

# Maine Climate Impacts and Costs

Climate change poses many costly risks to Maine residents, including sea level rise, increased precipitation and severe storms, extreme drought, and hotter temperatures.<sup>1</sup> Even if fossil fuel emissions and atmospheric concentrations of greenhouse gases eventually stabilize through aggressive climate action, the severity of these events will continue to rise as we adjust to the new reality of the climate crisis. Below we outline the impacts of climate change Maine faces and some of the potential costs associated with adapting to these impacts. This list is not exhaustive and other costs may be incurred as a result of additional necessary climate change adaptations.

## Sea Level Rise

Maine has an extensive shoreline, spanning 3,478 miles.<sup>2</sup> Globally, sea levels are rising,<sup>3</sup> as glaciers melt and ocean waters expand.<sup>4</sup> Sea level is estimated to increase on average by 1 to 4 feet by the end of the century.<sup>5</sup> The Maine State Climate Office predicts over 8 feet of sea level rise along Maine's coasts by 2100 under a high emissions scenario.<sup>6</sup> The rate of sea level rise has doubled over the past 30 years to 1.4 inches per decade and mean sea level from 2005-2023 has risen 7.5 inches in Maine since the early 1900's.<sup>7</sup> If just 4 feet of sea level rise occurs by the end of the century, over 3,700 homes, two power plants, a sewage plant, and other critical infrastructure will be inundated with water.<sup>8</sup> The property value at risk exceeds \$950 million.<sup>9</sup>

In 2023, tidal gauges registered record-breaking monthly mean high tides for at least six months out of the year.<sup>10</sup> Tidal flooding, also called nuisance flooding — flooding simply

- 1 EPA, "What Climate Change Means for Maine," 2016.
- 2 Shoreline Mileage of the United States. NOAA Office for Coastal Management. [coast.noaa.gov](https://coast.noaa.gov)
- 3 Ekwurzel et al., "The Rise in Global Atmospheric CO<sub>2</sub>, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers." <https://doi.org/10.1007/s10584-017-1978-0>.
- 4 Miller et al., "A Geological Perspective on Sea-Level Rise and Its Impacts along the U.S. Mid-Atlantic Coast." <https://onlinelibrary.wiley.com/doi/abs/10.1002/2013EF000135>.
- 5 Runkle, J., K.E. Kunkel, S.M. Champion, R. Frankson, B.C. Stewart, A.T DeGaetano, and J. Spaccio, 2022: Maine State Climate Summary 2022. NOAA Technical Report NESDIS 150-ME. NOAA/NESDIS, Silver Spring, MD, 4 pp.
- 6 Future, M. C. for D. C. & P., ME Governor's Office of Policy Innovation and the. (2023, July 6). The Maine Climate Impact Dashboard. ArcGIS StoryMaps. <https://storymaps.arcgis.com/collections/934e1d7f462740c69a279fbd8375969d>.
- 7 The Scientific and Technical Subcommittee of the Maine Climate Council, "Scientific Assessment of Climate Change and Its Effects in Maine: 2024 Update," 2024, [https://www.maine.gov/future/sites/maine.gov/future/files/inline-files/STS\\_2024\\_digital.pdf](https://www.maine.gov/future/sites/maine.gov/future/files/inline-files/STS_2024_digital.pdf).
- 8 *Surging Seas Risk Finder, Maine, USA*. (n.d.). Climate Central. Retrieved August 12, 2024, from <http://riskfinder.climatecentral.org>.
- 9 Ibid.
- 10 MCC STS. 2024. Scientific Assessment of Climate Change and Its Effects in Maine - 2024 Update. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 89 pp.

from strong high tides — is expected to get worse.<sup>11</sup> On January 10, 2024, major flooding occurred along Maine's coast as record high tides coincided with a storm surge.<sup>12</sup> The flood caused 10,000 Central Maine Power and Versant Power electric utility customers to lose power, and caused traffic congestion as waters made Route 1 impassable around Lincolnville Beach.<sup>13</sup> Minor flooding of any type is expected daily in Maine by 2100 according to the NASA Flooding Analysis Tool.<sup>14</sup>

Coastal wetlands span across Maine's extensive coastline, offering important ecosystem services such as being biodiversity hotspots, sequestering carbon, and buffering against storm surges.<sup>15</sup> Maine has four times the wetland area than the other states in New England.<sup>16</sup> However, since the early 1800s, humans have destroyed one-third of New England coastal wetlands with development.<sup>17</sup> In Maine, 20% of all coastal wetlands have been developed, inhibiting their ecosystem services.<sup>18</sup> Development also prevents the wetlands from migrating inland as sea level rises, further destroying these critical habitats and leaving developed coastal areas more susceptible to flooding.<sup>19</sup> Natural wetland restoration, which often involves removing roads or other impervious surfaces blocking the connection of the wetland to the sea, is a costly, but important adaptation measure to mitigate these impacts. In 2023, the Maine Natural Resource Conservation Program funded 11 projects to restore, enhance, and protect wetlands across Maine at the tune of over \$6.3 million.<sup>20</sup>

