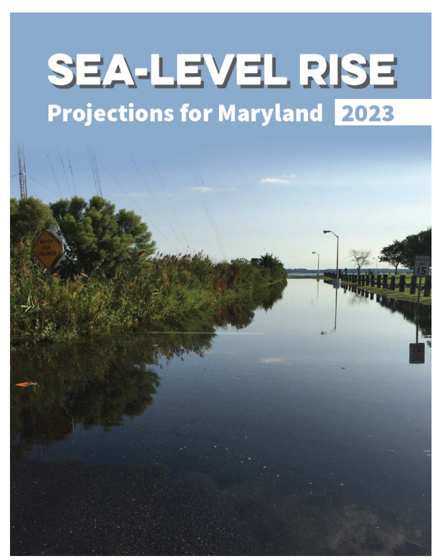
As our understanding of the changing climate continues to evolve, the international scientific community, in the form of the International Panel on Climate Change (IPCC), convenes at regular intervals to synthesize, assesses, and summarizes the latest science. In the United States, that information is then used by an interagency task force to further tailor the information for domestic application, including locally-specific scenarios that consider issues such as changes in currents and subsidence. In some states, such as Maryland, this information is further refined in state assessments that offer specific framing relevant to that state and provide quick references and clarity for stakeholders.

This analysis uses the data from the Maryland 2023 sea-level rise projections published in the recent ***Sea-level Rise Projections for Maryland 2023*** (Bosch, et al. 2023). These projections are already being used by the City in other planning efforts including the Disaster Preparedness and Planning Project (DP3) 2023 Update (Baltimore Office of Sustainability, 2023). In addition, this analysis utilizes frequency projections for high tide flooding derived from data and scenarios in the interagency task force 2022 ***Sea Level Rise Technical Report*** (Sweet et al. 2022). In addition to these data sources, two key documents that provide guidance on applying sea-level rise science guided our approach: the ***Application Guide for the 2022 Sea Level Rise Technical Report*** (Collini et al. 2022) and ***Guidance for Using Maryland's 2018 Sea Level Rise Projections*** (Mcclure et al. 2022).

Beyond sea-level rise, it is important to understand how rising seas will change flood elevations and flood extent over time. We utilized different datasets to ensure the best available science for characterizing future flood risk. The NOAA National Ocean Service provides standardized assessments of changing flood risk for minor, moderate, and major flooding. We assessed the increased height and frequency under future amounts of sea-level rise using the datasets and analysis from the ***Interagency 2022 Sea Level Rise Technical Report*** (Sweet et al., 2022). Additionally, we assessed changes in commonly referenced storm elevations, leveraging the Base Flood Elevation (BFE) from the most current available FEMA Preliminary Flood Insurance Rate Maps (FIRMs) and associated Flood Insurance Rate Study (FIRS) for the City of Baltimore published in 2018 and accessed through the City of Baltimore's Department of Planning's online repository for FEMA Map Products for the City of Baltimore (). Finally, we assessed and identified when specific flood elevations are reached at near-daily frequencies, leveraging the data and analysis available from the NASA Sea Level Change Team's ***Flooding Analysis Tool*** (NASA Sea Level Change Team and University Of Hawaii Sea Level Center,), which also draws from the data used for the ***Interagency 2022 Sea Level Rise Technical Report*** .







SUMMARY OF KEY DECISIONS IN IDENTIFYING SEA-LEVEL RISE PROJECTIONS

While the data and reports described above provide likely sea levels under differing assumptions, they do not recommend what assumptions to make and thus what quantity of sea-level rise to assume for a given location and plan/project. Selecting a sea-level rise projection does not rely entirely on science; there are a number of critical decisions that must be made in applying the science of sea-level rise that will depend on the purpose of the project or plan and, stakeholders' risk tolerances. A "risk tolerance" approach requires understanding and applying stakeholder's tolerance to risk and flooding in the specific context of the project in question and across stakeholders who may have diverse priorities and values. This is not typically an easy task. This section covers the key decisions—really, value judgements—that go into identifying a specific sea-level rise projection and are based in the previously mentioned application guidance resources. These are:

Project type, goals, and location: This involves defining the type and nature of a project and its location, as well as its planned program, uses/activities, and supporting infrastructure. Articulating and gaining partner/stakeholder consensus on these will likely drive assumptions/decisions on the subsequent decisions.

Project timeframe: This involves defining the planning horizon (for a master/framework plan) or service life (functional use) of the project; answering questions like: how long does the project need to perform as designed/intended before major improvements, renovations, or reconstruction?

Emissions scenario: This has to do with identifying how fast or effectively you think that we (people globally) will we curb emissions (or not) and based on that, what emissions-based climate change scenario you want to base your sea-level rise projections on.

Sea-level rise probability: This is about deciding how confident you want to be that, assuming a specific emissions pathway, the sea-level rise value that you select will not be exceeded.

Uncertainty & adaptation: This is about deciding, given the assumptions above, if you want to take other factors into account, consider other scenarios or timelines, or adjust your other thinking to account for uncertainties of climate change or enable adaptation or adaptive management of your project over time.

The reality is that you can rarely settle on one answer to each of these, and the result is you must consider a range of potential sea-level rise values. This is ok and ensures actions that are robust to the uncertainty of the future. Projecting climate change and sea-level rise comes with uncertainty. This is on top of the fact that coastlines and waterfronts are dynamic places, with water rising, falling and moving every day. Decision makers must take this variation and these uncertainties into account when planning for rising sea levels and future flooding.

The following section further explores these considerations for the Inner Harbor.

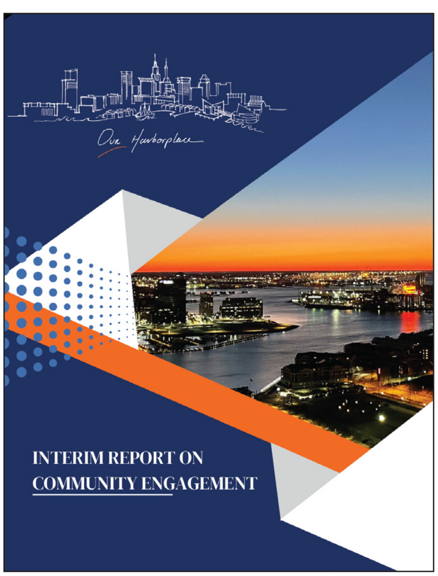
PROJECT TYPE, GOALS, AND LOCATION

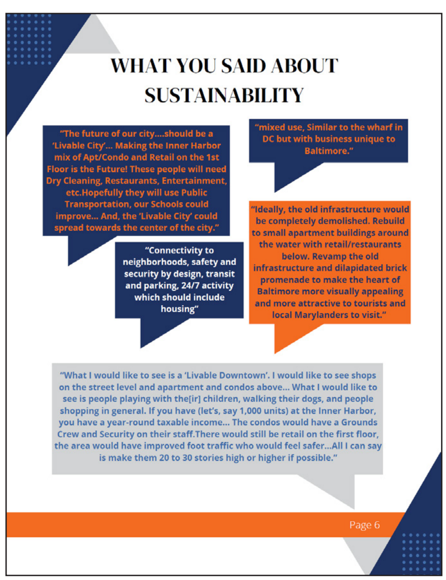
Tolerance for flooding and risk tolerance more broadly will vary greatly depending on where you are (location), what you are talking about (project purpose, program, design, and performance goals), and who you are talking to (stakeholders). As described in the ***Application Guide for the 2022 Sea Level Rise Technical Report***, "Risk tolerance is subjective and is unique to the community and the infrastructure, project, or landscape being considered. However, there are common considerations for setting risk tolerance that fosters objectivity. These include understanding how critical the location or asset is to the community, the cost of damage, sociocultural value, how easily it can be adapted to accommodate SLR (adaptive capacity), and its life expectancy" (Collini et al. 2022).

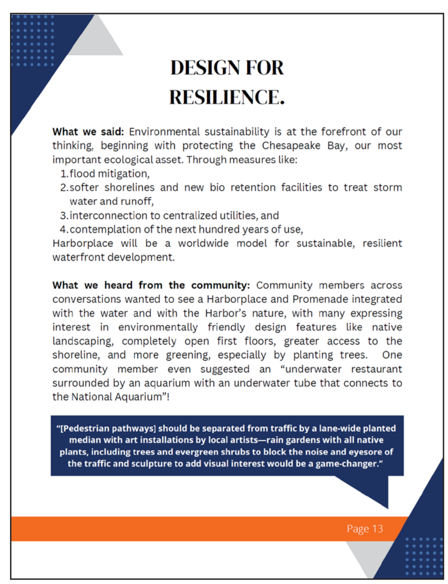
It is important to highlight that the subsequent decisions/value judgements can be difficult or even impossible to make in the absence of clear project definition and performance goals that are shared across project stakeholders. This includes defining planned program (uses/activities), types of places/facilities and associated supporting infrastructure, as well as any key design and performance goals for the project. Articulating and gaining partner/stakeholder consensus on these will likely drive assumptions/decisions on the subsequent decisions.

