CLIMATE RISK ASSESSMENT

New Bedford, Massachusetts

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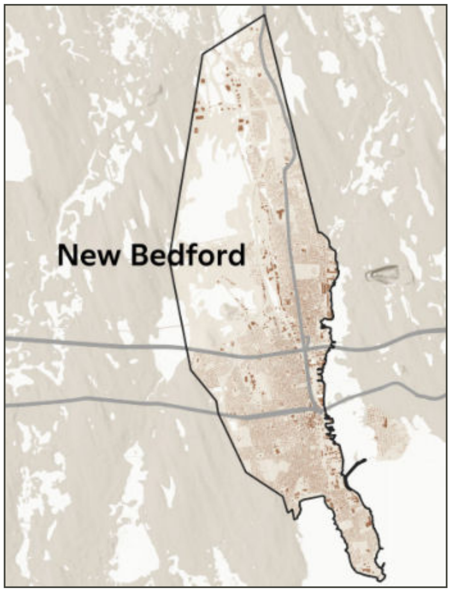
Woodwell Climate Research Center

Introduction

The impacts of climate change on the frequency and severity of physical hazards are putting many communities at risk. As the threat of climate change grows, so too does the need for accessible information, tools, and expertise to support climate-resilient decision making across multiple scales, from communities to countries. Woodwell Climate Research Center believes there is a need to localize and customize climate risk assessments. This information is critical for local government leaders as they make planning decisions, but it is not available to all communities. Woodwell believes that this science should be freely and widely available. To address this gap, Woodwell works with communities across the world, including New Bedford, MA, to provide community climate risk assessments, free of charge. We focused our modeling efforts on a select number of neighborhoods and streets, rather than the entire city of New Bedford, in order to directly respond to community priorities and address a specific, localized flood modeling challenge.



Results summary

As a result of climate change, flood risk is projected to increase for New Bedford. The probability of the historical 100-year rainfall event, a useful indicator of flood risk, is expected to double by mid-century and be more than three times more likely by the end of the century. Heavier rainfall will translate into slightly greater flood depths and extent for New Bedford. Making changes to the land elevation and culverts will help alleviate some of the flooding near Terry Lane and Chaffee Street. Here we present our findings on extreme precipitation and flooding to help New Bedford in its plans to create a more resilient future for all residents.

Extreme rainfall

The Fifth National Climate Assessment shows that the U.S. Northeast region has already seen a 60% increase, the largest in the U.S., in annual precipitation occurring from the heaviest 1% of events.[1] Future warming is expected to continue this trend of intensification, meaning more frequent and severe rainfall events. Here we use localized future precipitation data from downscaled global climate models to calculate the change in probability of extreme rainfall events. A detailed explanation of the precipitation data processing can be found in the methodology section of this document. In Table 1, we show the changes in the return period of the present-day (2000-2020) 100-year rainfall event for mid-century (2040-2060) and late-century (2070-2090). By mid-century, the present-day 100-year event will occur with a return period of 1-in-50. By late-century, the present-day 100-year event will become a 1-in-32 year event.

According to the National Atlas 14 published by the National Oceanic and Atmospheric Administration (NOAA), the 100-year rainfall amount, based on present-day rainfall records, for New Bedford is 7.6 inches (193 mm).[2] For reference, the present-day annual average rainfall for the New Bedford Municipal Airport is 45.9 inches (1165 mm).[3] By mid-century, the 100-year amount will increase to 8.7 inches (221 mm) and by late-century this will further rise to 9.9 inches (251 mm; Table 1).

	Present	**2040-2060**	**2070-2090**
Return Period (yr)	1-in-100	1-in-50	1-in-32
100-Year	7.6 in (193 mm)	8.7 in (221 mm)	9.9 in (251 mm)

Table 1: Mid and Late-21st Century Change in Historical 100-Year Return Period and Rainfall. The mean future return period in years and rainfall amounts in inches and millimeters for New Bedford of the present-day, 2040–2060, and 2070–2090 100-year rainfall events.

Flooding

For a detailed explanation of the flood model input data and flood modeling procedures, please refer to the methodology section of this document.

