

## CHAPTER SEVEN

# PEOPLE AND



### Impacts and Vulnerabilities



### Adaptation Strategies

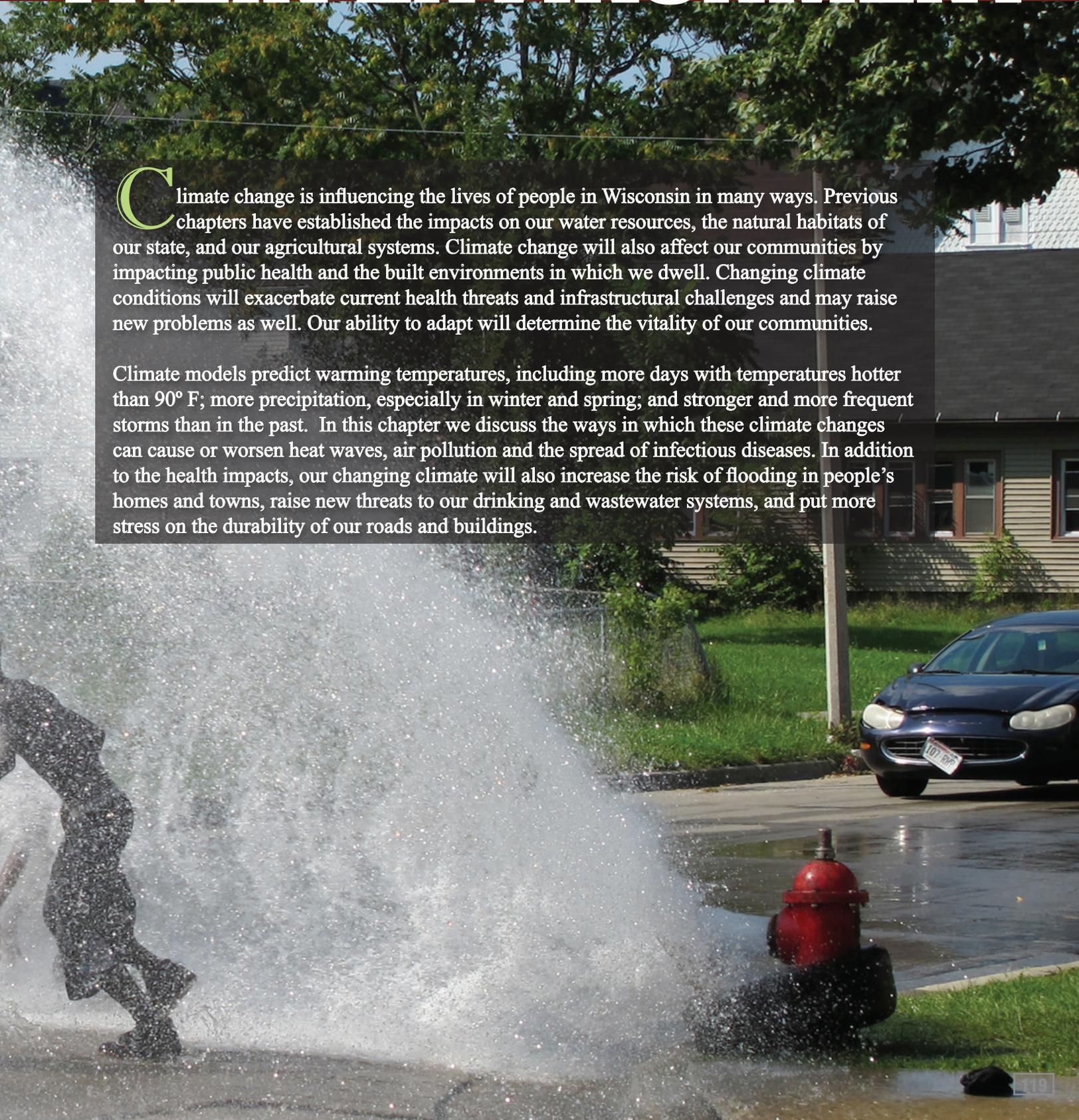


Photo: Courtesy of Finni Ryan and Climate Wisconsin

# THEIR ENVIRONMENT

**C**limate change is influencing the lives of people in Wisconsin in many ways. Previous chapters have established the impacts on our water resources, the natural habitats of our state, and our agricultural systems. Climate change will also affect our communities by impacting public health and the built environments in which we dwell. Changing climate conditions will exacerbate current health threats and infrastructural challenges and may raise new problems as well. Our ability to adapt will determine the vitality of our communities.