We understand that the reconstruction of the Inner Harbor Promenade (in conjunction with the Harborplace redevelopment) is considered a "generational" project intended to redesign, reconstruct, and reinvigorate the inner harbor as a major public destination for Baltimore residents and visitors alike; that it is seen as both a piece of critical infrastructure itself as well as must support and house other critical infrastructure (transportation, power, etc.); and that it must maintain a high level of performance and support the active, engaged, and safe visitation over its intended life.

It is the City's responsibility to establish the minimum development parameters and requirements. The City should work with the development team to articulate and document project definition and key performance objectives for the project to provide a basis for risk tolerance assumptions that will inform key decisions regarding sea level rise and use those to confirm and validate the assumptions and conclusions made here.






DESIGN FOR RESILIENCE.

What we said: Environmental sustainability is at the forefront of our thinking, beginning with protecting the Chesapeake Bay, our most important ecological asset. Through measures like:

1. flood mitigation,
2. softer shorelines and new bio retention facilities to treat storm water and runoff,
3. interconnection to centralized utilities, and
4. contemplation of the next hundred years of use,

Harborplace will be a worldwide model for sustainable, resilient waterfront development.

What we heard from the community: Community members across conversations wanted to see a Harborplace and Promenade integrated with the water and with the Harbor's nature, with many expressing interest in environmentally friendly design features like native landscaping, completely open first floors, greater access to the shoreline, and more greening, especially by planting trees. One community member even suggested an "underwater restaurant surrounded by an aquarium with an underwater tube that connects to the National Aquarium"!

"[Pedestrian pathways] should be separated from traffic by a lane-wide planted median with art installations by local artists—rain gardens with all native plants, including trees and evergreen shrubs to block the noise and eyesore of the traffic and sculpture to add visual interest would be a game-changer."

Page 13

PROJECT TIMEFRAME

Because sea-level rise risk is increasing over time, understanding the time horizon for the project in question and how long it needs to be functional before additional major investments are made, is critical in selecting sea-level rise projections. In addition to the magnitude of sea-level rise increasing with time, the level of uncertainty of those projections also becomes much greater the further into the future you try to project (see sea-level rise probability subsection below).

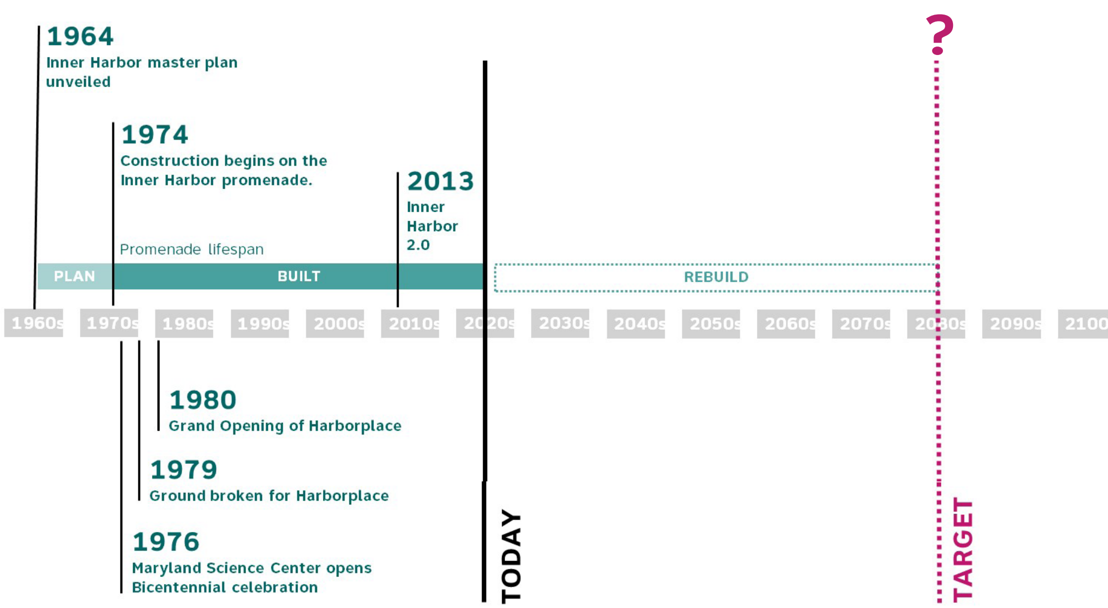
This is not just about picking one target date for a project, but rather you should consider the period over which you want the project to function as designed before any major reinvestment or reconstruction is made and what plans or opportunities there are for maintenance, adaptive management, or retrofits. Questions you might ask include: *When will the project be built /start being used? What do you want the functional life of your project to be before major re-investment is made (reconstruction or major retrofit)? Do you anticipate maintenance and adaptative management or retrofits and, if so, how frequently?* Generally, a longer service life means looking to dates further in the future and can mean considering climate changes toward the end of the century or even beyond.

For the Inner Harbor Promenade, the development team, the City, partners who will operate and maintain the promenade, and local stakeholders (residents, business owners, etc.) likely all have strong opinions on the project's functional life. Thus, this is an important area for discussion and, hopefully, consensus during the engagement and design process.

For these preliminary recommendations, we considered a few things, namely the timeline of the current harbor promenade design, development, and use as well as the documented engagement and stated goals from the Harborplace development project to date. We also discussed and got feedback from members of the City's Sustainability Subcabinet in a meeting on September 12, 2023 (Appendices 1 & 2) as well as in through stakeholder meetings held on October 6, 2023 (Appendices 3 & 4).

Construction on the current Inner Harbor Promenade began almost 50 years ago and planning more than 60. As you embark on this new visioning and design process, planning for a similar timeframe until the next redesign would put the target design year for the project around 2080 (57 years from now). However, in consulting the recent engagement reports from the development team, they place an emphasis on longevity and state that they will "contemplate the next 100 years of use." Feedback from participants in the Sustainability Subcabinet Meeting and the stakeholder workshops also indicated a preference to design for a 2080 to 2100 timeframe.

Based on this, designing for a service life that will perform in the near-term and maintain functionality without major overhaul through 2080, but building for adaptability through at least 2100 is advisable for the Inner Harbor Promenade redesign. Projections for 2050 should also be considered in designing near-term measures that may be upgraded and in prioritizing adaptation of areas that may become highly susceptible to flooding by 2050.



EMISSIONS SCENARIO

Seas will continue to rise into the future; how much they rise depends largely on greenhouse gas emissions. In the near term (out to 2050), the amount of rise is largely locked in given the amount of greenhouse gases already in the atmosphere, but the farther into the future we look, the more future emissions influence how much seas will rise. The international scientific community has described different emissions scenarios, known as SSPs, that could occur to assess how much seas might rise under different emissions. SSPs stands for Shared Socio-Economic Pathways and relate greenhouse gas emission scenarios with socio-economic factors such as climate policy. SSPs help us to understand how emissions may play a role in sea-level rise when planning a project and to make assumptions about emissions scenario(s). It is worth noting that there are not likelihoods or probabilities associated with any SSPs. This is a decision point, where project risk tolerance (how conservative about sea level rise you want to be) and local attitudes and opinions on future emissions will impact the amount of sea-level rise planned for at a project level.

The ***Sea-level Rise Projections for Maryland 2023*** contextualizes the different emissions scenarios to today's decision-making landscape. Sea-level rise projections under three emissions scenarios are provided – 1) the amount of sea-level rise under the emissions scenarios most closely linked with the Paris Agreement which would entail lowering emissions further than what has been committed to so far, 2) the amount of sea-level rise under current commitments to reduce emissions, and 3) the amount of sea-level rise with some increase in emissions. Note that some states, cities, and organizations chose to look at the combined probability of sea-level rise (see next subsection) across multiple emissions scenarios, but the State of Maryland has decided to use an emissions –scenario-based approach in providing sea-level rise projections for three distinct emissions scenarios.

When City officials were asked about emissions in the context of this project, there was a clear preference for considering the increasing emissions scenario (SP3.0-7, see results from poll taken during sustainability subcabinet meeting below) versus other scenarios included in the ***Sea-level Rise Projections for Maryland 2023***. This is consistent with views expressed by the City, WPB, and the developer team regarding the importance of the project, its intended longevity, local attitudes and perceptions around emissions, and that it will be harder to adapt after being built, all which pushed towards planning for a more conservative choice.

Based on feedback received, planning with the increasing emissions scenario (SP7-3.0) at a minimum is advisable.