Flood extent comparison

Before estimating future flood risk, we like to compare the present-day flood risk results against the Federal Emergency Management Agency (FEMA) flood maps. However, FEMA maps have the section of New Bedford that we are interested in categorized as an 'Area of Minimal Flood Hazard'. The likely reason for this is because FEMA focuses on fluvial flooding, which is flooding associated with water level changes in rivers, lakes, and streams, but does not take into account pluvial flooding. Intense rainfall events fall into the pluvial category and are not included in FEMA maps. It appears that for this region of New Bedford, FEMA maps were updated in 2021. This however does not include flooding associated with Ousamequin Creek (not official name) that flows directly through this part of New Bedford, which also likely contributes to FEMA's lack of flood risk in this area.

[1] Marvel et al. (2023). Ch. 2. Climate trends. In: *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. https://doi.org/10.7930/NCA5.2023.CH2

[2] NOAA calculates extreme rainfall frequencies with all available station data.

[3] https://www.weather.gov/wrh/Climate?wfo=box

Present and Future Flood Risk

The primary flood risk in this area of New Bedford, MA is from extreme rainfall. To accurately model this extreme rainfall, we included several culverts from Acushnet Avenue south to Chaffee Street, shown in Figure 1, the conveyance for them can be found in Table 2. In Figure 2, we show the depth of the present 100-year flood from rainfall for New Bedford. The highest depth values of around 1.6 ft (0.5 m) occur in several locations. Some examples are Lucy Street, Phillips Road, and Terry Lane. Flooding on Chaffee Street is also substantial with a maximum depth of approximately 0.85 ft (0.26 m). We mask wetland areas to focus the analysis on locations where human life and property are at risk.