## Potential Costs Related to Sea Level Rise

### Structure and Infrastructure Projects

- Stabilize susceptible coastal slopes and cliffs and shorelines using grading

**11** Ibid.

**12** Shortall, K., Sharon, S., & Miller, K. (2024, January 13). Maine coast walloped by flooding amid rainfall, astronomical tides. Maine Public. <https://www.mainepublic.org/environment-and-outdoors/2024-01-13/maine-coast-walloped-by-flooding-amid-rainfall-astronomical-tides>

**13** Ibid.

**14** MCC STS. 2024. Scientific Assessment of Climate Change and Its Effects in Maine - 2024 Update. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 89 pp.

**15** Coastal Wetlands. (n.d.). U.S. National Park Service. Retrieved August 13, 2024, from <https://www.nps.gov/articles/000/coastal-wetlands-key-to-supporting-life-in-the-watershed.htm>.

**16** "Panelists Discuss How Maine's Saltwater Wetlands Are under Pressure," *The Maine Monitor*, March 28, 2024, <https://themaine-monitor.org/wetlands-panel/>.

**17** EPA. (2016). What Climate Change Means for Maine.

**18** Threats to Wetlands. (n.d.). [Government]. Maine Department of Environmental Protection. Retrieved August 19, 2024, from <https://www.maine.gov/dep/water/wetlands/threats.htm>

**19** The Coastal Squeeze: Changing Tactics for Dealing with Climate Change (New England/Mid-Atlantic). (2021, January 27). [Government]. NOAA Fisheries. <https://www.fisheries.noaa.gov/feature-story/coastal-squeeze-changing-tactics-dealing-climate-change>

**20** "\$6.3 Million Awarded for Wetland Restoration and Conservation in Maine," *The Nature Conservancy* (blog), December 19, 2023, <https://www.nature.org/en-us/newsroom/mnrcp-award-2023/>.

techniques, planting vegetation, riprap or geotextile fabric, or bioengineering.

- Remove, relocate, acquire, or demolish structures to minimize future flood losses.
- Install, reroute, increase capacity, or implement a routine cleaning plan of the storm drainage system.
- Add extra culverts, increase dimensions of existing culverts, or implement routine cleaning and repairing to divert high-tide flood water.
- Install detention or retention basins, relief drains, spillways, drain widening/dredging or rerouting, green infrastructure, etc.<sup>21</sup>
- Inspect and maintain drainage systems and flood control structures (dams, levees, etc.).
- Elevate structures above base flood elevation (BFE),<sup>22</sup> or relocate utilities, water heaters, etc. above BFE.
- Floodproof inside of municipal buildings, for example by installing check valves, sump pumps, or backflow prevention devices.
- Floodproof wastewater treatment facilities located in coastal areas.
- Floodproof water treatment facilities located in coastal areas.
- Protect emergency operations by requiring or moving all emergency operations centers, police stations, and fire department facilities outside of coastal, flood-prone areas.
- Protect critical and emergency facilities from floods using any other technique, for example, raising components above BFE, installing pumping systems or back-up generators for pumping, building dikes, or stabilizing banks.

### Coastal Protection

- Protect critical infrastructure using techniques like beach nourishment, jetties, and seawalls.
- Restore natural wetland areas.

### Local Planning and Regulation

- Identify, map, and track coastal erosion and flood hazards.
- Develop and enforce a coastal zone management plan.
- Develop site and building standards.

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**21** Giese et al., “Assessing Watershed-Scale Stormwater Green Infrastructure Response to Climate Change in Clarksburg, Maryland.” [https://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0001099?casa\\_token=XUXNexpXVioAAAAA%3AhGupZ8-DSW\\_LpmJeH70D1zfz1RD\\_rMKFI9a\\_vwxzycN0fgN2inasD2c39yMqyiAbBARYYpM](https://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0001099?casa_token=XUXNexpXVioAAAAA%3AhGupZ8-DSW_LpmJeH70D1zfz1RD_rMKFI9a_vwxzycN0fgN2inasD2c39yMqyiAbBARYYpM).

**22** Base flood elevation (BFE), as defined by FEMA, is “the elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year.”

- Maintain and update existing laws on development.

### Education and Awareness Programs

- Increase awareness by disclosing location of high-risk areas to current and future property owners; offer mitigation technique information.
- Locate new utilities and critical facilities outside of susceptible areas.
- Identify, map, or track erosion hazard areas.
- Other education and awareness programs.