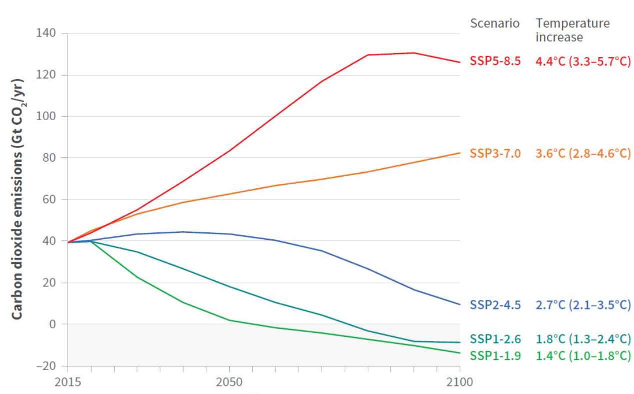


Figure 2. Median pathways of global emissions of carbon dioxide under the five IPCC AR6 scenarios and the best estimates and very likely (90% probable) ranges for increases in global mean temperature over pre-industrial levels that would result from each scenario by 2080–2100.

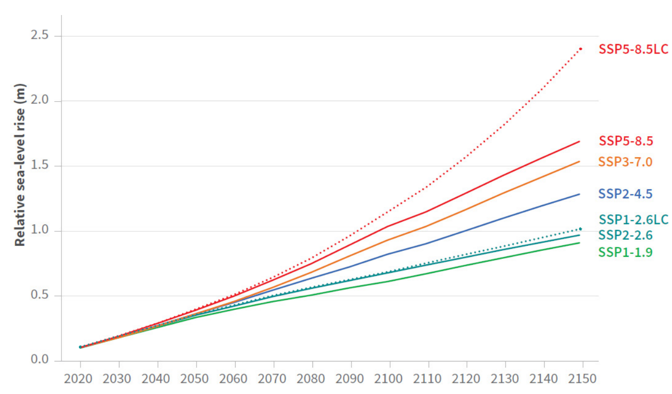


Figure 3. Median projections for sea-level rise at Baltimore under emissions scenarios included in the IPCC AR6. Projections labeled "LC" also include estimates of additional polar ice sheet losses that AR6 regarded with *low confidence*. Source: NASA Sea Level Projection Tool.

SEA-LEVEL RISE PROBABILITY

Since the exact amount of sea-level rise is uncertain, there is always some probability that it will be more or less than the actual value that you select. For any given year and emissions scenario, ***Sea-level Rise Projections for Maryland 2023*** provide the estimated amount of sea-level rise presented in percentiles (referred to as "quantiles") which are buckets that represent the probability distribution, or how likely specific amounts of rise are given those amounts of emissions at any particular year. The "tails" or the far ends of the distribution are less likely to occur, but still could. For example, the low values are very likely to be exceeded and the high values on the tails are very unlikely to be exceeded. The quantiles in the Maryland Sea-Level Rise projections represent the probability that the value associated with that quantile will not be exceeded for the assumed emissions scenario. For instance, if you select the "17%" quantile, there is an 83% chance that actual sea-level rise will be greater than the value shown under that emissions scenario. However, if you select the 95% quantile, there is only a 5% chance actual sea-level rise will exceed that value under that emissions scenario. Inherently, this means the more confident that you want to be that the assumed sea-level rise you select will not be exceeded, the higher that sea-level rise value will be.

The quantile can have a big impact on the total value you select, and it is important to discuss internally and with your key stakeholders. If you are designing critical but flood-sensitive infrastructure that has significant consequences if it were to flood, you might select a higher quantile than if you were designing a relatively flood-resilient open space. For example, ***Guidance for Using Maryland's 2018 Sea Level Rise Projections*** recommends:

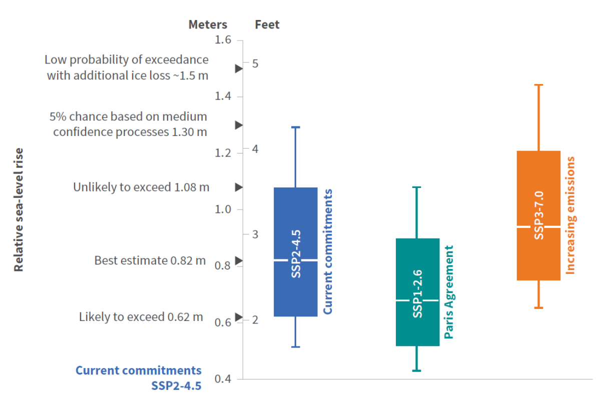


Figure 5. P-box probabilities for projected sea-level rise at Baltimore in 2100 under the three most plausible emissions pathways. Bars represent *likely* (17^{th}–83^{rd} percentile) ranges, vertical lines the 5^{th}–95^{th} percentile ranges, and white crossbars the medians.

"Sea-level rise estimates that are unlikely to be exceeded (83rd percentile) are recommended for built infrastructure and community-wide planning with medium tolerance for flood risk. Sea-level rise with a low probability of exceedance with additional ice loss is recommended as a reference point for projects that have both long-expected lifespans (greater than 50 years) and very little tolerance for flood risk because they provide essential services that cannot be disrupted" (Mcclure et al. 2022)

However, most of our projects are not so clear-cut, and the design of the Inner Harbor Promenade is a case-in point: there may be elements of the promenade that have higher or lower resilience to flooding and different stakeholders may feel differently. How tolerant you and your stakeholders/constituents are of flooding or how risk-averse you are to the Inner Harbor Promenade or elements of it flooding once complete, should influence how confident you want to be that the sea-level rise value you select will not be exceeded.

Given the criticality of the Inner Harbor Promenade to the city, the generational nature of the reconstruction project, the desired integration of critical infrastructure to adjacent buildings and public spaces (e.g. access and electricity supply), and the feedback received during the initial stakeholder discussions, it is clear that city stakeholders are relatively risk-averse when it comes the future flooding of the Inner Harbor Promenade. Thus, selecting a relatively high quantile (low likelihood of the value being exceeded) is advisable for this project: either 83% or 95%. For the purposes of preparing and illustrating the likely future water levels in this memo, the 95th quantile was used.

SCAPE

UNCERTAINTY & ADAPTATION

While we need to be able to quantify sea-level rise in some way—that is one of the desired outcomes of this effort—we must always remember that actual sea-level rise is uncertain, and the reality may end up being something different than we project now. Taking a risk tolerance-based approach also means stepping back to determine if there are other factors to consider in identifying a sea-level rise planning selection to ensure it adequately reflects your and your stakeholders' risk tolerance. If not, you may decide to select a more or less conservative sea level rise projection and/or identify the potential need for designing for adaptation or adaptive management over time.

One of the key uncertainties in selecting a sea-level rise scenario, as discussed in the previous sections, is the uncertainty around global emissions as well as their impact on climate change, particularly over longer time horizons (towards the end of the century and beyond). One factor discussed in the ***Sea-level Rise Projections for Maryland 2023*** is the potential for rapid ice melt. Rapid ice melt scenarios, while currently understood to be very unlikely, if they did occur, would result in dramatically larger and more rapid sea level rise. The other assumptions already identified—longer project timeframe, high emissions scenario, and a quantile resulting a low probability of exceedance for that emissions scenario--indicate a relatively low risk tolerance for the project. Thus, selecting the more conservative sea level rise projection and/or building in the capacity to change course or adapt may be critical to long-term viability; however, many projects will not serve their intended purpose if they are designed only for the end of their service life.

An important adaptation approach to dealing with uncertainty and changing conditions over time through the project design can be designing for or building in adaptive capacity. Adaptive capacity is "The ability of a person, asset, or system to adjust to a hazard, take advantage of new opportunities, or cope with change" (U.S. Climate Resilience Toolkit). For a specific project or asset like the Inner Harbor Promenade, this means designing for and building in the ability of the project or elements of the project to be adapted (retrofitted, upgraded, or otherwise modified over the project's service life) over time and/or developing an adaptive management plan that enables that. We often refer to this as designing adaptation pathways. Adaptation pathways offer operational and capital decision criteria tied to key thresholds and enable proactive planning should climate alter faster than the identified emissions scenario or selected sea level rise projection suggest.

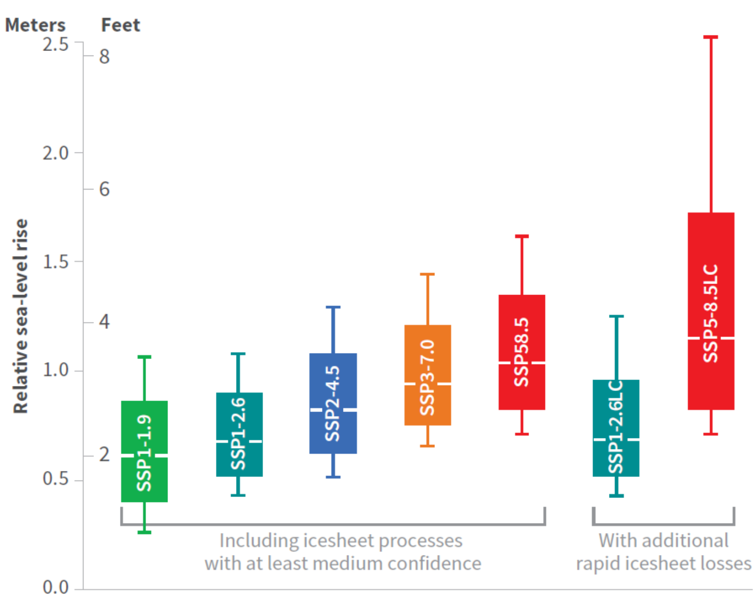


Figure 4. P-box probabilities for projected sea-level rise at Baltimore in 2100 under the IPCC AR6 emissions scenarios. Bars represent *likely* (17^{th}–83^{rd} percentile) ranges, vertical lines the 5^{th}–95^{th} percentile ranges, and white crossbars the medians. Sea-level rise is from a 1995–2015 baseline.