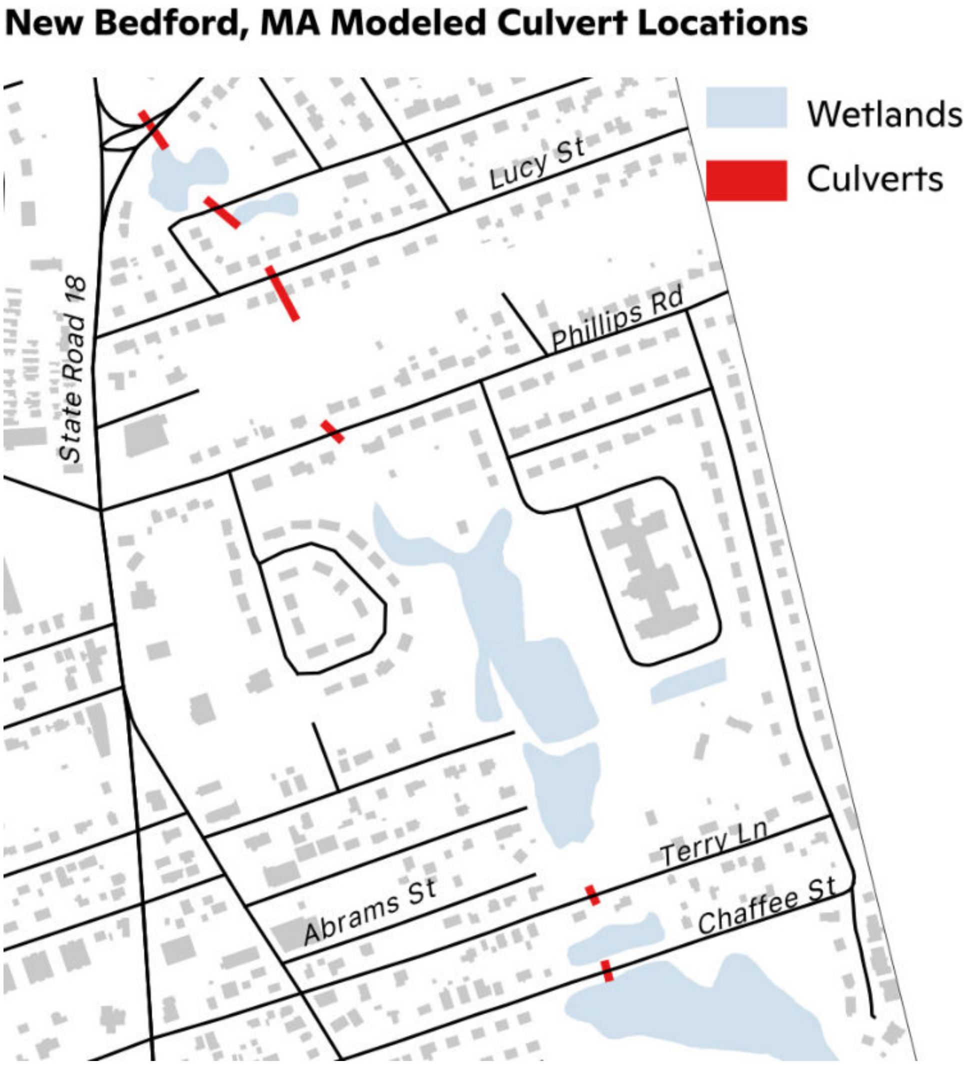


Figure 1: Culvert locations. These culverts were included in modeling for New Bedford, MA.

Culvert Location	Conveyance (%)
Acushnet Avenue	100
Winston Street	100
Lucy Street	100
Phillips Road	30
Terry Lane	85
Chaffee Street	85

Table 2: Conveyance for Culverts in Historical 100-Year Return Period and Rainfall. The % of conveyance for each modeled culvert. These were used in the present model run and for the two future runs where no changes were made to elevation or culverts.

