Section 7. Drought

Key changes reflected in the 2023 DP3 update:

- The hazard description, including location, extent, previous occurrences and losses, and future probability, has been updated.
- Information has been added about the potential impacts of climate change on the drought hazard.
- The 2018 DP3 did not include a vulnerability assessment for the drought hazard; the 2023 DP3 update includes a vulnerability assessment combined with the hazard description. The vulnerability assessment addresses the impacts to population, structures, and natural/historic/cultural resources.
- Information has been added about integration of cascading and compounding impacts.
- Information has been added about future changes that may impact vulnerability.

7.1 Description

Droughts affect the City's industries and make day-to-day tasks more difficult to complete because water usage has to be monitored.

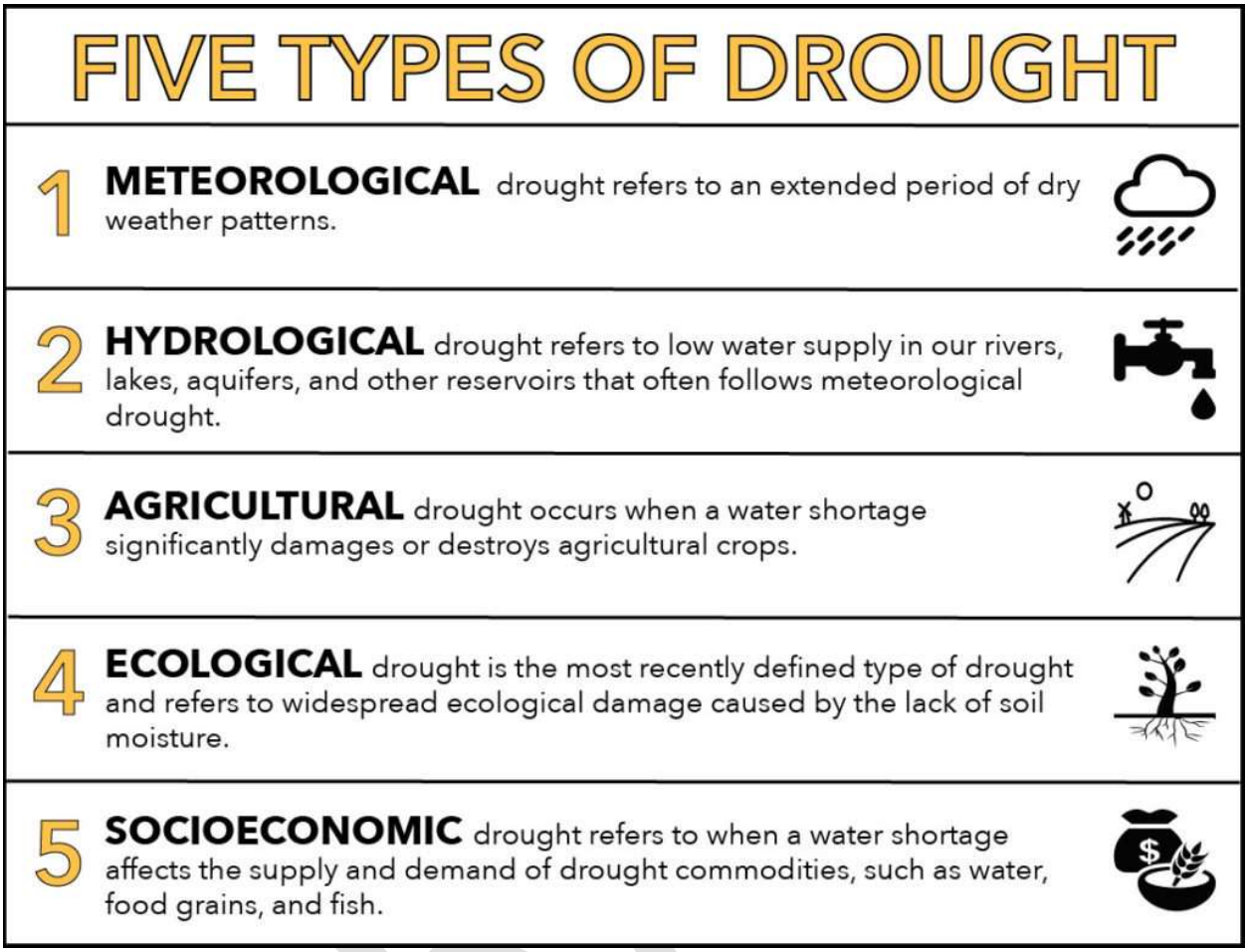
Key Terms

- **Drought**—A deficiency of precipitation over an extended period of time resulting in a water shortage (National Integrated Drought Information System 2023).

Drought is defined as a period of prolonged dryness. It is normal for the City to experience wet winter and spring seasons and drier summers. This fluctuation allows for reservoirs to fill and act as natural resources for water during the drier periods. When experiencing drought, the City's reservoirs may not retain enough water, causing a depletion in the total water supply available and limiting the public water supply for human consumption. The *Baltimore City Climate Action Plan* states that the City experienced the lowest levels in groundwater and stream flows during the year 2002 to 2003. Subsequently, water use restrictions were put in place to help restore the water supply back to normal (City of Baltimore Office of Sustainability 2012).

The National Weather Service (NWS) has defined four types of droughts: meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought. These types of droughts are further discussed in Figure 7-1.