There are other more immediately practical reasons to discuss adaptation pathways as well: when designing for a long service life, as is being discussed for the Inner Harbor Promenade, designing for conditions at the end of a project's service life may yield undesirable, impractical, or even untenable conditions in the near term. To illustrate this potential challenge, one example relevant to the inner harbor that came up during the October 6 workshops designing for water access, particularly for water-based transportation. People enjoy the proximity of the current promenade to the water today as well as needing to be able to access boats floating at low tide today from the promenade in a manner that meets accessibility regulations. Designing to avoid the main promenade flooding regularly at the end of its service life could result in the promenade being feet higher than it is today, but building to a much higher elevation in the next decade could jeopardize this proximity to the water and even the accessibility of water transportation in the near-term. This is not presented to suggest or discourage a particular design approach, but rather to illustrate a potential need or rationale for building-in adaptive capacity or the ability to adapt the project at intervals over its assumed service life.

While adaptative management or adaptation pathways are a part of design, this is an important aspect to consider in selecting sea level rise assumptions as it may influence what sea level rise projection you want to design for or how many different sea level rise projections you chose to consider; and applying those to different aspects or elements of the design. For instance, expensive, hard to replace or upgrade elements might be designed or engineered for a more conservative or longer timeframe, while elements that might be more easily (quickly, inexpensively) be changed or upgraded in the future might be designed or engineered for a less conservative or shorter timeframe.

The WPB and the City of Baltimore should identify performance parameters for the near term and long term and consider the project's adaptive capacity. This recommendation is based on the low risk tolerance expressed and the potential for other factors such as changing conditions in the built environment, increases in storm intensity/frequency, and rapid ice melt scenarios that are either outside the scope of this effort or the Maryland 2023 Projections. Selecting 2-3 additional sea-level rise amounts to explore performance parameters or how the design could potentially be adapted will foster preparedness under a variety of future scenarios. This is also reflected under the "project timeframe" section regarding designing now for near- and mid-term time horizons and building in adaptability over a longer timeframe.

SUMMARY

The discussion and recommendations provided above can be used to translate the table of possible sea-level rise values into a shortlist of sea-level rise numbers that can inform the identification of a range of future water levels and flood elevations to consider in design.

Key variables needed to identify specific sea-level rise value(s) to be considered in evaluating the adaptability and resilience of the Inner Harbor Promenade redesign are summarized below. The related sea-level rise projections are highlighted in the chart below. These conclusions are based on feedback from the City of Baltimore and their stakeholders.

Timeframe: Designing for a service life that will maintain functionality without major overhaul through 2080 but building for adaptability at least through 2100 (the emissions scenarios/SSPs extend into the next century) is advisable. Projections for 2050 should also be considered in designing near term measures that may be upgraded and also considering prioritizing areas that may become highly susceptible to flooding by 2050.

Emissions Scenario: Based on feedback received from stakeholders, starting with the higher emissions scenario examined in the, increasing emissions (SPP3-7.0) is advisable.

Sea Level Rise Probability (Quantile: Given the criticality of the Inner Harbor Promenade to the City, selecting a relatively high quantile (low likelihood of being exceeded) for this project: either 83% or 95%. The 95th Quantile is selected for projected water elevations shown in the next section.

Uncertainty & Adaptive Capacity: Given the criticality of the Inner Harbor Promenade to the City, the low risk tolerance expressed by city stakeholders and the potential for other factors such as changing conditions in the built environment, increases in storm intensity/frequency, and rapid ice melt scenarios that are either outside the scope of this effort or the Maryland 2023 Projections, selecting 2-3 additional sea level rise amounts to explore performance parameters or how the design could potentially be adapted will foster preparedness under a variety of future scenarios is advisable. The City of Baltimore should also identify performance parameters for the near-term and long-term to address potential changes in conditions over the project service life that may result from rising sea levels as well as consider the project's adaptive capacity for rapid ice melt scenarios.

	Scenario		Quantile	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150
FEET	Paris Agreement	SSP1-2.6	5	0.13	0.30	0.46	0.65	0.83	1.02	1.15	1.27	1.41	1.43	1.53	1.61	1.70	1.78
			17	0.22	0.42	0.63	0.85	1.04	1.25	1.40	1.54	1.70	1.77	1.89	2.00	2.12	2.22
			50	0.34	0.61	0.88	1.15	1.38	1.63	1.83	2.03	2.23	2.42	2.62	2.81	3.00	3.18
			83	0.47	0.82	1.16	1.51	1.79	2.11	2.40	2.67	2.95	3.29	3.59	3.88	4.18	4.47
			95	0.57	0.97	1.38	1.78	2.12	2.50	2.86	3.20	3.55	3.95	4.33	4.71	5.08	5.45
	Current commitments	SSP2-4.5	5	0.13	0.27	0.46	0.72	0.97	1.20	1.42	1.60	1.68	1.72	1.90	2.07	2.24	2.40
			17	0.22	0.41	0.63	0.90	1.16	1.42	1.66	1.88	2.04	2.15	2.37	2.59	2.80	3.01
			50	0.34	0.61	0.89	1.18	1.47	1.79	2.09	2.37	2.69	2.97	3.29	3.60	3.91	4.22
			83	0.47	0.82	1.16	1.52	1.86	2.27	2.65	3.06	3.54	4.02	4.48	4.93	5.39	5.84
			95	0.57	0.98	1.37	1.78	2.18	2.66	3.15	3.63	4.25	4.84	5.41	5.97	6.52	7.08
	Increasing emissions	SSP3-7.0	5	0.11	0.24	0.44	0.71	1.01	1.30	1.57	1.83	2.13	2.15	2.41	2.66	2.91	3.15
			17	0.21	0.39	0.62	0.90	1.19	1.51	1.82	2.13	2.47	2.56	2.86	3.17	3.46	3.75
			50	0.34	0.60	0.88	1.19	1.50	1.86	2.24	2.65	3.08	3.39	3.81	4.23	4.64	5.04
			83	0.48	0.82	1.16	1.53	1.89	2.33	2.83	3.39	3.96	4.48	5.06	5.64	6.21	6.78
			95	0.58	0.98	1.38	1.80	2.21	2.74	3.34	4.04	4.74	5.38	6.09	6.80	7.51	8.23

	Scenario		Quantile	2020	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150
FEET	Paris Agreement	SSP1-2.6	5	0.13	0.30	0.46	0.65	0.83	1.02	1.15	1.27	1.41	1.43	1.53	1.61	1.70	1.78
			17	0.22	0.42	0.63	0.85	1.04	1.25	1.40	1.54	1.70	1.77	1.89	2.00	2.12	2.22
			50	0.34	0.61	0.88	1.15	1.38	1.63	1.83	2.03	2.23	2.42	2.62	2.81	3.00	3.18
			83	0.47	0.82	1.16	1.51	1.79	2.11	2.40	2.67	2.95	3.29	3.59	3.88	4.18	4.47
			95	0.57	0.97	1.38	1.78	2.12	2.50	2.86	3.20	3.55	3.95	4.33	4.71	5.08	5.45
	Current commitments	SSP2-4.5	5	0.13	0.27	0.46	0.72	0.97	1.20	1.42	1.60	1.68	1.72	1.90	2.07	2.24	2.40
			17	0.22	0.41	0.63	0.90	1.16	1.42	1.66	1.88	2.04	2.15	2.37	2.59	2.80	3.01
			50	0.34	0.61	0.89	1.18	1.47	1.79	2.09	2.37	2.69	2.97	3.29	3.60	3.91	4.22
			83	0.47	0.82	1.16	1.52	1.86	2.27	2.65	3.06	3.54	4.02	4.48	4.93	5.39	5.84
			95	0.57	0.98	1.37	1.78	2.18	2.66	3.15	3.63	4.25	4.84	5.41	5.97	6.52	7.08
	Increasing emissions	SSP3-7.0	5	0.11	0.24	0.44	0.71	1.01	1.30	1.57	1.83	2.13	2.15	2.41	2.66	2.91	3.15
			17	0.21	0.39	0.62	0.90	1.19	1.51	1.82	2.13	2.47	2.56	2.86	3.17	3.46	3.75
			50	0.34	0.60	0.88	1.19	1.50	1.86	2.24	2.65	3.08	3.39	3.81	4.23	4.64	5.04
			83	0.48	0.82	1.16	1.53	1.89	2.33	2.83	3.39	3.96	4.48	5.06	5.64	6.21	6.78
			95	0.58	0.98	1.38	1.80	2.21	2.74	3.34	4.04	4.74	5.38	6.09	6.80	7.51	8.23