Climate models predict warming temperatures, including more days with temperatures hotter than 90° F; more precipitation, especially in winter and spring; and stronger and more frequent storms than in the past. In this chapter we discuss the ways in which these climate changes can cause or worsen heat waves, air pollution and the spread of infectious diseases. In addition to the health impacts, our changing climate will also increase the risk of flooding in people's homes and towns, raise new threats to our drinking and wastewater systems, and put more stress on the durability of our roads and buildings.



# Impacts and Vulnerabilities

## Public Health

While climate change in Wisconsin will bring some benefits to human health, such as fewer deaths from exposure to very cold temperatures, scientists agree that, overall, we will see more negative than positive climate impacts on health. Climate change poses regional and local public health risks in Wisconsin that will vary depending on the season, geographical location and physical characteristics of a landscape. The severity of the impacts depends on the age, health and other demographic characteristics of the population; the level of resources and preparedness of local public health agencies and communities; and the physical location of the affected areas. Climate can influence human health directly, such as by causing death or illness from exposure to extreme heat for an extended

period of time, or indirectly, as when climate changes foster the spread of diseases or increase exposure to pollution.

In this section, we focus on the direct impacts of heat waves and the indirect impacts of air pollution and infectious diseases, both water- and vector-borne. Our understanding of the full extent of climate change impacts on human health on a state and local scale is in its infancy. This is our first assessment of climate change impacts on public health in Wisconsin, and there is much work left to do. While this assessment includes a broad range

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Cities are particularly vulnerable to heat waves because of the “urban heat island effect,” in which urban areas become warmer than the surrounding rural areas because of the dry, impervious characteristics of their buildings, roads and other paved surfaces. Brick buildings, asphalt streets and tar roofs store and then radiate heat like a slow-burning furnace. Heat builds up during the day, and cities take longer to cool down at night than surrounding rural areas.

Southern Wisconsin experiences more days of heat waves than other parts of the state, and Milwaukee County has reported the highest numbers of heat-related deaths. Figure 1 illustrates the number of heat advisory days and heat-related deaths by county.

## Air Pollution

Research has established that exposure to air pollution increases the risk of respiratory diseases such as allergies, asthma and chronic lung diseases as well as the risk of heart disease. Air pollution could worsen with climate change, posing greater threats to public health. Prevalent air pollutants in Wisconsin include smog, particulate matter and airborne allergens.

**Smog:** Scientists expect that as temperatures continue to rise, air pollutants such as ozone will become a greater concern for public health. Ground-level ozone, or smog, is not emitted from a particular source; rather, it is a secondary pollutant that forms when hot air, sunlight and emissions from a variety of sources react in the atmosphere. This reaction depends heavily on high temperatures and ultraviolet energy from the sun, so the problem is at its worst in summer. Projections of increasing temperatures lead scientists to predict an increase in the formation of smog.

Smog damages lung tissue, and public health scientists have described the irritation as “sunburn on the lungs.” Smog worsens conditions such as asthma and chronic



Photo: David S. Liebl

*Smoke from residential wood heating can be a significant source of fine particle air pollution.*

lung diseases, and it is particularly risky for children because they often spend considerable amounts of time in activities outdoors, where they are more likely to inhale air pollutants and to breathe them deeper into their lungs.

Climate projections for the coastal regions along the southern shores of Lake Michigan suggest we will see an increase in smog in those areas. These projections include warmer temperatures with related changes in air circulation, humidity, cloud cover and precipitation. According to a study of ozone pollution in Chicago – located at the southern tip of Lake Michigan only 55 miles from Kenosha – these meteorological changes alone could result in an increase in the number of days when these coastal regions exceed the current National Ambient Air Quality Standards for ground-level ozone, growing from an average of 2.2 days per summer to up to an average of 16.8 days by the end of this century.