## Increased Precipitation and Severe Storms

Climate change has led to a warmer atmosphere that can hold more water to precipitate. Extreme precipitation, defined as the amount of rain falling on the top 1% of days with precipitation, in the northeastern United States has already increased over 60% from 1958-2021.<sup>23</sup> The number of days with over 5 inches of rain in total has doubled in the last 64 years from about five to about 15 days per year.<sup>24</sup> This will only continue to get worse — extreme events are predicted to increase another 50% by the end of this century.<sup>25</sup>

Average annual precipitation in Maine has already increased by about 6 inches since 1895 and the state now receives one to two more days each year with total precipitation over 2 inches than it did in the 1950s.<sup>26</sup> The increases in precipitation are expected to impact the winter and spring seasons the most,<sup>27</sup> but the summer of 2023 had the highest statewide mean precipitation ever recorded and the whole year was the 5th wettest year ever recorded in Maine.<sup>28</sup>

Increased precipitation has already had severe impacts on Maine. On October 30-31, 2021, a 50-year extreme precipitation event caused flash flooding and runoff in the counties of Knox, Waldo, and York.<sup>29</sup> Public infrastructure, including roads and a riverwalk,

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**23** “Extreme Precipitation in a Warming Climate,” Climate Central, 2024, <https://www.climatecentral.org/graphic/extreme-precipitation-in-a-warming-climate?graphicSet=Extreme+Precipitation+Change+1958+to+2021&location=US&lang=en>.

**24** Mara Hoplamazian, “National Climate Assessment Shows Extreme Precipitation Has Increased Most in the Northeast,” *New Hampshire Public Radio*, (November 20, 2023), sec. NH News, <https://www.nhpr.org/nh-news/2023-11-20/national-climate-assessment-shows-extreme-precipitation-has-increased-most-in-the-northeast>.

**25** Christopher J. Picard et al., “Twenty-First Century Increases in Total and Extreme Precipitation across the Northeastern USA,” *Climatic Change* 176, no. 6 (May 30, 2023): 72, <https://doi.org/10.1007/s10584-023-03545-w>.

**26** The Scientific and Technical Subcommittee of the Maine Climate Council, “Scientific Assessment of Climate Change and Its Effects in Maine: 2024 Update.”

**27** EPA, “What Climate Change Means for Maine.”

**28** The Scientific and Technical Subcommittee of the Maine Climate Council, “Scientific Assessment of Climate Change and Its Effects in Maine: 2024 Update.”

**29** MEMA, “Flooding,” *Maine Emergency Management Agency*, n.d., <https://www.maine.gov/mema/hazards/natural-hazards/flooding#NotableFloodsInMaine>.

were ruined by the storm.<sup>30</sup> It is estimated that the extensive flooding caused \$2.4 million in damage.<sup>31</sup> In March of 2022, the storm was declared a major disaster by the Federal Emergency Management Agency.<sup>32</sup> The agency has since obligated over \$6.2 million in public assistance grants for emergency and permanent work associated with the storm.<sup>33</sup>

The Maine Department of Transportation estimates that about 2,300 culverts are in danger of being overtopped from increasing precipitation and, in 2023, four have already failed. The culverts are valued around \$77 million.<sup>34</sup> According to NOAA, extreme weather events that cost over a billion dollars, or “billion-dollar events,” have been increasing. Billion-dollar flooding events cost an average of \$4.6 billion per event and billion-dollar severe storms cost an average of \$2.4 billion per event.<sup>35</sup> A recent analysis by Swiss Re, a reinsurance company, found that severe storms in the U.S. incurred \$60 billion in insured losses during 2023 — a record high.<sup>36</sup>

## Potential Costs Related to Increased Precipitation

### Structure and Infrastructure Projects

- Remove, relocate, acquire, or demolish structures to minimize future flood losses.
- Install, reroute, increase capacity, or implement a routine cleaning plan of the storm drainage system.
- Add extra culverts, increase dimensions of existing culverts, or implement routine cleaning and repairing.
- Install detention or retention basins, relief drains, spillways, drain widening/dredging or rerouting, etc.
- Inspect and maintain drainage systems and flood control structures (dams, levees, etc.).
- Inspect bridges in order to identify and/or implement repairs or retrofits or clean under low bridges.
- Resurface roads with more permeable pavement and concrete and/or pavement

**30** Ibid.

**31** Ibid.

**32** *Maine Severe Storm and Flooding (DR-4647-ME)*. (2024, March 15). [Government]. FEMA. <https://www.fema.gov/disaster/4647>.

**33** Ibid.

**34** Penelope Overton, “Climate Change Has Brought More Extreme Rain, Snow to Maine,” *Press Herald*, December 3, 2023, <https://www.pressherald.com/2023/12/03/changing-climate-brings-more-extreme-rain-and-snow-events-to-maine/>.