Figure 7-1. Five Types of Drought



Source: Living with Drought 2023

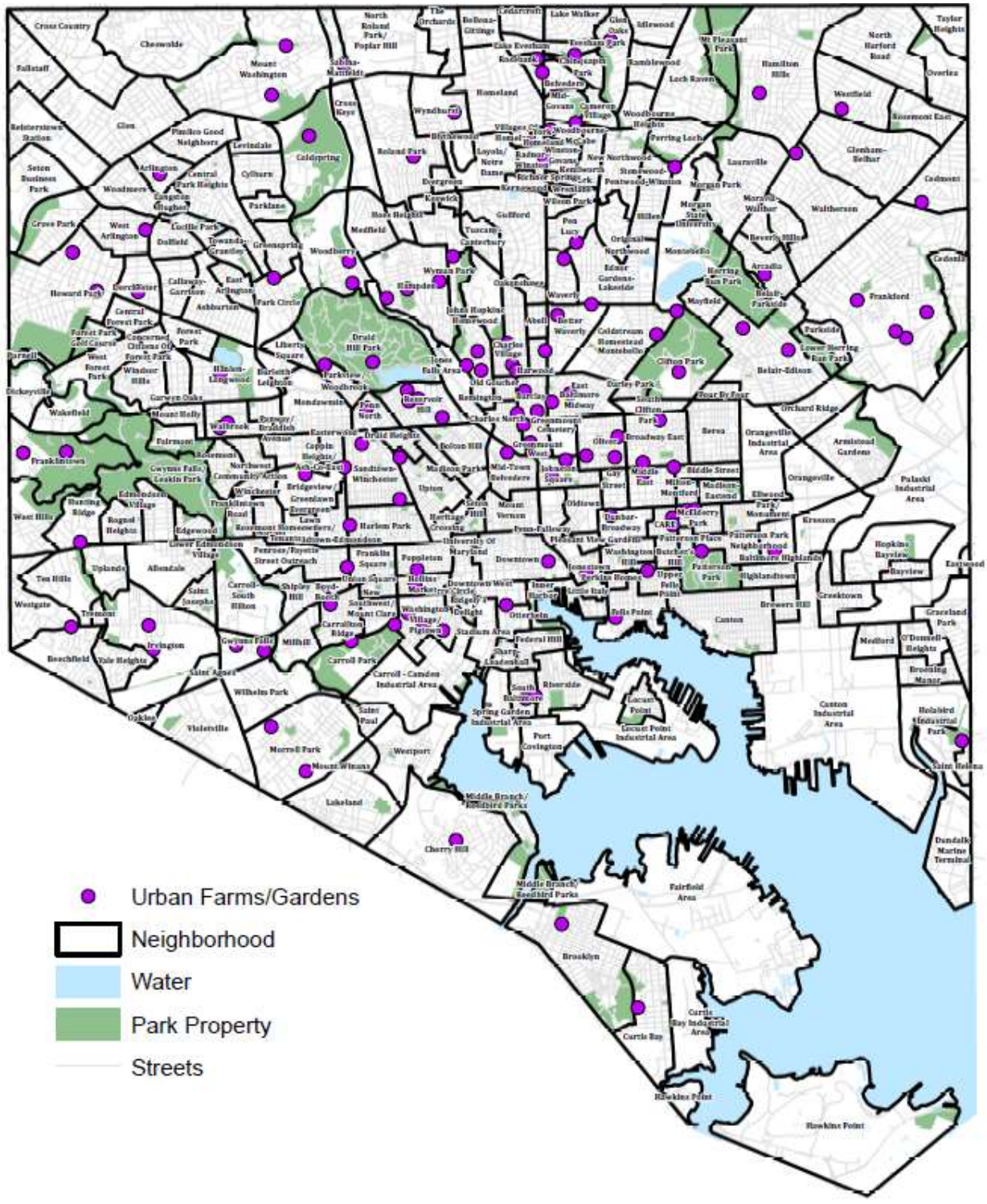
7.2 Location

Droughts occur on a regional scale; therefore, all areas within the City have equal risk of exposure to this hazard. The likelihood of drought occurring in the City is dependent upon the climatic and atmospheric conditions of the region.

Agriculture

When a drought occurs, the agricultural industry is most at risk in terms of economic impact and damage. For the City, this means urban agriculture operations could be severely impacted. According to the Baltimore City Department of Planning, there are approximately 120 food-producing community gardens and urban farms in the City, totaling approximately 32 acres (Baltimore Office of Sustainability 2019). The City was able to serve more than 5 million breakfasts and more than 10.5 million lunches to kids attending public school with the help from these community and urban gardens and farms (Baltimore Office of Sustainability 2019). Figure 7-2 depicts the location of urban farms and gardens across the City.