Although Wisconsin has made significant progress in reducing ozone levels, we will face greater challenges in meeting the federal regulations as climate change increases the conditions that lead to ozone formation.

**Particle pollution:** Particle pollution, also called particulate matter, is another form of air pollution that aggravates asthma and increases respiratory and heart disease. Particle pollution consists of a complex mixture of miniscule solid particles and liquid droplets that are suspended in the air and made up of a variety of components, including nitrogen oxides and sulfur dioxides. Some components of particle pollution are emitted directly from power plants, industrial sources, vehicles, agricultural sources, forest fires or wood stoves, while others form from chemical reactions in the atmosphere.

Particles such as dust, soot, smoke and dirt can be large or dark enough to see. Such pollution creates the white or brown haze that lingers over many areas of the United States, reducing visibility. Other smaller particles, called fine particulates, are so tiny they can be seen only through a microscope. These fine particulates can cause severe health effects because they are small enough to be inhaled into the deepest parts of the lungs and become trapped, potentially leading to lung disease, asthma, emphysema or heart disease.

Unlike smog, which is worse in hot months because of its dependence on sunlight and high temperatures, particle pollution can reach unsafe concentrations at any time of year. Milwaukee, Racine and Waukesha counties currently do not meet National Ambient Air Quality Standards for fine particle pollution. If Wisconsin faces climate conditions more favorable to the formation of particle pollution, such as warmer winters coupled with increased water vapor in the air, the combination may result in an increase in concentrations of particulate matter, posing greater threats to public health.

**Airborne allergens:** Airborne allergens can interact with other forms of air pollution, increasing the risk of respiratory diseases and other public health challenges. One of these pollutants is pollen. Higher levels of carbon dioxide – one of the greenhouse gases that have been increasing and continue to increase in the atmosphere – promote growth and reproduction by many plants, including those that produce allergens.

For example, ragweed plants experimentally exposed to high levels of carbon dioxide can increase their pollen production several-fold, which some scientists suspect may be part of the reason for rising ragweed pollen levels in recent decades. This common allergen can aggravate asthma and other respiratory diseases.

## Waterborne Disease

Studies have shown that heavy rainfalls and watershed land use patterns are associated with waterborne disease outbreaks. Land use patterns and the presence of human and animal waste make some watersheds more vulnerable to water contamination, especially after a heavy rain. Contamination of water results from a variety of causes including runoff from storms, contamination of wells or distribution pipes in areas of aging infrastructure, and sanitary sewer overflows that release sewage into waterways.

**Combined sanitary sewer overflows:** Contamination from sewage overflow is a major source of human pathogens and adversely impacts recreational beaches and drinking water sources. Older cities in the Great Lakes region, including Milwaukee, have combined sewer systems that handle both sewage and stormwater in large underground pipes. When rainwater inundates these systems following a heavy downpour, the pipes can overflow into surface waters like lakes and streams, posing a health risk from contamination.

Gastrointestinal illness and respiratory effects are all public health concerns that result from this type of contamination. While sewage is detectable in surface waters even under normal conditions, precipitation is a major driver of sewage delivery into surface water.

**When rainwater inundates these systems following a heavy downpour, the pipes can overflow into surface waters like lakes and streams, posing a health risk from contamination.**



Photo: Gabor Bibor

**B**esides the direct effect of flood-related deaths, flooding can spread harmful bacteria and viruses.

waterborne disease outbreak resulting from heavy rainfall is the 1993 *Cryptosporidium* outbreak in Milwaukee, when an estimated 400,000 people were exposed and 54 people died. The outbreak occurred following heavy rainfalls and coincided with combined sewage overflows and near-record flows in the Milwaukee River that delivered runoff from upstream agricultural areas.