**35** National Atmospheric and Oceanic Administration (NOAA), “NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters,” 2023. <https://doi.org/10.25921/stkw-7w73>.

**36** “Insured Losses from Severe Thunderstorms Reach New All-Time High of USD 60 Billion in 2023, Swiss Re Institute Estimates,” *Swiss Re*, December 7, 2023, <https://www.swissre.com/press-release/Insured-losses-from-severe-thunderstorms-reach-new-all-time-high-of-USD-60-billion-in-2023-Swiss-Re-Institute-estimates/4a15acf7-64b4-4766-8662-1c35d268ab12>.

able to withstand heavier precipitation.

- Stabilizing bridges against scour by hardening abutments and piers.
- Protect rural communities from flooding by installing flood control structures.
- Elevate roads and bridges above the BFE to maintain dry access.
- Elevate structures above the BFE, or relocate utilities, water heaters, etc. above BFE.
- Floodproof inside of municipal buildings, for example by installing check valves, sump pumps, or backflow prevention devices.
- Floodproof wastewater treatment facilities located in flood hazard areas.
- Floodproof water treatment facilities located in flood hazard areas.
- Protect emergency operations by requiring or moving all emergency operations centers, police stations, and fire department facilities outside of flood-prone areas.
- Protect critical and emergency facilities by requiring all critical facilities be built 1 foot above the 500-year flood elevation (to meet requirements of FEMA Executive Order 11988).<sup>37</sup>
- Protect critical and emergency facilities from floods using any other technique, for example, raising components above BFE, installing pumping systems or back-up generators for pumping, building dikes, or stabilizing banks.
- Construct floodwalls, small berms, revetments, bioengineered bank stabilization, or other small structural mitigants.
- Implement severe storm strategies for the future like burying utility lines underground.

### **Natural Flood Mitigation**

- Protect and enhance natural floodplain mitigation features (such as wetlands, dunes, and vegetative buffers) to help prevent flooding in other areas and increase water quality.

### **Public Health**

- Protect public water supplies from pollutants transported by runoff.
- Increased hospitalizations related to water-borne illness.

### **Local Planning and Regulation**

- Update flood risk maps and flood zones.
- Develop a floodplain management plan.

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<sup>37</sup> Federal Emergency Management Agency, "Executive Order 11988: Floodplain Management," [www.fema.gov/executive-order-11988-floodplain-management](https://www.fema.gov/executive-order-11988-floodplain-management).

- Adopt a stormwater management or drainage plan.
- Adopt, apply, and enforce building codes to ensure buildings can withstand flooding.
- Obtain easements to use privately-owned land for temporary water retention and drainage.
- Join or improve compliance with the National Flood Insurance Program (NFIP) if needed.<sup>38</sup>
- Preserve floodplains as open space using any of several land use planning tools: develop a plan that targets hazard areas for acquisition, reuse, and preservation, a land banking program, use of transfer of development rights to keep floodplains vacant, easements to prevent development, or acquiring properties in the floodplain and turning them into open space.

### Education and Awareness Programs

- Increase public outreach to encourage flood insurance purchase; educate residents in flood safety, flood mitigation, technical assistance availability, funding sources, and best practices.
- Increase public outreach to provide awareness of harmful algal blooms and their health impacts.
- Locate new utilities and critical facilities outside of susceptible areas.

## Extreme Drought

Climate change is making climate extremes more pronounced. This means, wetter seasons will experience more precipitation, and drier seasons will see more frequent droughts.<sup>39</sup> While long-term drought projections still remain uncertain in Maine, the Union of Concerned Scientists have suggested that short-term droughts, defined as lasting one to three months, could become as frequent as one each year in New England under a future high-emissions scenario.<sup>40</sup>

It may seem counterintuitive, but increased precipitation can be a driver for drought conditions. “Flash” droughts are caused by rapid dry periods following times of normal

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**38** U.S. Federal Emergency Management Agency (FEMA), The National Flood Insurance Program (NFIP), at [www.fema.gov/national-flood-insurance-program](http://www.fema.gov/national-flood-insurance-program) Policy Information by State (<https://nfipservices.floodsmart.gov/reports-flood-insurance-data>), accessed March 31, 2024; Maine has over \$2 billion in total coverage and over 7,500 policies, but local governments should make sure they comply.

**39** Xue, Z., & Ullrich, P. A. (2022). Changing Trends in Drought Patterns over the Northeastern United States Using Multiple Large Ensemble Datasets. <https://doi.org/10.1175/JCLI-D-21-0810.1>.