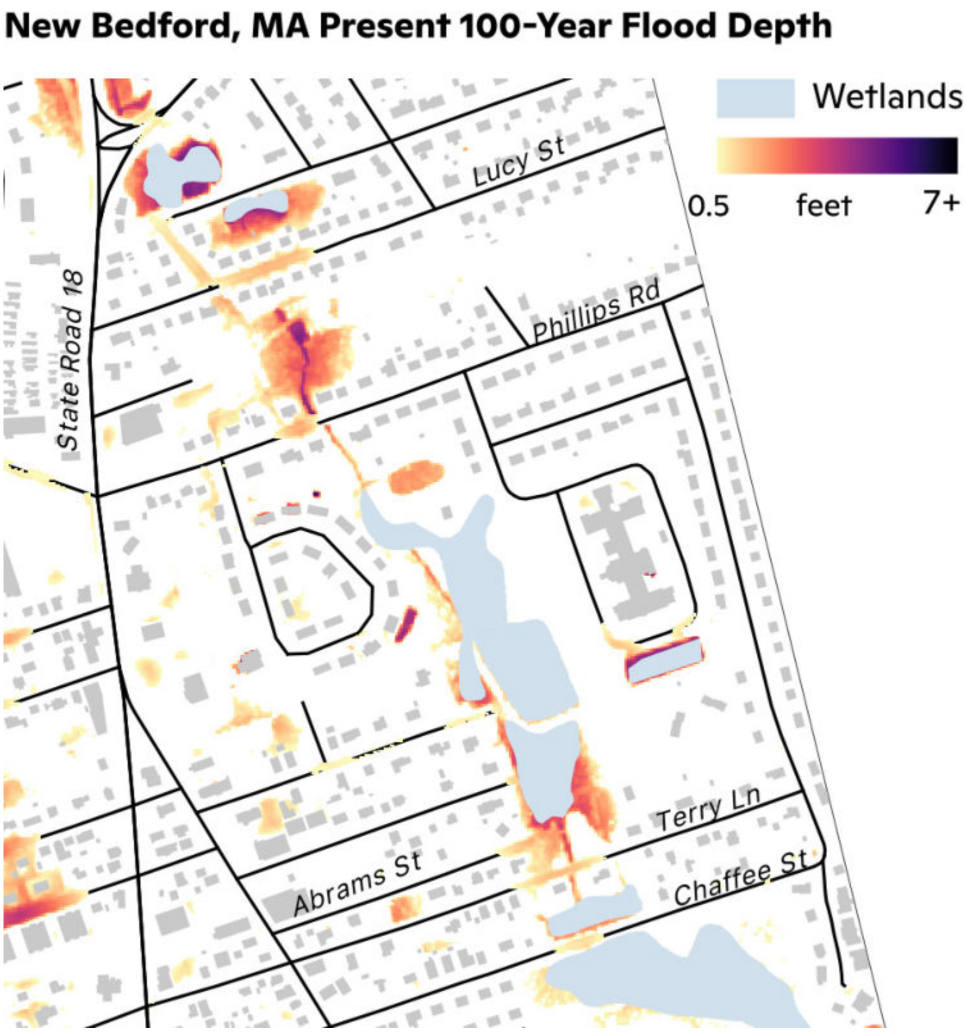


Figure 2: Present-Day 100-Year Flood. The flood depth, minimum of 0.5 ft (0.15 m), for New Bedford, MA. The maximum extent from the 100-year pluvial/riverine flood is shown.

Present and Future 100-year Flood

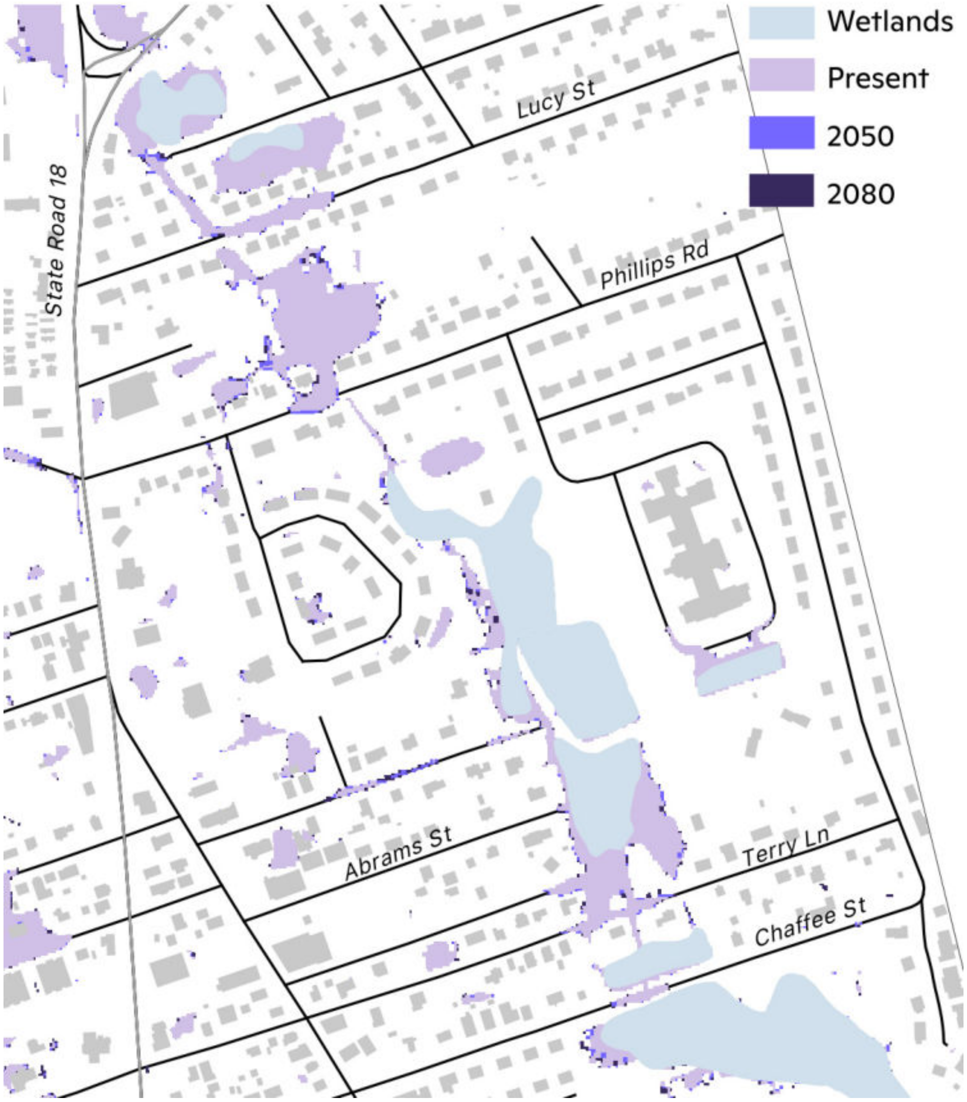


Figure 3: Present-Day and Future 100-Year Flood New Bedford, MA. The flood extent, quantified as having a depth of at least 0.5 ft (0.15 m), for New Bedford, MA. The maximum extent for the 100-year pluvial/riverine flood is shown.