Therefore, if instances of heavy rainfall increase in frequency and magnitude, as climate models project, we will see an increase in these public health risks resulting from sewer overflows. A notable example of

**Flooding:** Flooding poses additional human health risks. Besides the obvious direct effect of flood-related deaths, flooding can spread harmful bacteria and viruses. During 2007-08, Wisconsin experienced very large precipitation events that took a toll on public health. When a mid-August torrential rainfall fell on the heels of a drought, the rainfall landed on hardened ground, triggering large-scale flooding in southern Wisconsin. That winter brought record snowfalls for the region, with 101 inches falling in Madison, and as the snow melted into already saturated ground, river levels rose higher than they had been in decades, with floodwaters reaching the 100-500 year floodplains. The following June, severe weather swept through the entire Midwest, impacting already-flooded regions across the state and contaminating food and water supplies across southern Wisconsin. Some 41,000 house-

holds filed for emergency assistance, and more than 2,500 drinking water samples were tested. More than 30 percent of these samples proved to contain coliform or *E. coli* bacteria.

## Vector-Borne Disease

Many diseases that begin their life cycle in animals, such as West Nile virus and Lyme disease, are sensitive to fluctuations in climate. The timing of peak

**Unless we modify planning, design and management of infrastructure, the risk of economic and environmental damage will increase.**

years of West Nile outbreaks coinciding with unseasonable heat waves led scientists to investigate the effect of temperature on the ecology and transmission of the disease. They found that a West Nile out-

break in horses in the Midwest peaked during periods of high temperatures and dropped significantly following decreasing temperatures. These findings suggest a temperature effect, and scientists continue to study the possible link.

Even slight changes in temperature and moisture can go a long way toward changing the risk of transmission and determining the geographic range of a disease host. Such changes could make the world more hospitable for the tiny animals that transmit diseases. For cold-blooded insects and invertebrates such as mosquitoes and ticks, all it takes is a small shift in temperature to alter their transmission dynamics. Moisture is another factor that determines the survival of ticks, and increased dryness lowers tick survival rates. As long as there is adequate moisture, warmer conditions promote tick abundance.

The reported incidence in Wisconsin of Lyme disease, which is transmitted by ticks, has consistently been among the 10 high-

est among states in the U.S. and has doubled in the past decade. However, preliminary results from Lyme disease research by the Human Health Working Group and Canadian scientists suggest that climate change may be expanding the range of ticks northward, sending them out of Wisconsin and into Minnesota and Canada by the end of this century.

Moreover, other factors complicate Lyme disease predictions. Scientists question whether the increase in Lyme disease may be more a function of land use than of climate. This is one area at the interface of ecology and human health that is extremely important and illustrates the potential intersection of conservation and land use policy with public health policy. For example, the fragmentation of wooded areas sets up conditions for the ticks that spread Lyme disease. Large predators do not do well in isolated fragments of woodlands, and this allows populations of rodents and other small animals to grow. Rodents often carry Lyme disease, and they are also an ideal host for ticks. The infected rodents infect the ticks, and the ticks move on and spread the disease to people and their pets.

## Built Environment

Climate change will compound the challenges that people and their environments already face. Buildings, roads, and water and sewer systems will face different weather conditions than in the past, and current designs do not equip infrastructure to withstand the challenges that future climate changes may bring.

Unique challenges arise when concentrated populations of people live amid aging or inadequate infra-



Photo: Elizabeth Katt-Reinders

## Heavy rainfall amounts can exceed the capacity of stormwater systems in urban areas, leading to localized flooding.

accommodate the additional flow that follows a heavy storm. Bridges and culverts are built to allow safe passage over streams and rivers under all but the most extreme flood conditions. However, climate models project an increase in heavy storms that needs to be taken into account in current designs. Unless we modify planning, design and management of infrastructure, the risk of economic and environmental damage will increase.

structure. Society's infrastructure is built to manage the risks and impacts associated with precipitation and weather patterns, but it has been traditionally designed and evaluated using historical data. For example, sewer systems are designed to

## Runoff and Flooding

In Wisconsin's urban watersheds, stormwater runoff and sewer overflows are primary factors in water quality issues. Increases in the magnitude and frequency of large daily or shorter duration rainfalls are the most relevant climate change impacts, and they will require greater investments in stormwater infrastructure for both new and existing development.

