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Milwaukee Working Group Report

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MILWAUKEE WORKING GROUP ASSESSMENT REPORT

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Wisconsin Initiative on Climate Change Impacts

EXECUTIVE SUMMARY

Climate change has the potential to impact urban centers in several different ways. On a statewide basis, climate scientists project that annual average temperature will increase by 4-9º Fahrenheit between now and 2050. In addition, it is projected that the frequency of heavy rainfall events will increase. The complexities of the urban environment make it difficult to anticipate potential consequences and long-term impacts that will result from these changes in climate. The Milwaukee Working Group was formed to examine the aspects of the urban environment that may be sensitive to climate change and to identify adaptation strategies to minimize the negative impacts of those changes.

For this first assessment, the Milwaukee Working Group focused on three broad areas: water resources, urban infrastructure, and public health. The Milwaukee Working Group identified spring rainfall as the climate parameter that is likely to cause the greatest stress on water resources and urban infrastructure. The impacts on water infrastructure, roadways, and buildings resulting from these stresses are likely to have economic ramifications that are currently difficult to estimate. Scientists also expect climate change to adversely affect air and water quality. This is likely to have effects upon public health. For example, the deterioration of air quality that is expected to result from climate change may exacerbate existing problems with childhood asthma in urban areas. This may be particularly important for Milwaukee, which already has the second highest rate of childhood asthma in the nation. In addition, the impacts of climate change may fall more heavily on some sectors of the population than on others such as in urban areas with high population densities and a broad range of socioeconomic conditions. For instance, the additional costs associated with air conditioning make it likely that the elderly and the economically disadvantaged will be more heavily impacted by heat waves than other sectors of the population.

WATER RESOURCES

Water resources are vital to urban centers and are closely linked with economic vitality, human health and quality of life. Stormwater runoff is currently a major challenge in heavily developed areas due to their large amounts of impervious surfaces. Changes in rainfall patterns can impact flooding, water quality, and the infrastructure that is needed to meet stormwater regulations. In June 2008 and July 2010, extreme storm events that produced high-intensity rainfall caused extensive flooding. This overwhelmed sewer systems throughout Wisconsin, resulting in the release of untreated sewage into floodwaters. Such events highlight the vulnerability of the urban environment to high levels of precipitation. The WICCI Stormwater Working Group has said that it is premature to make significant changes in the design of stormwater infrastructure except where change is warranted by today's climate. The one exception is winter/spring rainfall, where model projections are fairly consistent. Rainfall-runoff modeling will be required to determine implications for watershed flooding.

Climate change may also alter the amount of groundwater recharge. Changes in the timing, amount, or intensity of precipitation may affect the amount of water available for recharge as well as the capacity of soil to accept water. Changes in temperature and humidity may alter the amount of water lost from soil through evapotranspiration, changing the amount of recharge. The resulting changes in recharge may affect both the availability of groundwater as a water supply source and the amount of discharge of groundwater to surface water bodies as baseflow.

Floodwaters impact Milwaukee neighborhoods following heavy rainfalls, June 7, 2008. (Photo courtesy of the Milwaukee Metropolitan Sewerage District.)

Lake Michigan surface water is the major drinking water source for Milwaukee County. This water source may become more difficult to treat due to changes in biological or chemical contaminant loads that are a consequence of changing storm patterns and increased pollutant discharges into surface waters. Changes in water temperature or suspended solids may also affect treatability of source water and, depending upon the magnitude of these changes, could necessitate infrastructure improvements.

Changing climatic conditions may stress wastewater infrastructure. Portions of Milwaukee are served by combined sewers, which convey both stormwater and sanitary sewage to wastewater treatment plants for treatment. Increases in the frequency and intensity of rainfall in spring months have the potential to overwhelm the capacity of this system, causing basement backups and/or combined sewage overflows. These events have public health implications resulting from the associated release of pathogens into buildings and surface waters. While the predictions for changes in the frequency of high intensity rainfall are modest, sewage contamination of homes and waterways is a serious issue and should be examined in depth.

PUBLIC HEALTH

The projected changes in climate may result in adverse impacts upon public health. It is likely that some existing public health problems may be worsened. This is especially the case in urban areas like Milwaukee because these areas have high population densities and contain large numbers of people who are members of susceptible populations.