Figure 7-2. Urban Farms and Gardens in Baltimore City

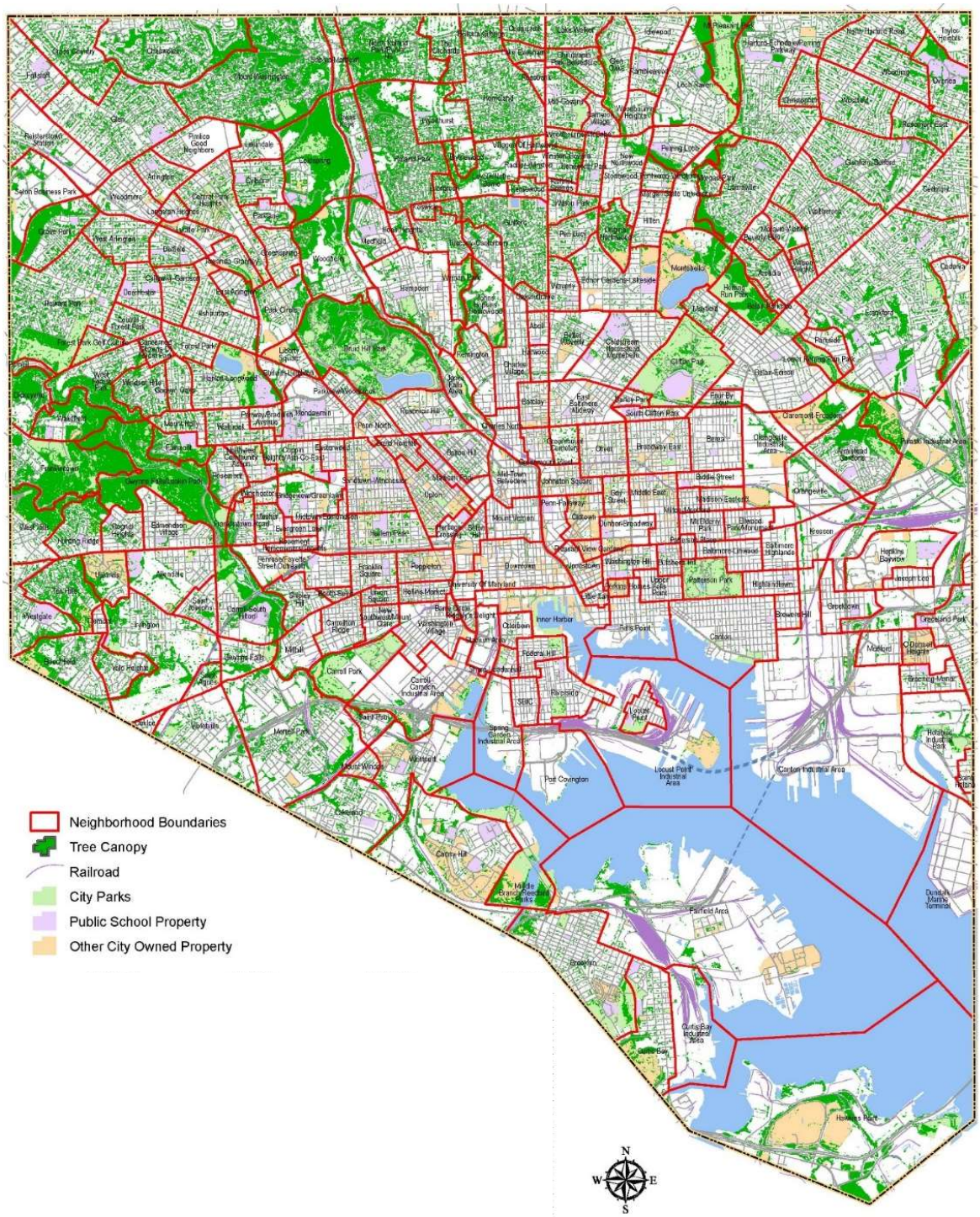


Source: Baltimore Office of Sustainability 2019

Tree Canopy

Tree canopy refers to the part of the City that is shaded by trees. In 2017, the Maryland Department of Natural Resources and the U.S. Forest Service measured the City's existing tree canopy at 27.4 percent. Trees provide clean air, reduce rainwater runoff and erosion, temper climate, and reduce air temperatures (Baltimore City Department of Recreation & Parks 2023). Tree canopy in the City can be affected by drought in varying degrees depending on the severity of the event. The most obvious issue is the fast dieback and degradation of the crowns of the trees, which can lead to scattered dead foliage along City sidewalks and pathways. Longer droughts can stunt the growth of plants and trees, which may inhibit them from growing tall enough to provide shaded areas within the City. Degrading tree canopy also impacts species that rely on these trees for shade and shelter, which affects the overall biodiversity of parks located in the City (Salle, et al. 2021). Figure 7-3 illustrates the tree canopy in the City.

Figure 7-3. Baltimore Neighborhood Tree Canopy



Source: Baltimore City Department of Recreation & Parks 2023

Urban Heat Island

Heat islands are urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes (i.e., forests and waterbodies). Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. Daytime temperatures in urban areas are about 1–7°F higher than temperatures in outlying areas, and nighttime temperatures are about 2-5°F higher (U.S. EPA 2023). Trees and vegetation help reduce temperatures in urbanized areas. Drought conditions increase tree mortality, leading to more heat islands in the City.

Surface Water

In addition to urban agriculture and tree canopy, surface water supplies are susceptible to severe impacts from drought. Baltimore City DPW stores potable water in three surface reservoirs: Prettyboy, Lock Raven, and Liberty. These reservoirs house 86 billion gallons of potable water to supply 1.8 million people living in the City and Anne Arundel, Baltimore, Carroll, and Howard Counties (Baltimore City Department of Public Works n.d.). Reservoirs are continuously monitored, and the Maryland Department of the Environment (MDE) performs monthly monitoring of precipitation, stream flow, groundwater levels, and reservoir storage. At full capacity, the three City reservoirs can provide potable water for approximately 350 days (Maryland Department of the Environment 2021). Drought can result in a loss of water supply as demand increases but precipitation to fill the reservoirs decreases. Figure 7-4**Error! Reference source not found.** depicts the three reservoirs along with watersheds located in the City.

Figure 7-4. Baltimore Region Reservoirs

Source: Baltimore County Government 2023

7.3 Extent

The State of Maryland has an average rainfall of 43.6 inches. Droughts vary in degrees of severity; however, there are indicators to look for when monitoring a potential drought. During the Drought of 2002, smaller streams dried up, which dried out both aquatic and terrestrial flora and fauna and increased levels of salinity in the Chesapeake Bay. This led to increased invasive species interference, and some native species died out.

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. The longer the duration of the drought and the larger the area impacted, the more severe the potential impacts (NOAA 2022). The U.S. Drought Monitor and the Palmer Drought Severity Index are used to determine areas of drought and the potential impacts. Additionally, the Maryland Department of the Environment performs monthly evaluations of hydrologic indicators to determine drought conditions.

U.S. Drought Monitor

The U.S. Drought Monitor (USDM) within the National Drought Mitigation Center uses six classifications for drought: normal conditions, abnormally dry (D0), moderate drought (D1), severe drought (D2), extreme drought (D3), and exceptional drought (D4) (USDM 2023). Moderate and severe droughts have short-term impacts, typically last less than six months, and primarily affect agriculture and grasslands. Extreme and exceptional droughts have longer-term impacts, typically last longer than six months, and start to affect hydrology and ecology.