**40** Frumhoff, P. C., McCarthy, J. J., Melillo, J. M., Moser, S. C., & Wuebbles, D. J. (2007). Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Union of Concerned Scientists (UCS). <https://doi.org/10.7282/T3HH6J8D>.

or above-normal precipitation.<sup>41</sup> This could become a problem in Maine as precipitation and evapotranspiration rates are likely to increase as temperatures rise.<sup>42</sup> Additionally, the state is already experiencing periods of snow drought, or periods when the snowpack is uncharacteristically thin. Snow drought is caused by a lack of precipitation or by precipitation falling as rain, rather than snow, in the winter.<sup>43</sup> Snow drought is suspected to have contributed to the droughts between 2020 and 2022 in Maine.<sup>44</sup> Lack of snowfall in the winter combined with warmer temperatures in Maine is threatening its \$68 million dollar winter recreation industry.<sup>45</sup>

Decreased snowpack also means there is less water available to melt in the springtime, limiting water recharge in the local aquifers.<sup>46</sup> In Maine, this could cause extensive problems as approximately 45% of the state's population depends on shallow wells for drinking water.<sup>47</sup> The droughts in 2020, 2021, and 2022 also caused extensive agricultural losses in Maine. For example, wild blueberry farmers saw losses of 60%.<sup>48</sup> During Maine's most impactful drought between 2001 and 2002, approximately 17,000 private wells dried up and crop loss cost \$32 million in damages to farmers — a scenario that will be more likely as climate change worsens.

Prolonged drought combined with hotter summer temperatures also puts Maine's 17.5 million acres of forest at risk of wildfires.<sup>49</sup> Maine has an average of 650 wildfires per year and with almost 80% of homes being located on the Wildland Urban Interface, which makes infrastructure and homes especially vulnerable to wildfires.<sup>50</sup> Maine also contends with wildfire smoke from Canada.<sup>51</sup> In August 2024, wildfire smoke caused poor

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- 41 Maine. (n.d.). [Government]. Drought.Gov. Retrieved August 8, 2024, from <https://www.drought.gov/states/maine>.
  - 42 Huntington, T. G., Richardson, A. D., McGuire, K. J., & Hayhoe, K. (2009). Climate and hydrological changes in the northeastern United States: Recent trends and implications for forested and aquatic ecosystems. *Canadian Journal of Forest Research*, 39(2), 199–212. <https://doi.org/10.1139/X08-116>.
  - 43 Maine. (n.d.). [Government]. Drought.Gov. Retrieved August 8, 2024, from <https://www.drought.gov/states/maine>.
  - 44 Birkel, S. (n.d.). Maine Summer 2022 Climate Summary. Maine Climate Office News. Retrieved August 8, 2024, from <https://extension.umaine.edu/maineclimatenews/update/summer-2022/>.
  - 45 Laurie Schreiber, "For Winter Recreation Industry — Now More than Ever — 'Climate Change Is Top of Mind,'" *Mainebiz*, February 26, 2024, <https://www.mainebiz.biz/article/for-winter-recreation-industry-now-more-than-ever-climate-change-is-top-of-mind>.
  - 46 Hyman-Rabeller, K. A., & Loheide II, S. P. (2023). Drivers of Variation in Winter and Spring Groundwater Recharge: Impacts of Midwinter Melt Events and Subsequent Freezeback. *Water Resources Research*, 59(1), e2022WR032733. <https://doi.org/10.1029/2022WR032733>.
  - 47 Drought. (n.d.). Maine Emergency Management Agency. Retrieved August 8, 2024, from <https://www.maine.gov/mema/hazards/natural-hazards/drought>.
  - 48 Bousquet, C. (2022, August 10). Maine's drought is devastating wild blueberry crops on the Blue Hill Peninsula [Local News]. *Maine Public*. <https://www.maine-public.org/environment-and-outdoors/2022-08-10/maines-drought-is-devastating-wild-blueberry-crops-on-the-blue-hill-peninsula>.
  - 49 Maine Emergency Management Agency, "Wildfires," 2020, <https://www.maine.gov/mema/hazards/natural-hazards/wildfires>.
  - 50 "Wildfires in Maine: Are You Ready?," n.d.
  - 51 Joe Lawlor, "Wildfire Smoke from Canada Affecting Air Quality in Maine," *Press Herald*, August 14, 2024, <https://www.pressherald.com/2024/08/14/wildfire-smoke-from-canada-affecting-air-quality-in-maine/>.



air quality throughout Maine, making it unsafe for people with sensitive conditions to spend prolonged periods of time outside.<sup>52</sup> Droughts have many other negative impacts on the environment, like leaving trees more susceptible to insects and disease<sup>53</sup> and decreased water quality in freshwater ecosystems, taxing aquatic life.<sup>54</sup>

## Potential Costs Related to Extreme Drought

### Water Management

- Purchase of water during water-scarce times.<sup>55</sup>
- Local farmers may need to purchase irrigation systems to mitigate crop loss during drought.
- Public health costs related to increased exposure to water-borne illnesses.<sup>56</sup>
- Replace old pipelines and related infrastructure that have water leak issues.<sup>57</sup>
- Building water conservation infrastructure.
- Upgrade water treatment, wastewater treatment, and other energy infrastructure.<sup>58</sup>
- “Maintain and expand urban and community tree canopy and support ongoing efforts to expand drought-tolerant trees.”<sup>59</sup>

### Wildfires

- Increase fire suppression, including staffing, equipment, and aviation.
- Rebuild or relocate damaged properties and public infrastructure, such as homes and utility lines.
- Relocate public infrastructure where necessary.
- Update power lines to withstand dust from wildfires.
- Implement fire mitigation strategies for the future like burying utility lines underground.