Air quality changes resulting from climate change are likely to produce public health impacts. Because heat is a factor promoting the production of ground-level ozone, the projected increases in temperature are likely to result in increases in the frequency at which concentrations of ozone at levels high enough to pose health risks to sensitive individuals occur. Exposure to these levels of ozone is associated with a number of health problems including decreased lung function, susceptibility to respiratory infections and reduced immune system function. Urban areas such as Milwaukee have high population densities, including populations susceptible to health problems.

The incidence of waterborne diseases such as gastroenteritis may increase as a result of potential impacts of the projected increase in the incidence of heavy storms. As noted above, urban flooding can overwhelm sewer systems, resulting in the release of untreated sewage into floodwaters in streets and basements. This may increase exposure to waterborne diseases. The projected increase in the incidence of heavy storms may also increase the potential for people to be exposed to pathogens through recreational water or drinking water. Currently, high concentrations of fecal indicator bacteria are routinely found in Milwaukee surface waters following rain events. While not all fecal pollution sources carry pathogens, these higher concentrations indicate a greater potential for pathogens to be present. A better understanding of the dynamics of how contamination enters surface waters would allow scientists to better characterize the risks of pathogen exposure associated with different storm event patterns and to assess how these potential risks may change with changing climatic conditions.

Mid-century climate projections for the Milwaukee area include an increase in the number of very hot days and higher nighttime low temperatures. This suggests that heat waves will become more frequent. Urban residents are particularly sensitive to the effects of heat waves. Urban areas experience a heat island effect because buildings, roads and other structures are efficient at absorbing and storing heat during the day and slowly releasing it during the night. Extreme heat can cause a number of heat-related illnesses, such as heat exhaustion and heatstroke that can result in death.

INFRASTRUCTURE

Urban areas have large infrastructure needs that include roadways, sewers, and buildings. Climate change may have direct impacts on the lifespan or integrity of materials used in structures. Stressors such as changes in freeze-thaw cycles may decrease the durability of roads, bridges or buildings. Climate change may also influence the design requirements. “Green” infrastructure that includes rain gardens and green roofs not only helps alleviate stormwater and urban heat island effects today but may also contribute to the resilience of the urban area in the face of changing climate.

RESEARCH NEEDS

The initial focus of the Milwaukee Working Group in 2008-2010 has been on water resources and the linkages to public health. Several research studies are underway that include assessing how the number and magnitude of combined and separated sewage overflows may change due to changes in storm frequency and intensity. We are also exploring the impact on the water quality of rivers and the potential changes in nearshore circulation patterns in Lake Michigan. The Milwaukee Working Group has identified immediate needs for detailed analyses of vulnerabilities and associated risks to flooding, air quality and concrete structures. An assessment of economic impacts due to climate change is of high importance as this information will be needed in weighing the costs of adaptive strategies against potential risks.

ADAPTATION

The Milwaukee Working Group is focusing on identifying "no regrets" adaptive strategies such as practices or policies that have little or no cost but would aid in adaptation. Developing adaptation strategies in response to climate change requires a comprehensive, multidisciplinary approach involving all stakeholders and taking into account that our knowledge of climate change impacts is limited but evolving rapidly. A step-by-step approach should be taken to be most effective.

We suggest:

1. Involving stakeholders in the process of identifying vulnerabilities and developing adaptation strategies.
2. Performing detailed analyses of sensitivities and risks.
3. Identifying and implementing adaptation strategies.
4. Implementing monitoring to determine the extent to which climate components have been incorporated into management decisions and the actual environmental impact of climate change and adaptation projects.

The Milwaukee Working Group does not yet recommend any specific adaptation strategies; however; we include below some examples of adaptation strategies that other major metropolitan cities have identified.

Stormwater/flooding
- Conduct public education on water usage, rain barrels and rain gardens.
- Examine capacity of sewers and/or pursue alternative operational procedures for wastewater treatment plants.
- Apply stormwater best management practices: stormwater retention, green infrastructure practices such as permeable pavement, rain gardens and buffer strips.

Air Quality
- Increase tree canopy.
- Increase transportation alternatives.
- Increase use of cogeneration for power production.
- Decrease use of carbon fuels.

Public Health
- Improve warning system for extreme weather events and air quality advisories.

- Conduct public education on climate-related health threats to urban areas.

Built Environment

- Improve energy efficiency of buildings and homes.
- Apply green infrastructure: green roofs and high-albedo surfaces
- Ensure buildings, roads, and bridges can withstand extreme weather events.