In rural areas, nutrient and sediment runoff from agricultural lands is a critical water quality concern. As is the case with urban watersheds, changes in the magnitude and frequency of rainfall events are critical, but more significant is the projected shift in precipitation to winter and spring. Agricultural lands are particularly vulnerable to large rainfall events that occur in the spring when soil is bare and there is no evapotranspiration. Nutrient and sediment runoff from agricultural watersheds is likely to increase as a result of projected increases in the magnitude and frequency of large rainfalls and in winter and spring precipitation.



Photo: FEMA 2008

*Crawfish River*

## GROUNDWATER FLOODING IN BRODHEAD

**During 2007-08, southern Wisconsin experienced above-normal precipitation and intense rainfall events. Rising regional groundwater levels resulting from increased recharge caused groundwater flooding of basements and yards. Low-lying developed areas situated over shallow groundwater (less than 10 feet) and with poor surface drainage reported continuously running sump pumps during this period. Several houses became uninhabitable due to persistent soil saturation and flood damage.**

It appears that climate change in Wisconsin will produce modest annual increases in daily rainfall over the next century, resulting in greater storm flows in urban watersheds. Projections by the Climate Working Group indicate that in southeastern Wisconsin the number of storms with daily rainfall totals of two inches or more will likely increase in frequency from the current 12 storms per decade to 14 to 15 storms per decade. This change could affect the performance of stormwater management systems and of flood mitigation efforts. It could also expand flood hazard areas, encompassing more existing development. With an increase in the magnitudes of rainfall comes an increased risk of flood damages and a need for larger, more costly stormwater management and flood mitigation facilities and programs.

Heavy rainfall amounts can exceed the capacity of stormwater systems in urban areas, leading to localized flooding. A number of factors influence the volumes and rates of runoff to stormwater management systems and receiving streams. The factors most likely to be influenced by climate change include the amount of rainfall, timing of storm events, and frequency and intensity of precipitation, followed by changes in temperature and humidity that may affect evapotranspiration. Other factors that come into play include leaf canopy, the amount of impervious land surface, infiltration capacities of pervious surfaces, land surface slopes, natural and constructed runoff storage and infiltration facilities, evapotranspiration of water from the ground surface and soil, and the capacity of the soil to store moisture.

Locally, stormwater causes high-water conditions as a result of heavy rainfall over relatively small areas, especially when the duration of the initiating storm event lasts only minutes to hours. Furthermore, a large portion of an urban watershed is usually impervious; therefore, soil moisture conditions have little effect on the rate of surface runoff. For these reasons, the design of stormwater infrastructure is usually based on single storm events. For urban stormwater management, changes in the magnitude of rainfall at the daily or shorter time scale are the most relevant.

Stormwater management systems typically include infrastructure designed to handle small and mid-range

storms as well as to safely handle runoff from large storms that have a statistical probability of 1 percent chance of occurring in a year. Flood mitigation planning and facilities are generally focused on flood events with annual probabilities of occurrence of 1 percent or less.

Long-lived infrastructure that is vulnerable to high-water conditions or that protects against the impacts of high-water conditions is of particular concern. This includes water supply systems, wastewater treatment systems, bridges and culverts as well as infrastructure that controls floods (such as dams and levees), manages stormwater, and controls soil and stream bank erosion.

The design of such infrastructure has been and continues to be based on historical precipitation and flood data. Unless appropriate adaptation strategies are adopted, we can expect increases in the frequency and severity of the following high-water impacts:

- Roadways and bridges washed out by high water or slope failure.
- Contamination of rural residential wells as a result of surface water and groundwater flooding.
- Flooding of urban streets and homes due to inadequate runoff drainage systems.
- Failure of impoundments, levees, and stormwater detention ponds.
- Failure of rain gardens and other biofiltration practices due to prolonged periods of saturated soils.
- Stormwater inflow and groundwater infiltration to sanitary sewers, resulting in untreated municipal wastewater overflowing into lakes and streams.
- Groundwater flooding of property and cropland.