During a Drought Watch, the State of Maryland notifies municipal and county governments of the Drought Watch status, continues to evaluate the drought biweekly, and activates the Water Conservation Plan. The Drought Watch aims for a 5–10 percent water reduction goal.

During a Drought Watch, the State of Maryland notifies municipal and county governments of the Drought Warning status and activates conservation measures. The Drought Watch aims for a 10–15 percent water reduction goal.

Table 7-1 provides examples of observed drought impacts and how they relate to the USDM.

Table 7-1. Examples of Observed Drought Impacts for Maryland

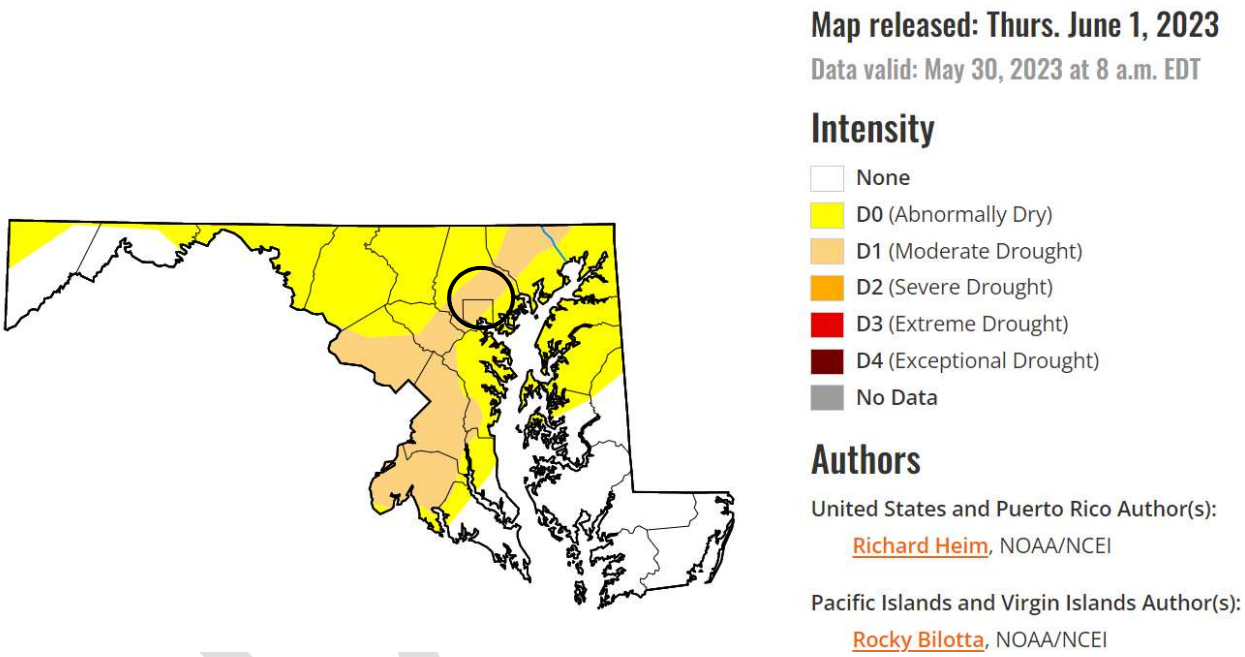
Drought Impacts	
Abnormally Dry: D0	Crop growth is stunted; planting is delayed
	Fire danger is elevated; spring fire season starts early
	Lawns brown early; gardens begin to wilt
	Surface water levels decline
Moderate: D1	Honey production declines
	Irrigation use increases; hay and grain yields are lower than normal
	Trees and landscaping are stressed; fish are stressed
	Voluntary water conservation is requested; reservoir and lake levels are below normal capacity
	Wildfires and ground fires increase
Severe: D2	Fish kills occur; wildlife move to farms for food
	Golf courses conserve water
	Producers begin feeding cattle; hay prices are high
	Specialty crops are impacted in both yield and fruit size
	Trees are brittle and susceptible to insects
	Warnings are issued on outdoor burns; air quality is poor
	Water quality is poor; groundwater is declining; irrigation ponds are dry; outdoor water restrictions are implemented

Drought Impacts	
Extreme: D3	Crop loss is widespread; Christmas tree farms are stressed; dairy farmers are struggling financially
	Extremely reduced flow to ceased flow of water is observed; river temperatures are warm; wells are running dry; people are digging more and deeper wells
	Water recreation and hunting are modified; wildlife disease outbreak is observed
	Well drillers and bulk water haulers see increased business
Exceptional: D4	Maryland has experienced little exceptional (D4) drought since the inception of the U.S. Drought Monitor, so no D4-level drought impacts are recorded in the Drought Impact Reporter

Source: USDM 2023

Figure 7-5 illustrates the levels of drought within the State of Maryland on May 30, 2023. The City is highlighted light orange, indicating that as of May 30, 2023, the City was classified to be in a moderate drought.

Figure 7-5. Maryland Drought Monitor



Source: US Drought Monitor 2023
Note: The black circle indicates the rough location of Baltimore City.

Palmer Drought Severity Index

Drought is also monitored through the Palmer Drought Severity Index (PDSI). According to the National Integrated Drought Information System (NIDIS), the PDSI was developed in 1965 and indicates prolonged and abnormal moisture deficiency or excess. It uses temperature and precipitation data to calculate water supply and demand, incorporates soil moisture, and is considered most effective for assessing moisture conditions in unirrigated cropland. The PDSI primarily indicates long-term drought and has been used extensively as a signal to initiate drought relief (NIDIS 2015). Refer to Table 7-2 for the PDSI classifications.