MILWAUKEE WORKING GROUP ASSESSMENT REPORT

The Milwaukee Working Group started in February 2008 to foster a multidisciplinary approach to address the impacts that climate change will have on the most urbanized area in the state of Wisconsin and Lake Michigan. The goals of this working group are to (1) organize a critical mass of researchers, professionals, and policy makers that span a wide range of disciplines (e.g., water resources, hydrology, public health, engineering, urban planning, economics); (2) explore the impact of recent climate changes on the urban environment and relevant infrastructure; (3) detail how future climate change is likely to influence the Milwaukee urban environment; and (4) formulate recommendations for adaptive management strategies.

Participants of the Milwaukee Working Group

- Sandra McLellan, UWM Great Lakes WATER Institute (Co-Chair)
- Sharon Gayan, Wisconsin Department of Natural Resources (Co-Chair)
- Beth Sauer, UWM Great Lakes WATER Institute
- Jerry Medinger, Wisconsin Department of Natural Resources
- Peter McMullen, Wisconsin Department of Natural Resources
- Mike Hahn, Southeastern Wisconsin Regional Planning Commission
- Joe Boxhorn, Southeastern Wisconsin Regional Planning Commission
- Mike Martin, Milwaukee Metropolitan Sewerage District
- Chris Magruder, Milwaukee Metropolitan Sewerage District
- Nancy Frank, UWM School of Architecture and Urban Planning
- Hector Bravo, UWM College of Engineering and Applied Sciences
- George Stone, Milwaukee Area Technical College

DESCRIPTION OF REGION

Climate change is expected to have certain, but unforeseen, consequences on the urban environment. Only recently have we begun to perform comprehensive assessments of climate change impacts on metropolitan areas in the US. Potential impacts range from effects on urban natural landscapes and green spaces, to implications for energy demands, water supplies, air quality, public health, as well as economic losses. Dense urban populations and the complexity of the infrastructure systems magnify the potential negative consequences of climate change.

Metropolitan Milwaukee is the most urbanized area within the state of Wisconsin, and faces unique challenges as an urban environment due to its close proximately to Lake Michigan. The meaning of Milwaukee is, appropriately, the “gathering place of the waters” since it is situated at the confluence of three major tributaries, the Milwaukee, Menomonee, and Kinnickinnic Rivers. The three rivers converge and drain to Lake Michigan through the Milwaukee harbor. The Milwaukee River Basin encompasses these three watersheds with nearly 850 square miles of mixed land use including suburban and heavily urbanized areas (**Figure 1**). Nearshore Lake Michigan, around Milwaukee, is considered an urban coast and is heavily impacted by runoff.