Groundwater drains much more slowly than surface water. High groundwater results when recharge exceeds drainage over periods of months or years. As with streams, rivers and lakes, the expected increases in winter and spring precipitation (when recharge is unaffected by transpiration) are likely to have the greatest impact on the occurrence of high groundwater conditions. As for runoff, the critical factors determining the amount of recharge versus runoff are soil type, soil moisture, vegetation and frost. Homes and businesses built over

former wetlands are vulnerable to flooding from rising groundwater caused by climate change.

### Wastewater

Climate change poses potential risks to wastewater treatment facilities in Wisconsin. The changes that may have the greatest potential influence are an increase in the number of intense rainfall events and high

groundwater that cause inflow and infiltration, leading to increased frequency, size and duration of sanitary sewer overflows and residential floor drain backups. In addition, these events could result in physical damage to treatment facilities, short-term loss of treatment

**An increase in the number of intense rainfall events and high groundwater that cause inflow and infiltration will lead to increased frequency, size and duration of sanitary sewer overflows and residential floor drain backups.**

capacity and increased need for inspection and maintenance. The potential also exists for increased risk of losing the biologic activity in wastewater treatment facilities, which could make it difficult to meet water quality standards and associated discharge limits.

Warmer and dryer summers can result in reduced wastewater system flows. This could lead to odors, more sewer pipe corrosion and an increased risk of sewer blockages due to stimulated plant growth and material deposit. Dry weather followed by intense precipitation events also poses operational issues for both wastewater collection and treatment systems. These issues manifest themselves in terms of highly variable wastewater strength and plant loadings, and, ultimately, as challenges in maintaining discharge-permit compliance.

Sewage overflows pose a serious health risk stemming from the introduction of pathogens into the environment. Combined and sanitary sewer overflows occur when the volume of heavy rainfall or groundwater infiltration exceeds the capacity of a sewer system. Projections of increased intensity and frequency of heavy rainfall events, particularly in spring when groundwater tables are often elevated, are likely to lead to increases in the number of sewage overflows.

### Drinking Water

Lakes Michigan and Superior constitute the primary water supplies for Wisconsin's coastal communities. Climate change impacts may alter the treatability of lake water. At the intakes, lake level has an important effect on pumping requirements, on the formation of ice blockages in winter and on the potential

## BARABOO RIVER AT I-90/94/39

**The flood damage experienced in Wisconsin in 2008 exposed many weaknesses in current strategies to protect against high-water conditions. In many cases, these weaknesses are being addressed. For example, the Wisconsin Department of Transportation is conducting a review of the vulnerability of the entire interstate highway system as a result of flood-triggered closures of I-39, I-90, and I-94 at the Baraboo River in Columbia County. Engineers will weigh the costs of flood-proofing stream crossings and embankments against the economic costs of temporary closures of this important roadway.**

for invasive species to impact both water quality and water utility infrastructure. Water temperature, biological and chemical contaminant types and loads, and amounts and sizes of suspended materials requiring physical removal all have an effect on lake water treatability. For example, the amount and sizes of suspended materials are typically driven by the occurrence and magnitude of storm events. The magnitude, frequency and duration of changes of in-flowing water characteristics could complicate treatment and possibly necessitate infrastructure improvements in treatment processes, especially if these changes occur sporadically.

Climate change may make drinking water distribution systems more vulnerable. If climate change leads to an increasing number of freeze-thaw cycles, it can, in turn, cause higher numbers of water main breaks and greater incidences of leaks that result in unaccounted-for water.

Climate changes may also drive shifts in water-use patterns outside the immediate coastal communities, which could expand the demand for lake water. These changes and challenges could then impact decisions related to expanding or replacing drinking water infrastructure.