HARLEM GROWN

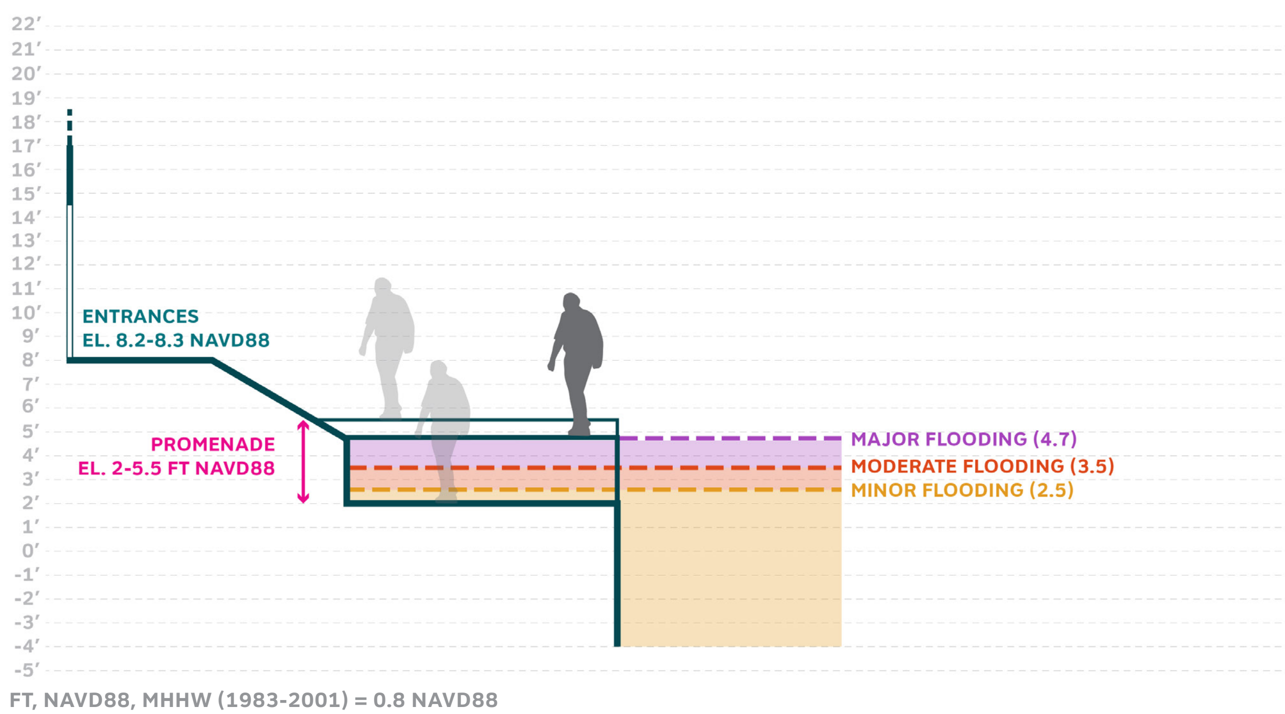
4. FUTURE COASTAL FLOODING WITH SEA-LEVEL RISE

The following section describes and illustrates the range of future water levels and flood frequencies for 2050, 2080, and 2100 for the Increasing Emissions Scenario (SSP3-7.0) with a 95% quantile (less than 5% chance of being exceeded).

FUTURE FLOOD FREQUENCIES: MINOR, MODERATE, AND MAJOR HIGH TIDE FLOODING

Using data from the ***interagency 2022 Sea Level Rise Technical Report***, it is possible to project the future frequency of high tide flooding in estimated average number of events per year exceeding NOAA's identified thresholds for minor, moderate, and major high tide flood events. The frequencies for the identified below were generated using the NASA ***Flooding Analysis Tool*** (Sea Level Change Team and University of Hawaii Sea Level Center (n.d.), ***Flooding Analysis Tool***) which uses data from the ***Interagency 2022 Sea Level Rise Technical Report*** (Sweet et al. 2022). All data reported are for the Baltimore, MD NOAA tide station (#8574680).

MINOR, MODERATE, AND MAJOR HIGH TIDE FLOODING



FUTURE PROJECTED WATER LEVELS

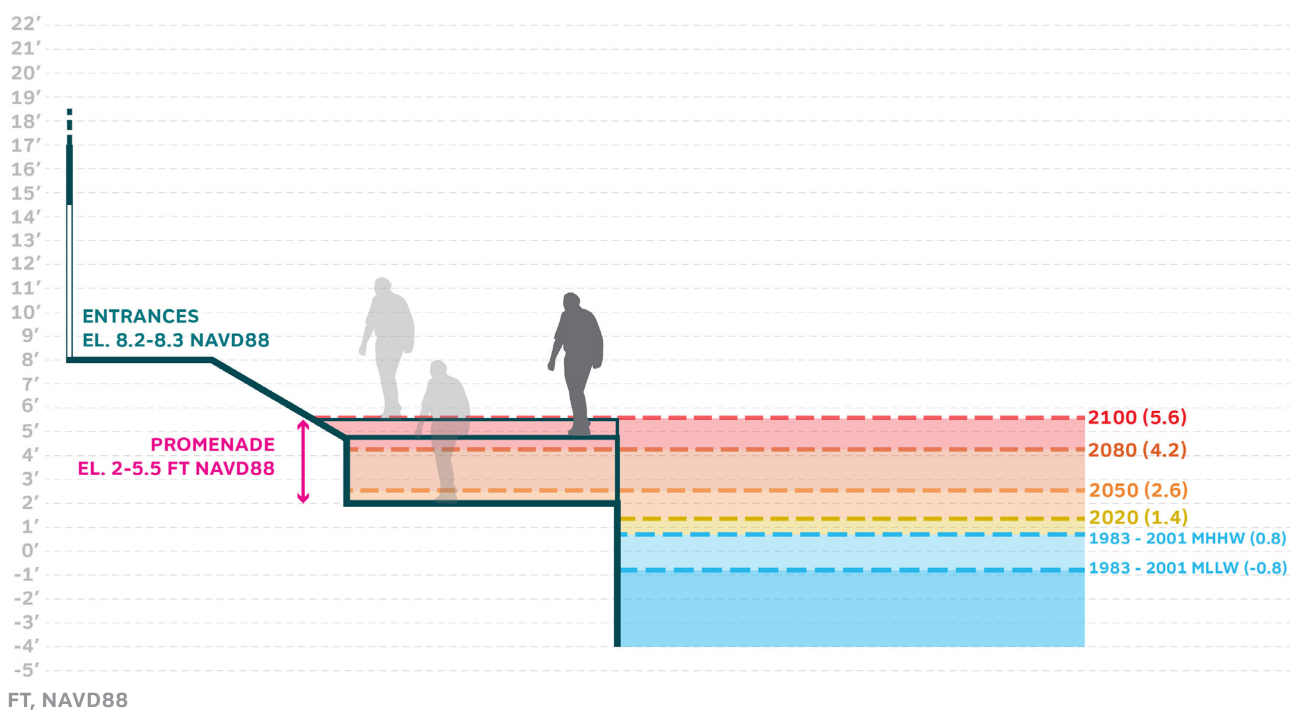
This section identifies future projected water levels for different flood event conditions in 2050, 2080, and 2100 using the assumed sea-level rise projections described in Section 3 (increasing emissions, 95% quantile). This is illustrated in sections for each coastal flood type/frequency/return period noted. These are shown here only for the increasing emissions, 95% quantile scenario; however, methods for developing these are described and the process can be replicated with other scenarios.

Tidal datum's: future daily high tide (elevation)

Some coastal areas experience two tide cycles each day, meaning there are two high and two low tides each day. Mean Higher High Water (MHHW) is "the average of the higher high water height of each tidal day over the national tidal datum epoch" (NOAA Tides & Currents, About Tidal Datums). While it does not correlate to this exactly because it is a numerical average and not a median, we can more or less understand it as an elevation that tides will reach or surpass about half the days of the year—approximately half the highest daily tides were higher, and half the highest daily tides were lower. The emphasis being that it is an average or middle value, rather than a maximum threshold.

Using the 1983-2001 MHHW tidal datum as a baseline, we projected MHHW levels for 2020, 2050, 2080, and 2100 by adding the selected sea-level rise to that datum. These are shown relative to the current Inner Harbor Promenade elevations in the section below.