Table 7-2. PDSI Classifications

Palmer Classifications	
4.0 or more	Extremely wet
3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.5 to -0.99	Incipient dry spell
-1.0 to -1.99	Mild drought
-2.0 to -2.99	Moderate drought
-3.0 to -3.99	Severe drought
-4.0 or less	Extreme drought

Source: NDMC 2023

State of Maryland Drought Evaluations

In Maryland, drought conditions are evaluated on a regional basis using hydrologic indicators, including precipitation, stream flow, groundwater levels, and reservoir storage. The State also looks at the condition of water supplies, status of utilities, temperature, season of year, and other relevant factors. Conditions of each are rated as Normal, Watch, Warning, or Emergency. Maryland determines a drought condition by notifying municipal and county governments and continuing to evaluate drought status on a biweekly basis. A drought watch aims to reduce water usage by 5–10 percent, and a drought warning aims to reduce water usage by 10–15 percent (Maryland Department of the Environment 2023).

7.4 Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with drought throughout the City.

FEMA Major Disaster and Emergency Declarations

Between 1953 and 2023, the City was not included in any drought-related major disaster declaration (DR) or emergency declaration (EM) (FEMA 2023).

Previous Events

The USGS identified five regional droughts that had a significant extent and duration: (1) 1930 to 1932; (2) 1953 to 1956; (3) 1958 to 1971; (4) 1980 to 1983; and (5) 1984 to 1988. The drought from 1930 to 1932 was likely the most severe agricultural drought ever recorded in Maryland. Rainfall during that period was approximately 40 percent less than average, and 1930 was the driest year recorded since 1869. Total cost of crop losses during 1930 were estimated at $40 million in the region (City of Baltimore 2018). Table 7-3 lists drought events that impacted the City between 1950 and 2023. Figure 7-6 shows the news article documenting the first statewide emergency declaration for drought.

Figure 7-6. Statewide Drought Emergency Announcement

Drought is emergency; conserve, governor says

7-30-99

DOUG KAPUSTIN : SUN STAFF

Waterline recedes: *A man fishes in Liberty Reservoir, where lack of rain has lowered the water level 24 feet. Gov. Parris N. Glendening said a statewide response is needed.*

Rain shortfall among worst in state history; restrictions imminent

By GREG GARLAND
SUN STAFF

Gov. Parris N. Glendening declared a statewide drought emergency yesterday — the first in Maryland history — and said mandatory water conservation measures "almost certainly" will be imposed as early as next week.

In the meantime, he called on Marylanders to voluntarily conserve water and said the state will provide $3 million to help farmers while also seeking federal aid.

Glendening made the announcements while standing on the banks of Liberty Reservoir, which is down 24 feet and now holds less than half its capacity of 43 billion gallons of water.

The reservoir along the Carroll-Baltimore County line is one of three that supply water to 1.8 million people in the Baltimore area.

"We are in one of the worst droughts Maryland has ever experienced," Glendening said, adding that the problem demanded a statewide response.

"In the past, we have left this up to individual communities," he said. "But with water supplies very seriously stressed across the state, and with forecasters predicting only minimal relief, it is vital that we take a coordinated, [*See Drought, 4A*]

Source: Baltimore Sun 1999

Table 7-3. Drought Events in Baltimore City, 1950–2023

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City included in declaration?	Location Impacted	Description
July 1-December 31, 1998	Drought	N/A	N/A	Citywide	The 6-month precipitation total at BWI Airport was only 7.06 inches, 13.66 inches below normal. Water reserves were greatly affected by the persistent drought. The Liberty Reservoir that serves the City was down 24 feet and only at half of its capacity. Stream flows on rivers within the Potomac and Shenandoah River basins were 85 percent below normal. More than 2,000 households and businesses were forced to receive water from a temporary pipeline linked to the Frostburg flow. Crop damage was reported and totaled around $1.67 million.
September 1998-August 1999	Drought	N/A	N/A	Citywide	From September 1998 through August 1999, precipitation was a staggering 12–16 inches below average. During the first week of August, the USGS reported ground water levels in Central Maryland were 16 feet below the surface, just under the minimum level. The drought cost Maryland farmers over $75 million. The City reported losing over 300 street trees due to the drought.
April 5-May 5, 2002	Drought	N/A	N/A	Citywide	Maryland Governor issues an executive order declaring a drought emergency and imposing Level 1 mandatory restrictions for all areas except for the City service area. All state residents were asked to reduce water use by 10 percent.
October 1-31, 2007	Drought	N/A	N/A	Citywide	Rainfall deficits totaled nearly 10 inches making water restrictions become mandated throughout the month.
September 23-October 23, 2010	Drought	N/A	N/A	Citywide	Jellyfish were documented moving into the Inner Harbor due to drought raising the salinity of the water because there was less water flowing in from freshwater rivers.
August 13-September 12, 2012	Drought	N/A	N/A	Citywide	The size of the dead zone in the Chesapeake Bay decreased from 30 percent to 12 percent in August because there was less runoff from precipitation to encourage the growth of algal blooms.