Future flood risk is driven by increased rainfall. Overall, the changes in extent are minor and are shown in Figure 3. This change in pluvial flood risk is due to projected increases in rainfall between 1.1 inches to 2.3 inches (28-58 mm) from the present-day period, as shown in Table 1. Since the extent doesn't increase substantially, the wetland areas in this section of New Bedford are able to store the increased amount of precipitation. While the extent doesn't increase much, the areas that flooded previously, Terry Lane and Chaffee Street in particular, will continue to be inundated.

Culvert modifications

To explore potential changes that could be made to culverts and wetlands, we also did two additional future model runs for 2050 and 2080 to compare to the previously discussed results. We set conveyance through the culverts at 100% meaning there is no debris or anything blocking the flow of water through any of the culverts shown in Figure 1. We also used the previous work done for New Bedford, *Stormwater Collection System Needs and Issues*, created by CDM Smith, that proposed a box culvert at Terry Lane to reduce flooding. Based on this, the culvert at Terry Lane was made into a 4 ft by 6 ft box culvert to allow for more flow. Additionally for these model runs, we convert the area between Terry Lane and Chaffee Street into a wetland by lowering the elevation just south of Terry Lane so there is additional water storage space. Lastly, we are treating Chaffee Street as having a bridge that spans across the flooded section. In Figure 2 the depth was approximately 0.85 ft (0.26 m) so we assume a bridge spanning this area would at minimum need to be approximately 1–2 ft above its present elevation to allow water to freely flow underneath southward. These elevation changes are shown in Figure 4. Figure 5 shows the result of these modifications. The flooding on Terry Lane is greatly reduced in this scenario by allowing all the water that was on the street to flow southward. Visually Chaffee Street appears more flooded, but since the road would be higher this is showing all the water flowing under the created bridge. Figure 5 shows the changes that were made to the elevation to include the new wetland area just south of Terry Lane and to make changes to Chaffee Street.

Elevation Changes for Modifications

Figure 4: Elevation changes. The area shown has the elevation lowered to include flood model modifications. The two buildings shown in the elevation change would be removed in this model scenario.