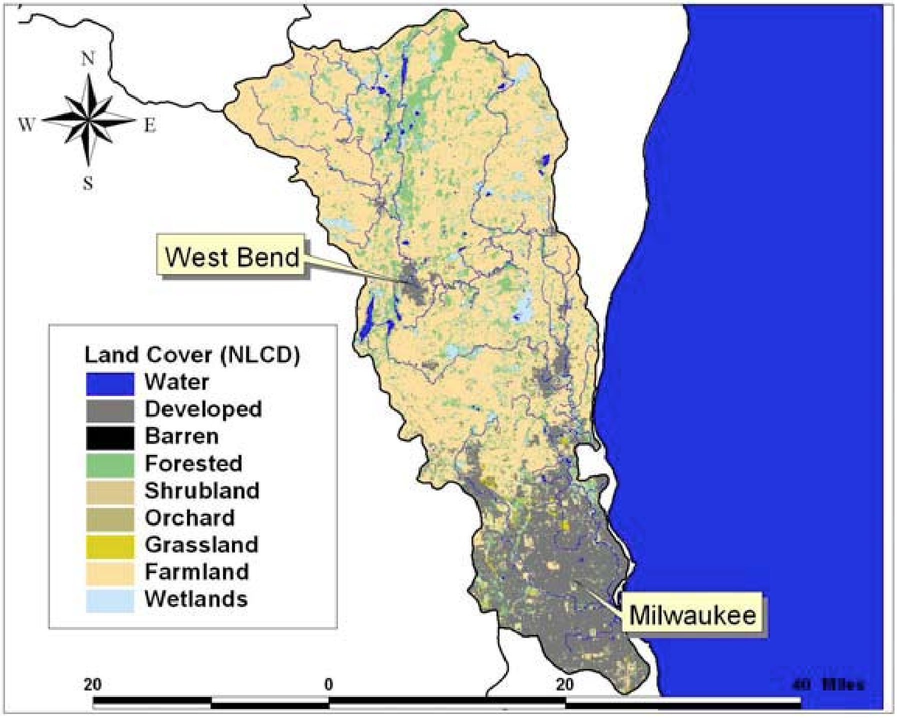

Figure 1. Milwaukee River Basin and nearshore Lake Michigan. The Milwaukee Working Group has focused on the developed areas of the watershed. Urban areas such as Milwaukee have large impacts on nearshore waters of the Great Lakes because of the pollutant loads delivered from urban land use following rain events.

Milwaukee has dense areas of impermeable surfaces such as streets and parking lots, which can make it especially vulnerable to extreme precipitation events and can amplify heat waves (urban heat island effect) due to the ability of the region to cool effectively during nighttime hours. Air and water quality are currently issues of concern in the Milwaukee urban area, and deteriorated quality in these areas may be further exacerbated by changing climate. Milwaukee is a key economic driver in the state, and businesses could be adversely affected by increased energy costs, stricter regulations, or costs associated with extreme weather events. Foresight in planning could minimize some of these impacts. The interconnections among urban natural resources (e.g., air, water, green space, trees), public health, engineered systems and structures (e.g., roads, buildings, water supply, wastewater treatment), and economic and social aspects pose several challenges in terms of identifying potential impacts and crafting adaptive management strategies that will minimize negative consequences.

FUTURE CLIMATE IMPACTS

The latest IPCC (2007) projections for mean summer temperatures suggest that temperature may potentially increase by 4ºC by the end of this century. The outlook for changes in precipitation is less certain. Climate predictions specific for Wisconsin and the Great Lakes Region continue to be developed; however, they are not expected to provide definitive projections. Because of this, a range of climate change scenarios may need to be considered. In general, downscaled model projections using a mid-range anticipated increase in greenhouse gases suggest changes in both temperature and precipitation for the Milwaukee area (Vimont, 2009). In general, temperature is expected to increase, with warmer winters (4ºC above average) and warmer summers (3.5ºC above average). The frequency of summer days with daily maximum temperatures above 90ºF is expected to increase in future years. Both nighttime minimum temperatures and daily humidity levels are expected to continue to increase. These factors contribute to an expectation that the summer "heat index" will increase. This has consequences for both public health and energy consumption and may be exacerbated in urban areas like Milwaukee due to the "heat island" effect.

Regional downscaling of global climate models has generated predictions for southeastern Wisconsin. Using the A1B emission scenario (e.g. mid-range anticipated increased in greenhouse gases), precipitation patterns show increases in large rain events. Rain events of greater than 1 inch in a 24 hour period are expected to increase by seven events per decade, and rain events greater than 2 inches are expected to increase by three per decade (Figure 2). The seasonal precipitation totals for winter, spring, and autumn precipitation are expected to increase whereas summer precipitation is expected to decrease. Changes in the distribution of rainfall may result in an increase in the frequency of intense storms that deliver high amounts of precipitation over short periods of time. This would increase the risk of excessive surface runoff. In older cities such as Milwaukee, combined sewers can become inundated with large rainfall volumes and overflow. Overflows release untreated sewage and stormwater into local rivers and subsequently, Lake Michigan.