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**52** Christopher Burns, “Canadian Wildfire Smoke Is Making Maine’s Air Unhealthy,” *Bangor Daily News*, accessed August 16, 2024, <https://www.bangordailynews.com/2024/08/14/weather/maine-air-quality-canada-wildfire-smoke/>.

**53** What does a hotter planet mean for wildfires? (n.d.). Environmental Defense Fund. Retrieved August 8, 2024, from <https://www.edf.org/climate/heres-how-climate-change-affects-wildfires>.

**54** Mosley, L. M. (2015). Drought impacts on the water quality of freshwater systems; review and integration. *Earth-Science Reviews*, 140, 203–214. <https://doi.org/10.1016/j.earscirev.2014.11.010>.

**55** Zoë Roller et al., “Closing the Water Access Gap in the United States: A National Action Plan,” Dig Deep and US Water Alliance, 2022. [https://static1.squarespace.com/static/5e80f1a64ed7dc3408525fb9/t/6092ddcc499e1b6a6a07ba3a/1620237782228/Dig-Deep\\_Closing-the-Water-Access-Gap-in-the-United-States\\_DIGITAL\\_compressed.pdf](https://static1.squarespace.com/static/5e80f1a64ed7dc3408525fb9/t/6092ddcc499e1b6a6a07ba3a/1620237782228/Dig-Deep_Closing-the-Water-Access-Gap-in-the-United-States_DIGITAL_compressed.pdf).

**56** Ibid.

**57** CISA, “Drought and Infrastructure - A Planning Guide” [https://www.cisa.gov/sites/default/files/publications/Drought\\_and\\_Infrastructure\\_A\\_Planning\\_Guide\\_508c.pdf](https://www.cisa.gov/sites/default/files/publications/Drought_and_Infrastructure_A_Planning_Guide_508c.pdf)

**58** Ibid.

**59** Gibson and Jones, “Clark County, Nevada: Climate Vulnerability Assessment.”

- Plan for and disburse community aid after wildfires.
- Implement fire detection strategies, like solar-powered sensors.<sup>60</sup>
- Rehabilitate the landscape post-fire to reduce the risk of erosion and invasive species and mitigate future fire risk.
- Increased hospitalization costs for asthma attacks and other chronic health conditions (resulting from decreased air quality due to wildfire smoke) from both local fires and wildfire smoke traveling from other places like Canada.

### **Local Planning and Regulation**

- Organize public participation and staffing in the creation of water scarcity management plans.<sup>61</sup>
- Develop tools for monitoring ground and surface water resources for public use.<sup>62</sup>

### **Education and Awareness Programs**

- Public education, outreach, and awareness campaigns about water conservation.<sup>63</sup>
- Increase public outreach to encourage wildfire risk management; educate residents in wildfire safety, technical assistance availability, funding sources, and best practices.

### **Economic Losses**

- Agricultural losses due to lost crop and/or infertile topsoil.
- Loss of natural services, such as rain providing farmers with free irrigation and flood protection by infiltration of rainwater through soil.

## **Hotter Temperatures – Air and Water**

Anthropogenic greenhouse gas emissions have increased the global average temperature by an estimated 2.01°F since the pre-industrial age,<sup>64</sup> with the rate of warming increasing over the past 30 years.<sup>65</sup> Not all places on the Earth are warming at the same rate. The average annual temperature in Maine has increased by about 3.5°F since the beginning of the 20th century.<sup>66</sup> The recent calendar years of 2020-2023 all rank in the top 10 warmest

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<sup>60</sup> Jennifer L., “Wildfires Cost Over \$148B” <https://carboncredits.com/wildfires-cost-emissions/>

<sup>61</sup> CISA, “Drought and Infrastructure - A Planning Guide”

<sup>62</sup> Ibid.

<sup>63</sup> Ibid.

<sup>64</sup> Lindsey, R., & Dahlman, L. (2024, January 18). Climate Change: Global Temperature [Government]. NOAA. <http://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature>.

<sup>65</sup> Ibid.