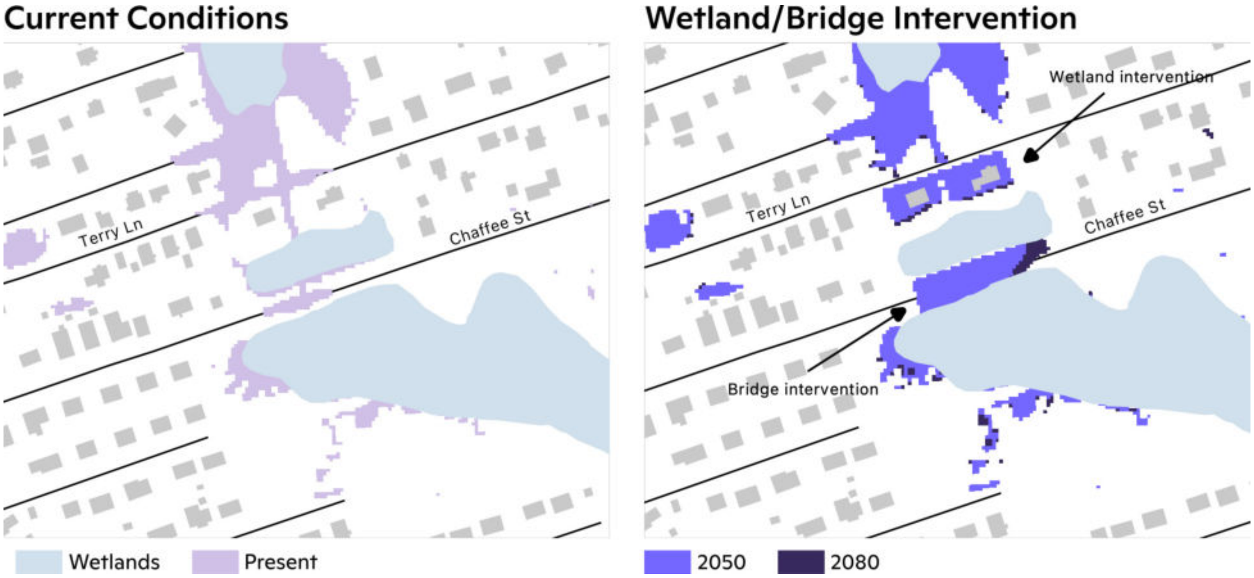


Figure 5: Present-Day and Future 100-Year Flood Modifications. The flood extent, quantified as having a depth of at least 0.5 ft (0.15 m), for New Bedford, MA. Current culverts are modeled on the left, and the right includes changes to the culverts and elevations. In this scenario, the two buildings in the wetland would be removed. The maximum extent for the 100-year pluvial/riverine flood is shown.

Conclusion

New Bedford is currently at risk from flooding, primarily from extreme rainfall events, and this exposure will only increase under climate change. The results presented in this study were compared to FEMA's maps which denote the lack of a flood zone in this section of New Bedford, revealing significant discrepancies due to the exclusion of pluvial flooding in FEMA's analysis. Our findings show an expected increase in the frequency and intensity of heavy rainfall with the probability of the present-day 100-year rainfall event to be twice as likely by the mid-21st century and just over three times as likely by the end of the century. New Bedford's culverts aren't able to handle the water capacity required presently, so enlarging the culvert at Terry Lane and creating a wetland area just south of the road is recommended. To further mitigate flooding, Chaffee Street could be raised by installing a bridge to allow the water to flow southward. This report provides insight into the climate vulnerability of the City of New Bedford, where an increasing area will be exposed to increased flood waters and more frequent flood events by the end of the century, and it provides ways to proactively mitigate the harmful effects of extreme flooding that the city faces.

Methodology

To simulate flood risk we use a coupled version of the LISFLOOD-FP v8.1 flood model (LISFLOOD-FP developers, 2022; Shaw et al., 2021) and the Environmental Protection Agency's (EPA) Stormwater Management Model (SWMM). LISFLOOD-FP is a two-dimensional raster hydraulic model that solves all terms of the shallow water equations. LISFLOOD-FP has been extensively used from the river reach scale to continental simulations and we refer the reader to Shaw et al. (2021) for a detailed explanation of LISFLOOD-FP. SWMM was introduced in 1971 by the USA Environmental Protection Agency and has been continuously developed since. SWMM is a one-dimensional stormwater system model solving the one-dimensional Saint-Venant equations.

LISFLOOD-FP and SWMM are coupled based on the methodology presented in Leandro and Martins (2016). SWMM and LISFLOOD-FP were coupled using SWMM's dynamic link library (DDL). LISFLOOD-FP's source code was modified to allow for bidirectional interaction between the two models at outfalls, catch basins, and manholes by calling SWMM functions during each LISFLOOD-FP time step. Time step synchronization between LISFLOOD-FP and SWMM is controlled by LISFLOOD-FP. Flow from LISFLOOD-FP to SWMM through manholes and catch basins are governed by the orifice and weir equations. Flood volumes that occur at manholes and catch basins are transferred to LISFLOOD-FP. Further detail on flow interactions can be found in Chen et al. (2016).

All flood model results show flooding above 15 cm (~0.5 ft) as this is an average curb height and any flooding above this threshold would likely result in flood damages. All areas that are wetland and permanent water cover as determined by the MassDEP Dataset (https://www.mass.gov/info-details/massgis-data-massdep-wetlands-2005).

Three time periods were used for this study: 2000–2020 (also referred to as present-day), 2040–2060, and 2070–2090. These time periods can also be interpreted as warming levels in the context of climate policy. The 2000–2020, 2040–2060, and 2070–2090 periods correspond to 1, 2 and 3 degrees Celsius of warming respectively. For each time period, a pluvial/riverine flooding run was performed.