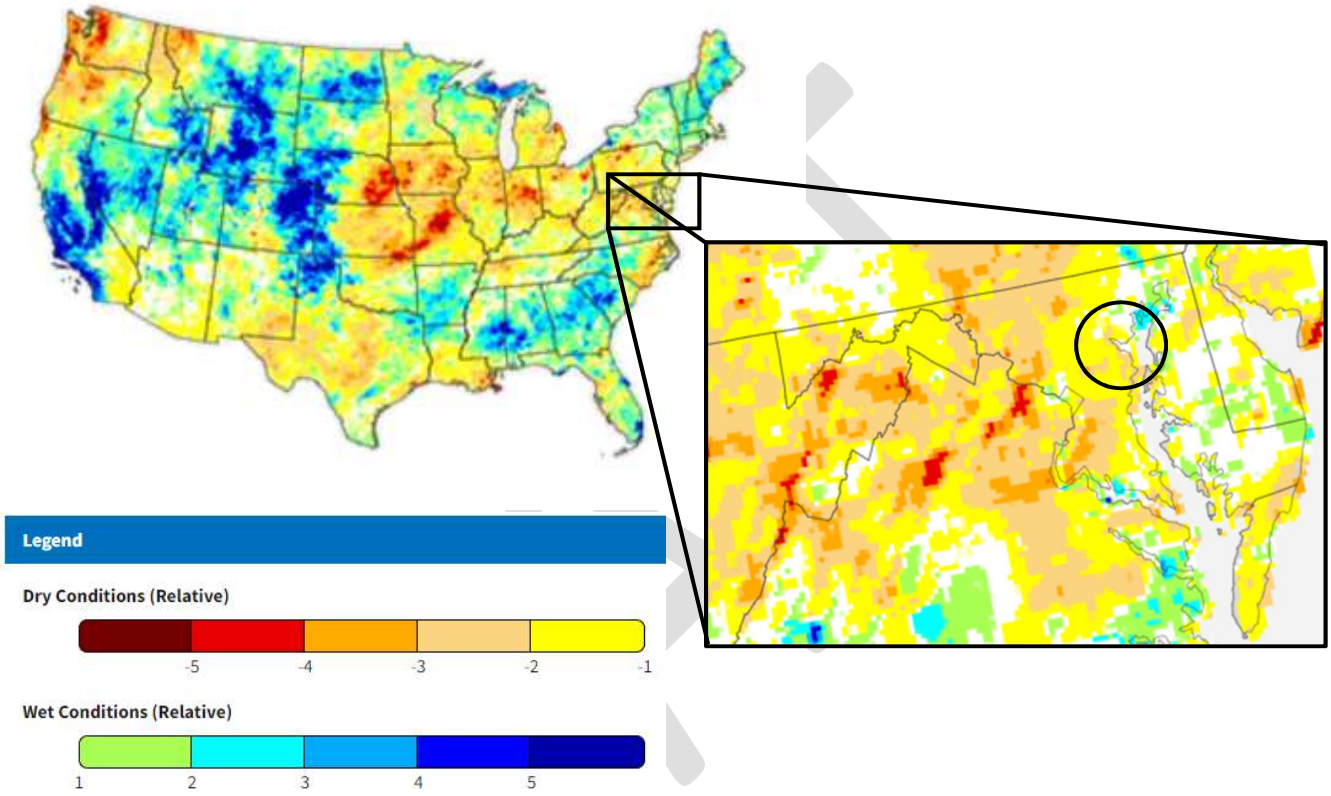
Source: FEMA 2023; NCEI 2023; National Drought Mitigation Center 2023

Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources in relation to the City specifically.

7.5 Probability of Future Hazard Events

The frequency of droughts is difficult to forecast as drought occurrences are cyclical in nature and will occur in the future. Based on national annual data from 1980 to present, the City has minor dry soil conditions (illustrated in Figure 7-7).

Figure 7-7. U.S. Gridded Palmer Drought Severity Index (PDSI) (1980–2023)



Source: NIDIS 2023

Based on historic and more recent events, it is likely that drought events will occur in the City in the future. Climate projections indicate air temperature will continue to rise. As temperatures increase in the future, the probability of future droughts will most likely increase as well (see Section 7.6). Therefore, it is likely that droughts of varied severity will occur in the State and the City in the future. It is estimated that the City will continue to experience direct and indirect impacts of drought and its impacts on occasion, with the secondary effects causing potential disruption or damage to agricultural activities and creating shortages in water supply within communities. Table 7-4 shows the probability of future occurrences in the City.

Table 7-4. Future Occurrence of Drought Events in Baltimore City

Hazard Type	Number of Occurrences Between 1950 and 2022	% Chance of Occurrence in Any Given Year
Drought	6	12.17

Source: *NCEI 2023*
Note: *Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected events since 1968. Due to limitations in data, not all drought events occurring between 1953 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.*

In Section 3.0, the identified hazards of concern for the City are ranked (Table 3-5). The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the CPT, HMAC, and community members, the probability of drought occurring in the City is considered ”occasional” .

7.6 Potential Impacts of Climate Change

Climate is determined not only by average temperature and precipitation but also by the type, frequency, and intensity of weather events. Temperatures in the northeast rose by nearly 2°F between 1895 and 2011, and some models show the region experiencing a warming of 4.5–10°F by the 2080s, assuming conditions stay as trending. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extremes such as droughts. While predicting changes of drought events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society, and the environment (EPA 2016). Longer warm seasons also affect plant health and productivity, which will greatly impact the City’s urban farming initiatives. With warmer overall weather, risks of pests such as ticks, deer, and mice increase due to a longer reproduction season, which leads to an increased risk of Lyme disease (University of Maryland 2023).

With a warmer climate, droughts can become more frequent, more severe, and longer lasting. According to the National Climate Assessment, variable precipitation and rising temperatures are intensifying droughts, increasing heavy downpours, reducing snowpack, and causing declines in surface water quality. Future warming will add to the stress on water supplies and impact the availability of water supply (USGCRP 2018). Additionally, Maryland experiences increased downpours and intense rainfall spurts, which causes tremendous soil erosion and flooding. Due to the speed and rate at which the precipitation falls, the soil is unable to absorb as much water as it would with a gradual precipitation event, making droughts able to happen at a faster rate (University of Maryland 2023).

Average precipitation is likely to increase during the winter and spring months but not change significantly during the summer and fall months. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during the summer and fall. In July 2008, the University of Maryland’s Center for Environmental Science projected an additional 2° F of warming by 2025 for the entire State. If emissions are reduced by 2050, there is the possibility of a 4.8° F increase in the summer. If emissions are not reduced, the State of Maryland could see a temperature increase of nearly 9° F by the year 2100 (University of Maryland Center for Environmental Science 2008). Currently, projections are following the high emission scenario. As a result, the changing climate is likely to intensify flooding during the winter and spring and drought during the summer and fall.