<sup>66</sup> Runkle, J., K.E. Kunkel, S.M. Champion, R. Frankson, B.C. Stewart, A.T DeGaetano, and J. Spaccio, 2022: Maine State Climate Summary 2022. NOAA Technical Report NESDIS 150-ME. NOAA/NESDIS, Silver Spring, MD, 4 pp.

years in Maine since the historical record started in 1895.<sup>67</sup> Higher temperatures drive a cascading effect of other climate impacts — some of which are described earlier in this memo, including increased precipitation, drought, and sea level rise. Warmer air and water temperatures will continue to have devastating environmental effects on the state of Maine.

By 2050, the mean annual temperature will be 2 to 4°F warmer in Maine.<sup>68</sup> By 2100, the temperatures may be as high as 10°F warmer under a high emissions scenario.<sup>69</sup> Public services are already being disrupted by heat. At the beginning of the 2023-2024 school year, some Maine school districts had to change the school day schedule to accommodate the warmer temperatures.<sup>70</sup> Hotter temperatures also lead to many other adverse impacts, like increasing mosquito and tick populations, both of which spread vector-borne illnesses, such as West Nile Virus and Lyme disease.<sup>71</sup> In Maine, tick-borne disease infection rates have been increasing in recent years.<sup>72</sup>

Winter is experiencing the highest amount of warming, at a rate twice as fast as warming in the summer, extending the growing season and shrinking ice cover.<sup>73</sup> As stated earlier, winter recreation contributes around \$68 million to Maine's economy.<sup>74</sup> As temperatures warm, snowpack conditions are deteriorating<sup>75</sup> causing recreational closures across the state. For example, a snowmobile path that crosses Moosehead Lake was closed in 2024 due to safety concerns.<sup>76</sup>

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**67** Runkle, J., K.E. Kunkel, S.M. Champion, R. Frankson, B.C. Stewart, A.T DeGaetano, and J. Spaccio, 2022: Maine State Climate Summary 2022. NOAA Technical Report NESDIS 150-ME. NOAA/NESDIS, Silver Spring, MD, 4 pp.

**68** *Climate Change in Maine*. (2023). [Open-File Report]. Maine Climate Office. [https://mco.umaine.edu/pubs/climate\\_summary/#f1](https://mco.umaine.edu/pubs/climate_summary/#f1).

**69** Ibid.

**70** Brookes, K. (2023, September 8). Some Maine schools switching to early release due to lack of air conditioning. WMTW. <https://www.wmtw.com/article/some-maine-schools-switching-early-release-lack-air-conditioning/45041052>.

**71** Pien Huang, "The U.S. Is Unprepared for the Growing Threat of Mosquito- and Tick-Borne Viruses," NPR, December 15, 2023, sec. Public Health, <https://www.npr.org/sections/health-shots/2023/12/15/1219478835/arboviruses-mosquito-tick-borne-viruses-tropical-disease>.

**72** Future, M. C. for D. C. & P., ME Governor's Office of Policy Innovation and the. (2023, July 6). The Maine Climate Impact Dashboard. ArcGIS StoryMaps. <https://storymaps.arcgis.com/collections/934e1d7f462740c69a279fbd8375969d>.

**73** Runkle, J., K.E. Kunkel, S.M. Champion, R. Frankson, B.C. Stewart, A.T DeGaetano, and J. Spaccio, 2022: Maine State Climate Summary 2022. NOAA Technical Report NESDIS 150-ME. NOAA/NESDIS, Silver Spring, MD, 4 pp.

**74** Maine Office of Outdoor Recreation. (n.d.). [Government]. Department of Economic and Community Development. Retrieved August 9, 2024, from <http://www.maine.gov/decd/programs/maine-office-of-outdoor-recreation>.

**75** Gottlieb, A. R., & Mankin, J. S. (2024). Evidence of human influence on Northern Hemisphere snow loss. *Nature*, 625(7994), 293–300. <https://doi.org/10.1038/s41586-023-06794-y>.

**76** Harris, J. (2024, February 26). Climate change is taxing Maine's winter recreation [News]. Piscataquis Observer. <https://observer-me.com/2024/02/26/news/climate-change-is-taxing-maines-winter-recreation/>.