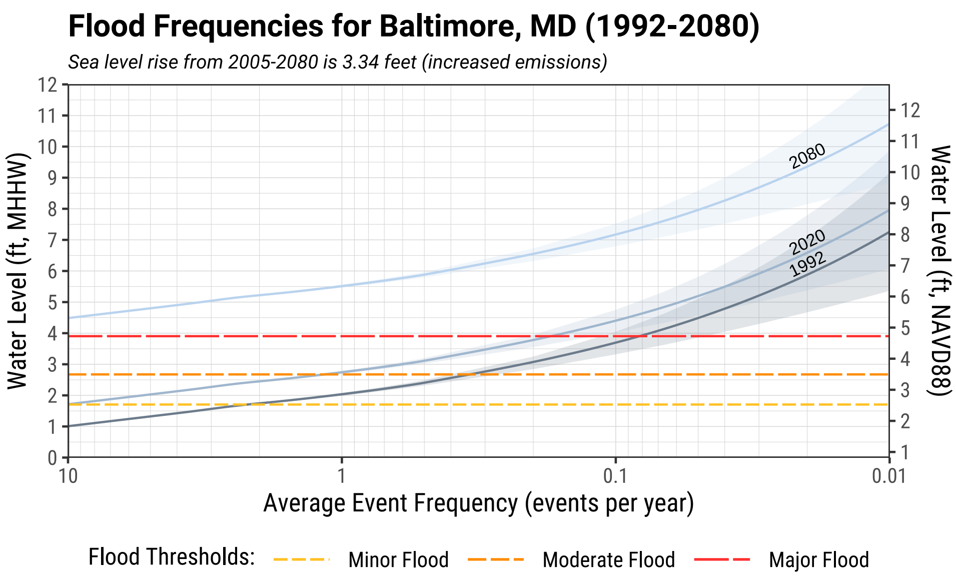
MEAN HIGHER HIGH WATER (AVERAGE HIGH TIDE)

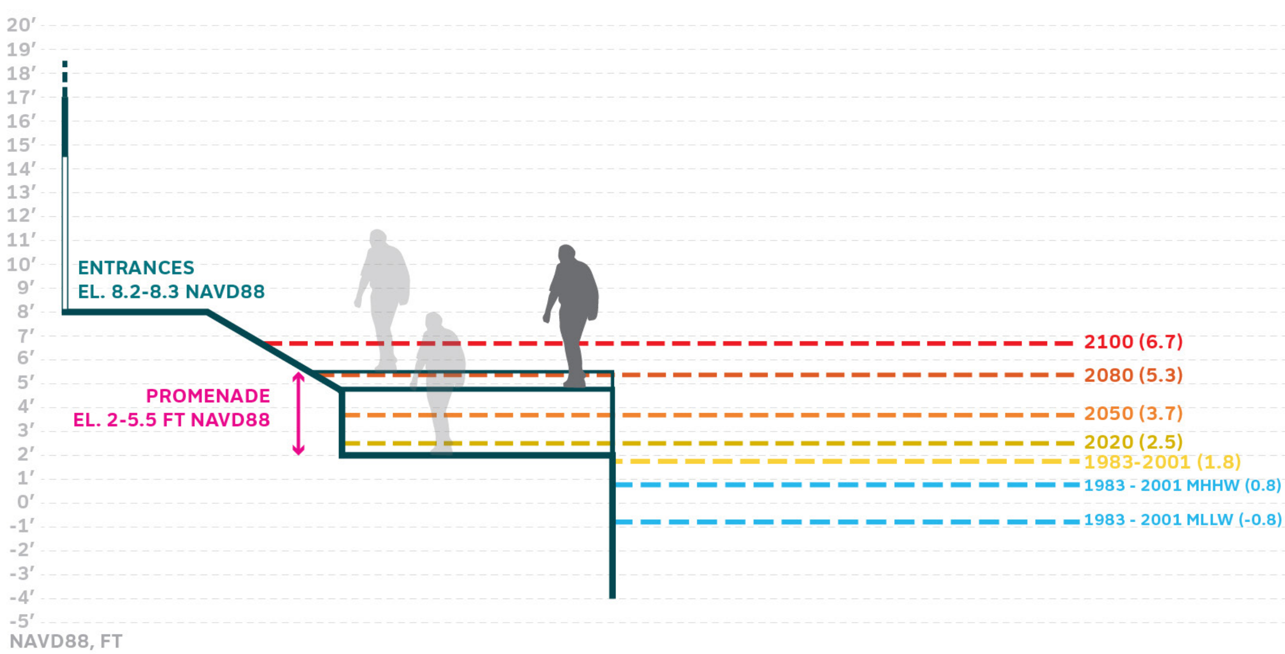


SCAPE

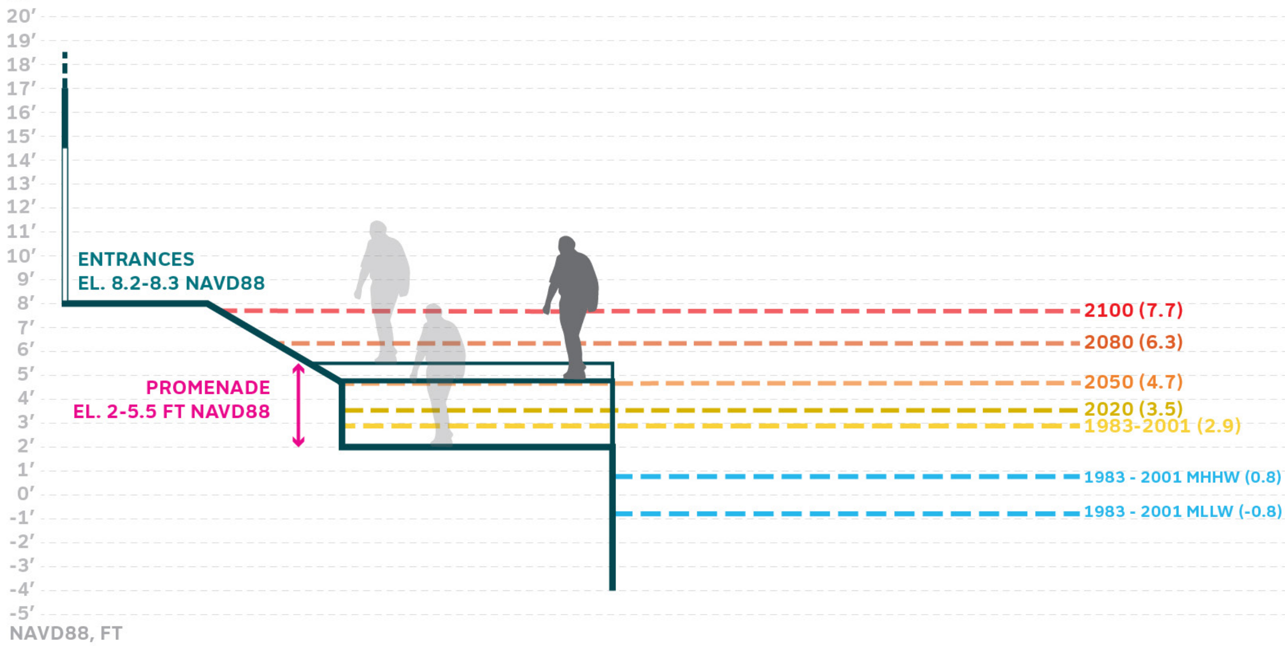
High frequency coastal flooding due to normal coastal process

Water levels associated with high frequency coastal flooding due to normal coastal processes were estimated for the 10 times per year, once per year (annual), and once in 10 years (10% annual chance) flood events. These were determined based on frequency return curves provided by Jamie Carter at NOAA Office for Coastal Management. These curves were generated based on NOAA analysis of past and projected water levels due to non-storm tidal conditions and coastal processes (versus extreme storm events) and draw in the data from the ***Interagency 2022 Sea Level Rise Technical Report*** (Sweet et al. 2022). The curve for the selected sea-level rise assumptions (increasing emissions, 95% quantile) used to generate these projected water levels is shown below.