Saltwater intrusion is another concern farther inland or upstream in bays, rivers, and wetlands due to lack of freshwater runoff. Saltwater can further intrude into aquifers near the coast, which may impact soils and growing areas and infiltrate personal human-used freshwater sources, intensifying droughts’ effects (EPA 2017).

In general, the tourism industry of the City is threatened due to the economy being partially based around the Inner Harbor. Sea level rise and degradation of water and air quality will impact tourism that is focused on water-based activities that the harbor currently offers (U.S. Climate Resilience Toolkit 2022).

7.7 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the hazard area identified. The entire City has been identified as exposed to the drought hazard. Therefore, all assets in the City (population, structures, critical facilities, and lifelines), as described in Section 3 (Risk Assessment), are exposed and potentially vulnerable.

7.7.1 Impacts to Population

The entire population of the City (591,489 people) is vulnerable to drought events. Drought conditions can affect people's health and safety, including health problems related to low water flows and poor water quality and health problems related to dust. Droughts also can lead to loss of human life (NDMC 2013). Other possible impacts on health from drought include effects on air quality; diminished living conditions related to energy, air quality, and sanitation and hygiene; compromised food and nutrition; and increased incidence of illness and disease. Health implications of drought are numerous and can include readily available access to drinking water (CDC 2012).

Impacts to Socially Vulnerable Populations and Underserved Communities

Social vulnerability is defined as the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood. Social vulnerability considers the social, economic, demographic, and housing characteristics of a community that influence its ability to prepare for, respond to, cope with, recover from, and adapt to environmental hazards. According to FEMA's National Risk Index, socially vulnerable populations in Baltimore City have a very high susceptibility to the adverse impacts of natural hazards when compared to the rest of the United States (FEMA n.d.).

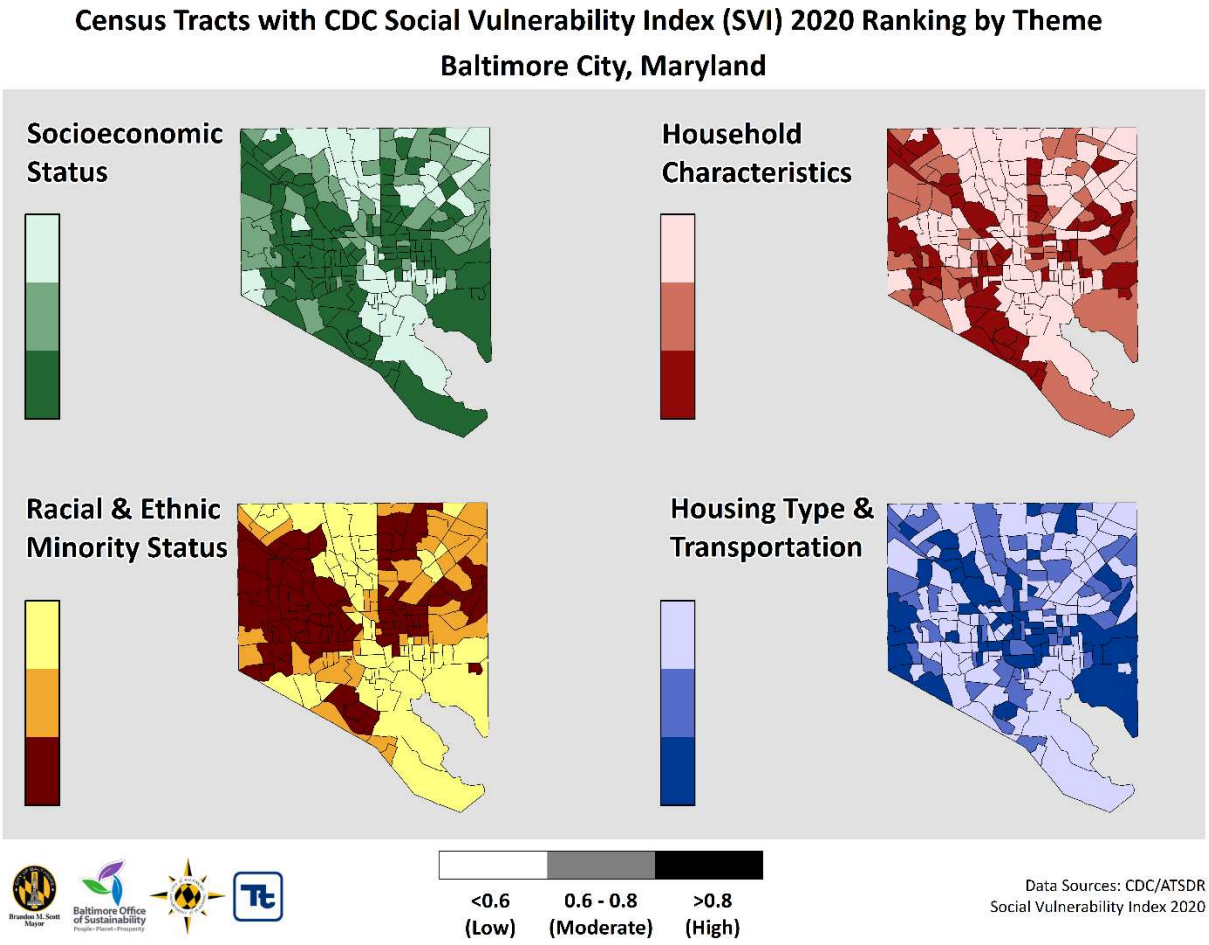
Socially vulnerable populations are most susceptible to drought events based on several factors, including their physical and financial ability to react or respond during a drought. Vulnerable populations include:

- Individuals experiencing homelessness,
- Older adults (over 65 years old),
- Economically disadvantaged,
- People who are linguistically isolated or have limited English proficiency,
- People with life-threatening illnesses, and
- People who have limited access to water in non-drought conditions.