### **Structure Durability**

Climate change will impact the durability of a number of structures and materials. Among other things, it will increase stress on concrete, which affects roads, bridges and buildings, and it will increase stress on asphalt roads because

of changes in the freeze-thaw cycle. The American Society for Testing and Materials has established standards for road concrete durability. These standards require that highway concrete remain durable through 300 freeze-thaw cycles. If climate projections can predict the changes in frequency of freeze-thaw cycles, then scientists can calculate the likely change in the useful life of concrete. The extent of these impacts requires further study.



# Adaptation Strategies

The diversity of factors that contribute to climate impacts on public health and infrastructure lead to a wide range of possible strategies for adaptation. In

keeping with the organizational framework presented in *Chapter 2: Understanding Adaptation*, we present

## ADAPTATION

### TAKING ACTION

Policy-makers should carefully weigh the impacts of their infrastructure investment decisions on human health and the state's capacity to adapt to a changing climate. For example, the health co-benefits of "green" transportation planning should be included in any cost-benefit analyses of adaptation to climate change.

#### Air Quality

Expand the Wisconsin Department of Transportation Congestion Mitigation and Air Quality grants to reduce the number of vehicle miles traveled and improve vehicle and fuel technologies to reduce vehicle emissions. Companies should reduce emissions of hazardous air pollutants to improve air quality and reduce ozone.

#### Human Health

Increase the urban tree canopy to reduce the urban heat island effect.

#### Water Infrastructure

Upgrade urban storm drains and best management practices based on continuous hydrologic modeling and climate predictions. Manage runoff to minimize high-flow impacts rather than sediment removal during high storm flows. Distribute management strategies throughout urban watersheds to mitigate high flows. Anticipate groundwater impacts on stormwater infiltration management practices.

Implement stormwater best management practices that will improve water quality while reducing sanitary sewer overflows. Increase capacity of municipal wastewater systems and minimize storm-

water inflow and groundwater infiltration to prevent overflows. Require standby power for buildings with sump pumps to avoid system inflows caused by storm-related power outages.

Identify locations that are vulnerable to climate impacts and apply more stringent design criteria. Flood-proof vulnerable buildings and infrastructure.

Acquire land along waterways to prevent flooding, improve water quality and reduce sewer overflows.

Use low-impact design to minimize runoff from newly developed areas. Construct green roofs to improve water quality, reduce sewer overflows and improve building cooling.

### BUILDING CAPACITY

Expand the activities of the Wisconsin Environmental Public Health Tracking program to include indicators of air pollution conditions linked to climate variability and change. Establish a Vector-borne Disease Surveillance Program to collect data and assist in generating statistical reports and other epidemiological reports. Build capacity for drinking water quality emergency assessment and response.

Develop comprehensive transit strategies and explore alternatives for mass transit (for example, street cars, commuter rail, and high-speed rail) to improve air quality and reduce ozone.

The state should develop minimum design and performance standards for the control of the high-water impacts of development. In addition, it should:

- Provide local units of government with the



here several adaptation strategies relevant to public health and infrastructure in Wisconsin. (Please see the

Human Health, Milwaukee and Stormwater Working Group reports at [www.wicci.wisc.edu](http://www.wicci.wisc.edu) for a more detailed discussion of adaptation strategies.)

## STRATEGIES

technical and financial assistance needed to assess and mitigate their vulnerabilities to potential high-water conditions caused by present and future climate conditions.

- Identify at-risk stream crossings and develop maintenance and high-water contingency plans.
- Periodically update estimates of high-water profiles based on revised rainfall data.
- Provide assistance to local governments for development of regional continuous hydrologic simulation models for both surface water and groundwater.
- Use updated models to predict groundwater impacts on development.
- Incorporate climate change considerations into watershed management and restoration plans.
- Revise building standards to address runoff volume control.

The Wisconsin Department of Natural Resources should develop an approval process for prior converted wetlands that are being removed from agricultural use to encourage their restoration and prevent development in flood-prone areas.

County and municipal governments should adopt an approval process for, or place land use controls on, development over hydric soils in areas that will experience future flooding.

Planners should coordinate with regulators to identify future land use changes and control land use around internally drained areas and over hydric soils and use updated models to predict groundwater impacts on development.