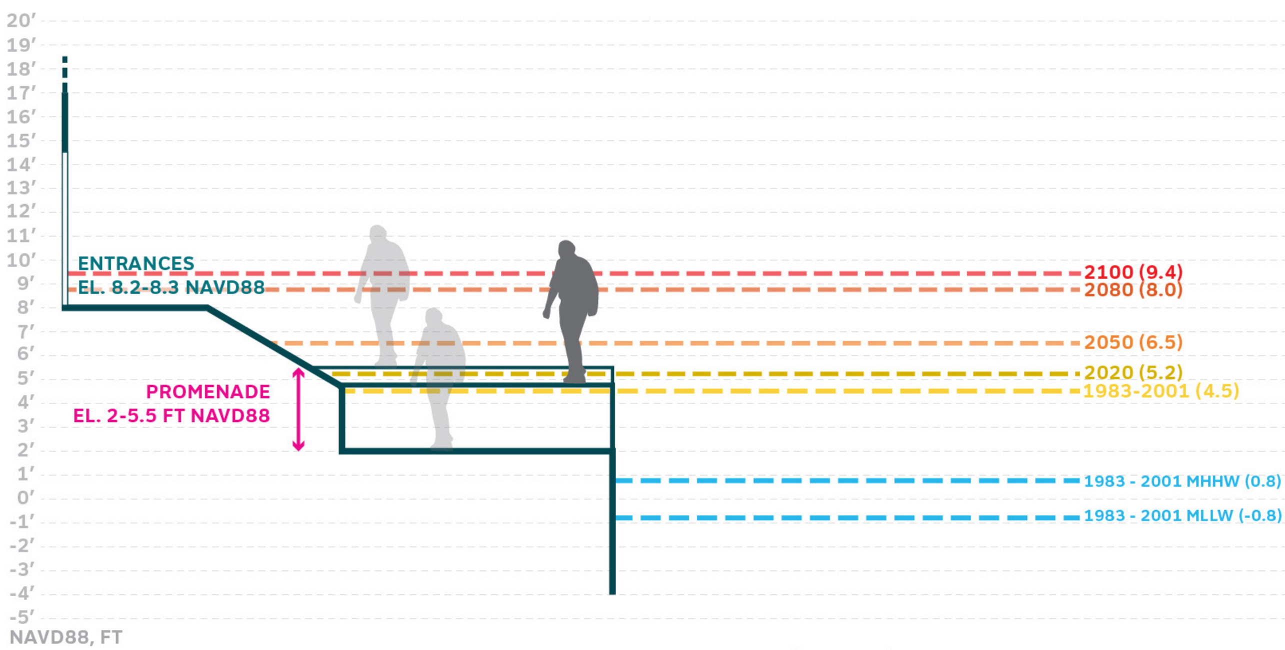




AVERAGE EVENT FREQUENCY: 10 TIMES PER YEAR, INCREASING EMMISSIONS (SSP3-7.0), 95th PERCENTILE



AVERAGE EVENT FREQUENCY: ONCE PER YEAR, INCREASING EMMISSIONS (SSP3-7.0), 95th PERCENTILE

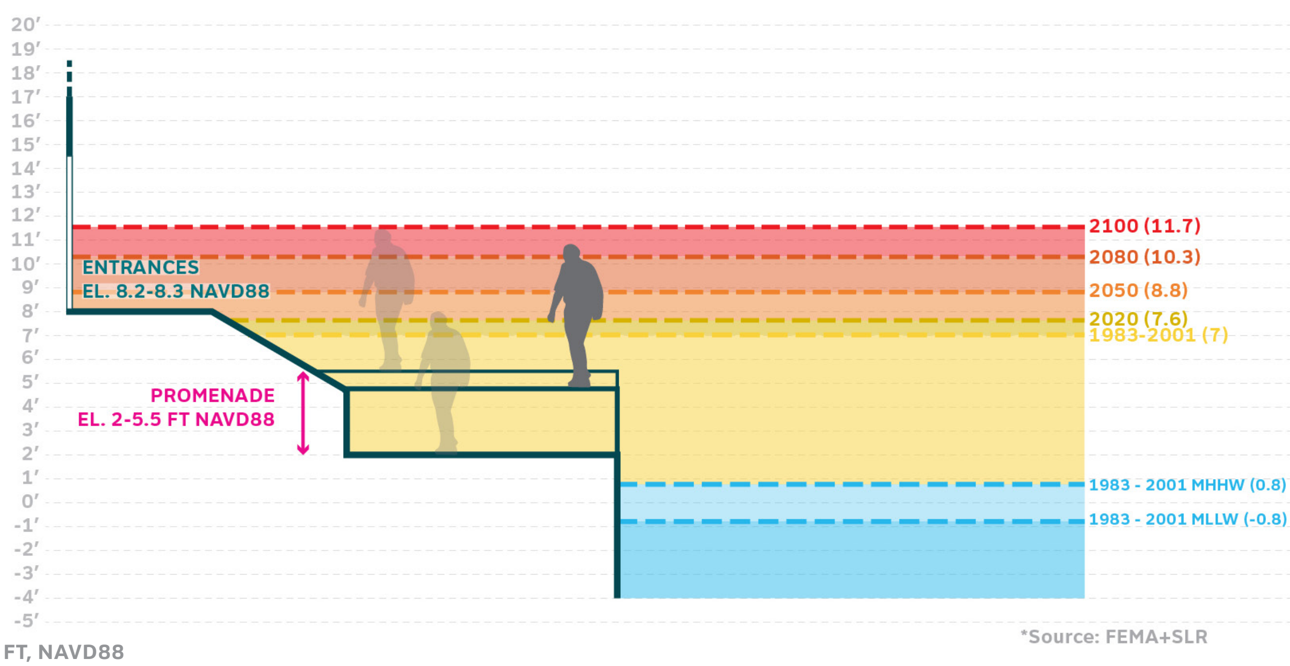


AVERAGE EVENT FREQUENCY: ONCE EVERY 10 YEARS, INCREASING EMMISSIONS (SSP3-7.0), 95th PERCENTILE

Flooding from more extreme coastal storm events (tropical and extratropical storm events)

The 1% annual chance flood (100-year flood) event was used to represent flooding from a high-intensity, low-frequency coastal storm event. While flooding from coastal storm events can vary greatly, the 1% annual chance event is a common reference point for infrequent storm event flooding as it is modeled, mapped, and used by the Federal Emergency Management Agency (FEMA) for flood insurance purposes, so historic/current water levels for this flood event are available from FEMA. Water levels associated with a 1% annual chance storm event "today" were derived from the base flood elevation (BFE) for the Inner Harbor area indicated in the 2018 Preliminary Flood Insurance Rate Map (FEMA, National Flood Insurance Program. ***Flood Insurance Rate Map, City of Baltimore, Maryland, Independent City, PANEL 0018 OF 0037***; Version Number, 2.3.3.3, 2400870018G. Preliminary December 26, 2018). Using the 1% annual chance flood BFE as a baseline, we estimated the 1% annual chance BFE for 2020, 2050, 2080, and 2100 by adding the selected sea-level rise to that elevation. These are shown relative to the current Inner Harbor Promenade elevations in the section below.

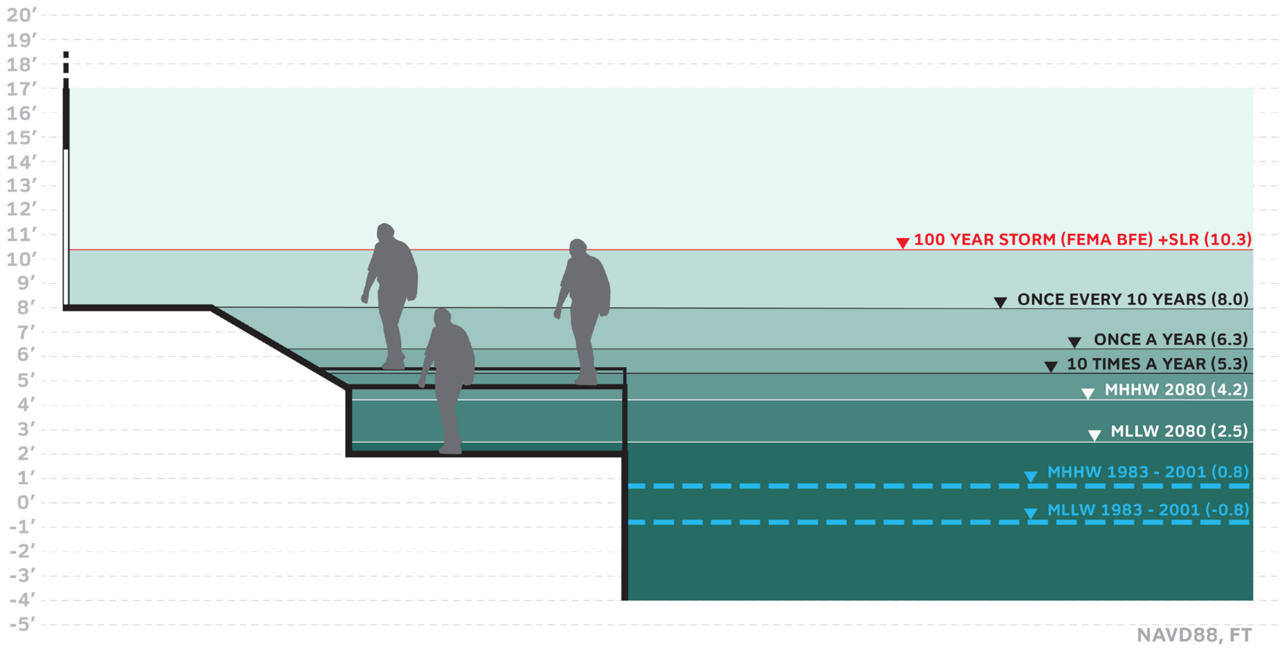
ONCE IN 100-YEAR (1% ANNUAL CHANCE) FLOOD EVENT