Ocean temperatures are also rising. The Gulf of Maine is warming faster than 97% of the world's ocean surfaces,<sup>77</sup> due to both warming of the Gulf Stream<sup>78</sup> and the shape of the Gulf of Maine trapping the ocean current's warmer waters.<sup>79</sup> This trapped water stays for long periods in the Gulf of Maine, which is now experiencing almost constant ocean heat waves,<sup>80</sup> defined as ocean temperatures being over the 90th percentile for at least five consecutive days.<sup>81</sup>

These higher than normal ocean temperatures have already started to impact the state. Maine has a \$600 million fishing industry that is threatened by climate change.<sup>82</sup> Warmer waters have rendered the coast of Maine inhospitable to northern shrimp, forcing the industry to be in a moratorium since 2013, with little hope of recovery.<sup>83</sup> Warmer waters have also disrupted plankton-based food chains, causing lobster harvests to decline by 26% from 2016 to 2022.<sup>84</sup> In addition, the Gulf of Maine is experiencing ocean acidification, making shellfish further susceptible to disease and predators as their shells weaken.<sup>85</sup>

## Potential Costs Related to Hotter Temperatures

### Structure and Infrastructure Projects

- Energy efficiency retrofits in public and private buildings and housing, including costs for the design and development of standards.
- Increased cooling costs for all public buildings, including green roofs or cool roofing systems on public buildings and new AC installation or upgrade costs for schools.
- Increased road damage due to more frequent extreme heat events.

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**77** MCC STS. 2024. Scientific Assessment of Climate Change and Its Effects in Maine - 2024 Update. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 13 pp.

**78** Todd, R.E., Ren, A.S. Warming and lateral shift of the Gulf Stream from in situ observations since 2001. *Nat. Clim. Chang.* 13, 1348–1352 (2023). <https://doi.org/10.1038/s41558-023-01835-w>

**79** Reidmiller, D. (2023, August 17). Gulf of Maine, Explained: Causes & Impacts of Rapid Warming. Gulf of Maine Research Institute. <https://www.gmri.org/stories/gulf-of-maine-explained-causes-impacts-of-rapid-warming/>.

**80** Runkle, J., K.E. Kunkel, S.M. Champion, R. Frankson, B.C. Stewart, A.T DeGaetano, and J. Spaccio, 2022: Maine State Climate Summary 2022. NOAA Technical Report NESDIS 150-ME. NOAA/NESDIS, Silver Spring, MD, 13 pp.

**81** Marine Heatwave. (2019, August 22). Gulf of Maine Research Institute. <https://gmri.org/stories/marine-heatwave/>.

**82** "Maine 2023 Commercial Fisheries Value Increases by More than \$25 Million," Department of Marine Resources, March 1, 2024, <https://www.maine.gov/dmr/news/fri-03012024-1200-maine-2023-commercial-fisheries-value-increases-more-25-million>.

**83** Whittle, P. (2023, December 1). New England's decades-old shrimp fishery, a victim of climate change, to remain closed indefinitely. AP News. <https://apnews.com/article/new-england-shrimp-fishing-shutdown-climate-1e2daaf234a29434d3f5f780e8a5d3f>.

**84** MCC STS. 2024. Scientific Assessment of Climate Change and Its Effects in Maine - 2024 Update. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 14 pp.

**85** Climate Change Threatens Maine's Fisheries. (2018, July 31). Natural Resources Council of Maine. <https://www.nrcm.org/programs/federal/federal-climate-energy/climate-change-threatens-maines-fisheries/>.

- Plan for and increase capacity for increased energy demands due to both increased daytime and nighttime temperature.
- Increase high-albedo surfaces on buildings, roads, and other locations where feasible.

### **Public Health Projects**

- Build and manage more cooling centers, including staffing and tracking of high-risk individuals.
- Increased demand for publicly-financed air conditioning targeted to low-income families and public housing.
- Control the increase of vector borne illness using education and physical and chemical controls for ticks and mosquitoes.
- Treat victims of vector borne illness.
- Treat an increase in asthma attacks requiring hospitalization (resulting from increased heat and ground level ozone, and the increase in airborne allergens).
- Reduce the urban heat island effect by planting trees.
- Protect drinking water supplies from hazardous algae blooms.

### **Economic Losses**

- Winter recreation and tourism industry losses due to shorter winters and less snowpack.
- Damage to the fishing industry as animals migrate to cooler waters and become more susceptible to disease.<sup>86</sup>

## **Other Potential Costs**

Other plausible impacts from climate change that would incur public health costs are increased allergen levels, food- and water-borne infections, and zoonotic diseases.<sup>87</sup> Since the northeast U.S. climate is historically cooler, Maine is also likely to see an influx of climate refugees, which will incur costs as they plan for and accommodate more residents.<sup>88</sup>

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**86** Climate Change Threatens Maine's Fisheries. (2018, July 31). Natural Resources Council of Maine. <https://www.nrcm.org/programs/federal/federal-climate-energy/climate-change-threatens-maines-fisheries/>.

**87** Carmen Milanes et al., "Indicators of Climate Change in California" (Office of Environmental Health Hazard Assessment, 2022), <https://oehha.ca.gov/media/downloads/climate-change/document/2022caindicatorsreport.pdf>.

**88** Schauffer, M. (2020, October 11). Fleeing to Maine from climate disasters. The Maine Monitor. <https://themainemonitor.org/fleeing-to-maine-from-climate-disasters/>.