### COMMUNICATING

Provide outreach and education on health impacts of air quality to county and city public health departments, school nurses, day care centers, summer camps, nursing homes and other facilities.

Educate communities about the hazards of building in areas prone to high water.

Coordinate with regulators to identify future land use changes and control land use around internally drained areas and over hydric soils.

Educate property owners about sanitary sewer inflow prevention.

### FILLING THE GAPS

Improve and maintain Wisconsin's climate monitoring network (weather, stream flow, groundwater) to provide continued high-quality data to support short-and long-term climate impact modeling.

Invest in research at the state and national levels to build capacity and provide knowledge in the areas of winter-spring hydrology, hydrologic modeling and decision-making under uncertainty for water resource management.

Study the impact of increased precipitation on the frequency of combined and sanitary sewer overflows and water quality.

Research opportunities for mass transit such as street cars, commuter rail, and high-speed rail to improve air quality and reduce ozone.

## ADAPTATION IN ACTION: GREEN INFRASTRUCTURE

When it rains, the water running off roofs, driveways, parking lots and streets picks up pollutants along the way. Currently, much of this untreated runoff is directed through culverts and storm sewers to the state's streams, rivers, and lakes. But there is a better, more sustainable way to work *with* nature in managing stormwater. Green infrastructure can help reestablish natural hydrologic cycles through an integrated system of natural areas and constructed elements ranging from restored riparian corridors to "green" streets, parking lots, and roofs. Green infrastructure reduces stormwater runoff volumes and slows rates of discharge by using the natural retention and absorption capabilities of vegetation and soils. This approach to managing wet weather also uses plants and soil microorganisms to break down many of the pollutants found in runoff.

### DESIGN PRINCIPLES

Natural landscape features such as forests, floodplains and wetlands are critical components of green infrastructure. By protecting these ecologically important areas, communities can improve air and water quality while also providing plant and wildlife habitat, scenic beauty, and opportunities for outdoor recreation. Green infrastructure also includes smaller features such as rain gardens, porous pavements and bioswales within parking lots, and green roofs. These technologies can reduce flooding and sewer overflow events and help prevent pollutants from being transported to nearby surface waters. Green infrastructure is especially cost-effective when it is strategically designed to yield multiple functions that have ecological, economic and social benefits.

### MULTIPLE BENEFITS

Green infrastructure can make communities more livable and enhance property values. The benefits of green infrastructure increase in urban and suburban areas where green space is limited and impervious surfaces are more extensive. Urban heat islands form when natural land cover is replaced with dense concentrations of pavement, buildings and other surfaces that absorb and retain heat. By increasing urban green space and trees, green infrastructure can lower the demand for air conditioning, thereby reducing both energy consumption and air pollutants emitted from power plants. Recent research has linked the presence of trees and green space to reduced levels of inner-city crime and violence, improved academic performance, increased physical activity and reduced childhood obesity.

## Conclusion

Current threats to public health will likely worsen in the face of climate change. With projections for more days with temperatures greater than 90° F, heat waves will likely occur more frequently, more intensely, and they will last longer. Air pollution including smog, particle pollution and airborne allergens will worsen. Waterborne diseases may increase as heavy rainfall events occur more frequently, and vector-borne disease transmission will be affected as climate change alters the habitat conditions of the disease carriers.

Our climate is changing at a pace more rapid than it has historically, and current infrastructure designs will likely prove inadequate over the next century. The infrastructure of our cities, towns and transportation systems has been designed based on historical weather and climate data. We need to design, build and manage our built environment with future climate projections in mind to reduce the risks of stormwater runoff and flooding and to protect our drinking water, wastewater systems and infrastructure durability. For human health and the built environment, “business as usual” is not adequate to manage current and future risks posed by climate change to society.

**Source material for this chapter was drawn from the Human Health, Milwaukee, and Stormwater Working Group reports, available online at [www.wicci.wisc.edu](http://www.wicci.wisc.edu).**



Photo: The Kubala Washatko Architects, Inc./Mark F. Heffron



Photo: Courtesy of Finn Ryan and Climate Wisconsin



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