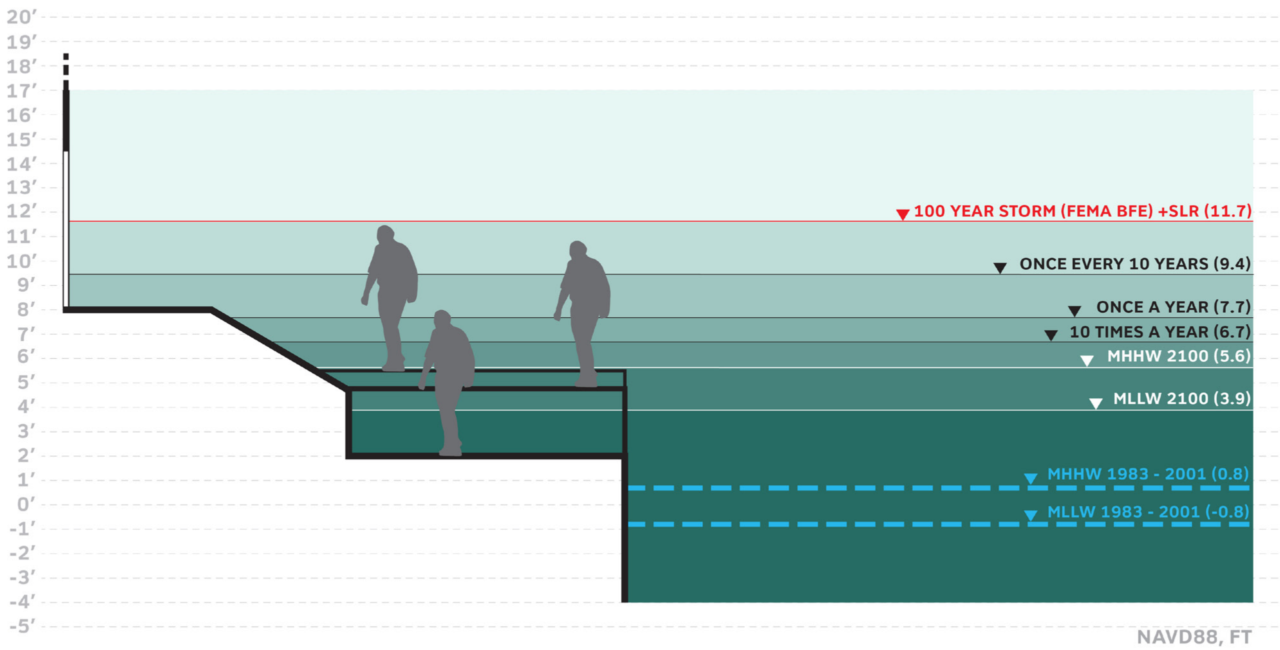
Future water levels by year

These future water levels can also be looked at together in a future year to better understand the range of possible flood conditions at the end of the target project service life. The sections below illustrate these water levels in 2080 and 2100.

INCREASING EMISSIONS (SSP3-7.0), 2080, 95TH PERCENTILE



INCREASING EMISSIONS (SSP3-7.0), 2100, 95TH PERCENTILE



5. BIBLIOGRAPHY

The following resources were referenced and utilized in the preparation of this memo.

Baltimore Office of Sustainability. 2023. ***Disaster Preparedness and Planning Project (DP3) 2023 Update***. Drafts provided by Baltimore Office of Sustainability on August 24, 2023.

Baltimore City Department of City Planning Office of Sustainability. ***Nuisance Flood Plan***. 2020. https://www.baltimoresustainability.org/wp-content/uploads/2021/04/Baltimore-Nuisance-Flood-Plan-2020.pdf.

Boesch, D. F., Baecher, G. B., Boicourt, W. C., Cullather, R. I., Dangendorf, S., Henderson, G. R., Kilbourne, H. H., Kirwan, M. L., Kopp, R. E., Land, S., Li, M., McClure., K., Nardin, W., & Sweet, W. V. 2023. ***Sea-level Rise Projections for Maryland 2023***. University of Maryland Center for Environmental Science, Cambridge, MD. https://www.umces.edu/sites/default/files/Maryland%20Sea-Level%20Rise%20Projections%202023%20report_0.pdf.

Collini, R.C., J. Carter, L. Auermuller, L. Engeman, K. Hintzen, J. Gambill, R.E. Johnson, I. Miller, C. Schafer, and H. Stiller. 2022. ***Application Guide for the 2022 Sea Level Rise Technical Report***. National Oceanic and Atmospheric Administration Office for Coastal Management, Mississippi–Alabama Sea Grant Consortium (MASGP-22-028), and Florida Sea Grant (SGEB 88). https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt02-globalregional-SLR-scenarios-US-application-guide.pdf

Federal Emergency Management Agency (FEMA), National Flood Insurance Program. ***Flood Insurance Rate Map, City of Baltimore, Maryland, Independent City, PANEL 0018 OF 0037***; Version Number, 2.3.3.3, 2400870018G. Preliminary December 26, 2018. https://planning.baltimorecity.gov/sites/default/files/2400870018G.pdf. NOTE: accessed via the City of Baltimore's Department of Planning's online repository for FEMA Map Products for the City of Baltimore (https://planning.baltimorecity.gov/flood-insurance-rate-maps.

Federal Emergency Management Agency (FEMA), National Flood Insurance Program. ***Flood Insurance Study, City of Baltimore, Maryland, Independent City, Vol. 1***. Flood Insurance Study Number 240087V001C; version number 2.3.3.3. Preliminary December 26, 2018. https://planning.baltimorecity.gov/sites/default/files/Preliminary%20Flood%20Insurance%20Study%20vol%201.pdf. NOTE: accessed via the City of Baltimore's Department of Planning's online repository for FEMA Map Products for the City of Baltimore (https://planning.baltimorecity.gov/flood-insurance-rate-maps.

Mcclure, Kate, Allison Breitenother, and Sasha Land. 2022. ***Guidance for Using Maryland's 2018 Sea Level Rise Projections***. University Of Maryland Sea Grant Extension and Maryland Department Of Natural Resources. https://dnr.maryland.gov/ccs/Documents/MD_SLRGuidance_June2022.pdf

National Aeronautics and Space Administration (NASA) Sea Level Change Team and University Of Hawaii Sea Level Center (n.d.). Flooding Analysis Tool (website). Retrieved October 2023 from https://sealevel.nasa.gov/flooding-analysis-tool/projected-flooding.

National Oceanic and Atmospheric Association (NOAA) National Ocean Service (n.d.) What is High Tide Flooding? Retrieved October 2023 from https://oceanservice.noaa.gov/facts/high-tide-flooding.html

National Oceanic and Atmospheric Association (NOAA) National Ocean Service (n.d.) What is Storm Surge? Retrieved October 2023 from https://oceanservice.noaa.gov/facts/stormsurge-stormtide.html .

National Oceanic and Atmospheric Association (NOAA) Tides & Currents (n.d.) About Tidal Datums. Retrieved October 2023 from https://tidesandcurrents.noaa.gov/datum_options.html.

National Oceanic and Atmospheric Association (NOAA) Tides & Currents (n.d.) Coastal Inundation Dashboard. Retrieved October 2023 from https://tidesandcurrents.noaa.gov/inundationdb/

National Oceanic and Atmospheric Association (NOAA) Tides & Currents (n.d.) Station Home Page: Baltimore, MD - Station ID: 8574680. Retrieved October 2023 from https://tidesandcurrents.noaa.gov/stationhome.html?id=8574680.

Reidmiller, D.R. et al. 2018. ***Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II***. U.S. Global Change Research Program.

Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak. 2022. ***Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines***. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD. https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report-sections.html or https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf (also referred to as the ***Interagency 2022 Sea Level Rise Technical Report***).

Sweet, William V. et al. 2018. ***Patterns and Projections of High Tide Flooding along the U.S. Coastline Using a Common Impact Threshold***. Silver Spring, Maryland: National Oceanic and Atmospheric Administration. https://tidesandcurrents.noaa.gov/publications/techrpt86_PaP_of_HTFlooding.pdf.

Terando, Adam et al. 2018. ***"Southeast," Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II***. Washington, D.C.: U.S. Global Change Research Program.

U.S. Climate Resilience Toolkit. March, 2021. "Glossary" U.S. Climate Resilience Toolkit. Accessed October 2023 from https://toolkit.climate.gov/content/glossary.

6. APPENDICIES

The following documents have been packaged as digital appendices.

Presentation deck presented to the Sustainability Subcabinet on September 12, 2023 (230912_Subcabinet Presentation.ppx)

Summary of take-aways from the Sustainability Subcabinet meeting, prepared September 15, 2023 (230915_Post Subcabinet Takeaways_SCAPE.pdf)

Brandon M. Scott
Mayor

WATERFRONT PARTNERSHIP
OF BALTIMORE

NOVEMBER 2023