Any maps involving structures used the MassGIS Data: Building Structures (https://www.mass.gov/info-details/massgis-data-building-structures-2-d).

The following are the coupled LISFLOOD-FP and SWMM inputs:

1 Rainfall

A | Historical rainfall

The 24-hour 1-in-100 year rainfall event was used from NOAA Atlas 14 (NA14) point precipitation frequency estimates for New Bedford, MA (Perica et al., 2015). The temporal distribution, also from NOAA Atlas 14, of the 24-hour rainfall is taken from the combined cases of the four quartiles and uses the 90% cumulative probability.

B | Future rainfall

CMIP6 climate model data were bilinearly interpolated to a 1-km grid and then bias-adjusted using phase 3 of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) version 2.5 methodology (ISIMIP3BASD v2.5) (Lange, 2019; Lange, 2021). High-resolution, 1-km Daymet reanalysis data (Thornton et al., 2022) were selected as the observation dataset for bias adjustment. We utilize a nonstationary (NS) approach to estimate future-projected extreme rainfall. In the NS approach, precipitation estimates are calculated for the entire time period (i.e., 1971–2100) using a temporal parameter to represent changes in extreme precipitation through time. NOAA recommends using a NS approach since it considers the whole time series in addition to any trends in the data, offering a more robust analysis and more stable estimate of future extreme precipitation in a changing climate. The NS approach is better suited for engineering applications as future relative changes are more realistic compared to a quasistationary approach. We use a regional fitting method to estimate the parameters of the Generalized Extreme Value (GEV) distribution. For each target pixel, a 40-mile radius is used to capture the annual maxima of the surrounding pixels. Each pixel's annual maxima is given a weight using a triweight kernel function based on distance (e.g., pixels ≥ 40 miles have zero weight). The log-likelihood function of the GEV distribution is then minimized with the Nelder-Mead algorithm using the annual maxima and pixel weights to estimate the GEV parameters. The beta distribution of penalized coefficients ranging between -0.5 and 0.5 is used to constrict the shape parameter as specified by NOAA.

To estimate future daily precipitation frequency estimates (PFEs), the biases (ratio) between the baseline period and the NA14 daily PFEs are calculated and then multiplied by the future climate model daily PFEs. We assume the daily temporal distribution of rainfall does not change in the future so we continue the use of the historical temporal distribution.

2 Digital Elevation Model

The 2021 USGS Lidar DEM: Central Eastern Massachusetts was used to create the New Bedford, MA elevation domain. The resolution of the raw data was 1m. The final DEM resolution was set to 2m to allow for faster model run times.

3 Friction coefficients

Friction coefficients, or Manning N values, were determined based on the land cover type of the area. The 2023 land cover was used for this from the National Land Cover Database (NLCD). Based on each classification of land cover, an associated friction coefficient is provided. See table here: https://rashms.com/wp-content/uploads/2021/01/Mannings-n-values-NLCD-NRCS.pdf

4 Infiltration

To calculate soil infiltration rates, the USDA Soil Survey Geographic Database (SSURGO) for Massachusetts was used to obtain the soil hydrologic groups. These hydrologic groups have defined infiltration rates depending on the type of soil. Infiltration values per hydrologic group were used from Musgrave (1955). These rates in combination with the 2023 NLCD impervious surface percentages were used to compute more accurate infiltration rates. The impervious surfaces take into account built-up areas where rainfall will not be able to infiltrate. We do not incorporate the impact of stormwater systems to convey runoff from streetscapes.

Methodology references

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Cover: Aerial view of the city. / photo by Jacob Boomsma

Above: Union Street sloping down to the waterfont. / photo by Dan Logan

WOODWELL CLIMATE RESEARCH CENTER conducts science for solutions at the nexus of climate, people and nature. We partner with leaders and communities for just, meaningful impact to address the climate crisis. Our scientists helped to launch the United Nations Framework Convention on Climate Change in 1992, and in 2007, Woodwell scientists shared the Nobel Prize awarded to the Intergovernmental Panel on Climate Change. For 40 years, Woodwell has combined hands-on experience and policy impact to identify and support societal-scale solutions that can be put into immediate action. This includes working with communities on the frontlines of the climate crisis.

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