According to the 2021 American Community Survey, there are roughly 84,000 persons over age 65 (14.1 percent of the total population); approximately 36,000 persons (6.2-percent of the total population) under the age of 5; just over 10,000 persons (1.7-percent of the total population) which do not speak English; an estimated 93,000 persons (15.7-percent of the total population) who have a disability; and about 116,000 persons (19.5-percent of the total population) living at or below the poverty level. Socially vulnerable populations may require extra water supplies or need assistance to obtain water and are more likely to seek or need medical attention. Additionally, economically disadvantaged individuals and individuals experiencing homelessness may not have access to a safe water source.

Figure 7-8 shows the CDC SVI for census tracts in the City. The figure shows the four themes of the CDC's SVI, with darked census tracts representing geographic areas of higher social vulnerability where individuals may face increased vulnerabilities from droughts.

Figure 7-8. CDC Social Vulnerability Index by Census Tract



Source: CDC/ATSDR 2020

7.7.2 Impacts to Structures

General Building Stock

A drought event is not expected to directly affect any structures. However, risk to structures may increase during droughts as fire-fighting capabilities may be diminished due to limited water supply for fire suppression.

Critical Facilities, Infrastructure, and Community Lifelines

All critical facilities and infrastructure and community lifelines in the City are exposed to the drought hazard. Critical facilities will experience similar issues as described above for general building stock. Water supply facilities may be affected by short supplies of water. It is essential that community lifelines remain operational during extreme temperature events so that the lifelines may address any issues affecting health, safety, and economic security. As mentioned, drought events generally do not impact buildings; however, droughts can impact critical facilities associated with potable water supplies.

7.7.3 Impacts to the Economy

Droughts impact the economy of an area in many ways. The City's urban agriculture program may experience decreased crop yield, thereby impacting the earnings of the farmers and driving up the cost of produce for consumers. Low water levels will affect any industry powered by hydroelectric power due to decreased production. The Inner Harbor is a lynchpin of the tourism industry in the City; the area would experience significant challenges due to a reduced number of tourists.

Droughts also can spur additional brushfires due to the dry environmental conditions, which can devastate large areas depending on how large the fire becomes (NOAA 2016). An increase in brushfires, and fires in general, in the City may cause a strain on the City's Fire Department. An increased number of responses would also impact the health and integrity of the Fire Department's staff and equipment, potentially costing the City and its taxpayers extra money.

7.7.4 Impacts to Natural, Historic, and Cultural Resources

Droughts can impact the environment because they can trigger wildfires, increase insect infestations, and exacerbate the spread of disease in animals and humans (NOAA 2000). Droughts will also impact water resources that are relied upon by aquatic and terrestrial species. Ecologically sensitive areas, such as wetlands, can be particularly vulnerable to drought periods because they are dependent on a relatively consistent water level and soil moisture availability to sustain growth. As a result, these types of habitats can be negatively impacted after long periods of drought. Additionally, tree canopy is affected by drought conditions because it leads to tree branch and foliage death that limits shade area available to City residents.

Droughts also have the potential to lead to water pollution. Rainwater typically dilutes pollutants in water sources, but in a drought, those pollutants become concentrated due to the lack of rainwater to dilute any pollutants in water sources. Contaminated water supplies may be harmful to plants and animals. If water is not getting into the soil, the ground may become unstable (CDC 2022).

7.7.5 Cascading and Compounding Impacts

Drought increases conditions that may trigger fires in the City, such as dead and dying trees, and grasses. Drought can lead to increasing temperatures and evaporation of moisture, which are ideal dry conditions for wildfire events to occur. Dry, hot, and windy weather combined with dry vegetation makes some areas more susceptible to sparking wildfires when met with a spark created by humans or natural events, including lightning (National Integrated Drought Information System 2020). Additionally, droughts can lead to the following:

- Long-term damage to crop quality and crop losses,
- Insect infestation leading to crop losses and reduced tree canopy, and
- Reduction in the ability to perform outdoor activities, which could result in loss of tourism and recreation opportunities.

7.7.6 Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in the City can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The City considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development,
- Projected changes in the population, and
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Changes in Land Use and Development

All projected land use and development are at risk of being impacted by drought events. The ability of new land use to withstand drought impacts can be enhanced through updated land use practices and consistent enforcement of codes and regulations. New development will change the landscape where buildings, roads, and other infrastructure potentially replace open land and vegetation. Growing urbanization will contribute to an increase in the urban island heat effect, which exacerbates high temperatures and can enhance the effects of droughts.

Changes in Population

Baltimore has experienced an decrease in its population since 2010. According to the U.S. Census Bureau, the City's population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the Maryland Department of Planning indicate that the City's population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020).

Climate Change

Climate temperatures are rising due to high levels of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming (IPCC I. P., Climate Change 2021: Physical Science Basis, 2021). Global temperatures are expected to rise by 2.7° Celsius by the end of the century. The seven warmest years on record have all occurred in the last decade: 2020 was the second warmest year on record; 2016 was the warmest year on record.

Although the climate is always changing, the rate of global warming is unprecedented. Climate change is affecting both people and resources in the City, and these impacts are projected to continue growing. Other impacts from climate change include an unequal distribution of precipitation, which can lead to an increase in drought events. The 2018 National Climate Assessment noted that the number of hot days are increasing, and the frequency of heatwaves in the United States jumped from an average of two per year in the 1960s to six per year by the 2010s (Maryland Commission on Climate Change 2021).

7.7.7 Change in Vulnerability Since 2018 DP3

The City continues to be vulnerable to the drought hazard. Updated population and building stock statistics were used in the current risk assessment. Further, exposure for both the population and critical facilities was analyzed. These updated datasets provide a more accurate exposure analysis to the drought hazard. Due to hazard events and rising temperatures since the previous plan, the City's vulnerability has increased since 2018.