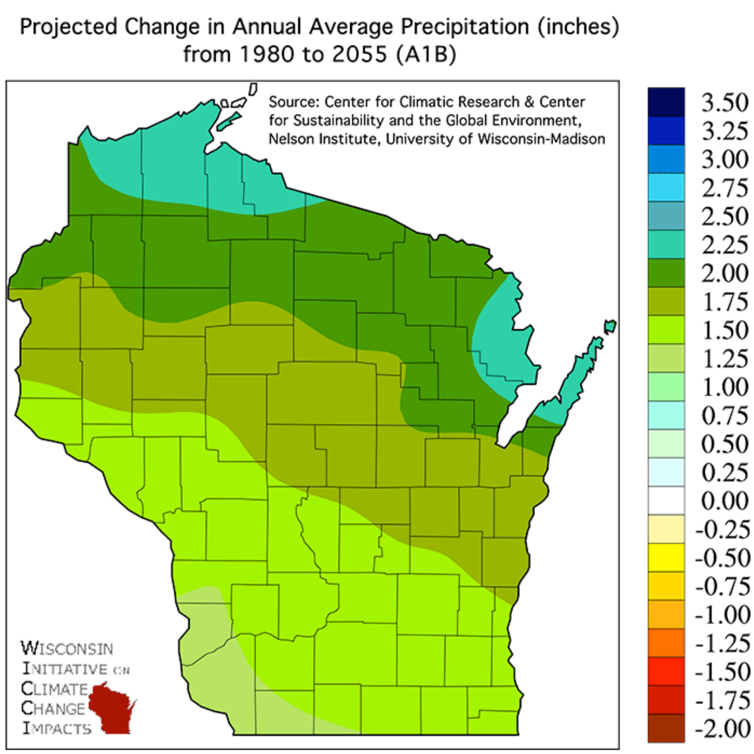

Figure 2. Change in average annual rainfall across Wisconsin by mid-century (we want to exchange this with extreme events, but the map was not available on the web site).

VULNERABILITY ASSESSMENTS

Climate change is expected to exert negative consequences and produce unquantified costs on the environment (including air, water, land, wildlife and general ecology) and to public health (as related to the quality of air, water, soil, food, and natural areas). The urban environment has vulnerable resources, infrastructure, and populations. Assessment of climate changes impacts will allow us to begin to estimate the potential costs and weigh the benefits of investment in adaptation strategies. Further, identification of vulnerabilities may also allow us to identify no or low cost strategies to adapt to future climate stressors.

The Milwaukee working group identified three broad areas that were potentially vulnerable to climate change impacts. These are considered high priority for vulnerability assessments and formulation of adaptive strategies. These areas include water resources, public health and the built environment.

A. Water Resources

Metropolitan Milwaukee contains a variety of water resources systems. These systems are potentially vulnerable to damages from the changes in hydrologic conditions that would result from the anticipated effects of climate change. Some of these damages are likely to impair the ability of current and future uses to utilize these resources. Examples of specific potential impacts that may result from climate change-related hydrological changes include adverse effects on the quality of surface waters, increases in localized flooding, increases in polluted stormwater, higher costs related to treating and discharging additional wastewater, health related risks to reduced drinking water quality, and changes in the amount and quality of groundwater recharge. It is likely that changes in the timing and quantity of precipitation will increase the stresses on both existing water resources systems and current and future users in urbanized watersheds.

Recent experiences with increased rainfall intensity and extreme flooding in the Milwaukee watersheds have profound implications for how we manage these systems, both now and in the future. The baselines used for determining minimum water levels and flows, ordinary high water marks, flood frequency curves and floodplain mapping have changed due to changes in the timing and quantity of precipitation. The Milwaukee working group will propose additional studies to determine appropriate changes to flow frequency models to account for future changes and will update existing predictive models used for surface waters (temperatures, flows and water levels) as they relate to the Greater Milwaukee area.[1,2] An important element to consider for identifying additional studies is the management of water as an integrated resource. Such studies will need to focus on the variability of both climate and these systems and to consider the uncertainties inherent in current climate change projections. Future studies should also

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[1] The Coastal Working Group is considering other aspects of water resource vulnerabilities such as impacts on shipping.

[2] The Water Resource Working Group is addressing a broad range of impacts on water resources statewide.

weigh the costs and benefits of various mitigation and adaptation strategies to ecosystem services, such as water quality, drinking water quantity and quality, flood mitigation, and habitat for aquatic species, and evaluate potential unintended consequences of mitigation and adaptation.

A.1 Stormwater and Flooding

Rainfall generates stormwater runoff that carries with it pollutant loads and debris washed from impervious surfaces (Figure 3). In extreme cases, rainfall amounts can exceed stormwater system capacity in urban areas, leading to flooding. Volumes and rates of runoff to stormwater management systems and receiving streams are influenced by a number of factors, including the amount, timing, frequency, and intensity of precipitation; interception of precipitation by the overlying plant canopy; amounts of pervious and impervious land surfaces; infiltration capacities of pervious surfaces; land surface slopes; natural and constructed runoff storage and/or infiltration facilities; evapotranspiration of water from the ground surface and soil; and soil moisture storage capacity. The amount, timing, frequency, and intensity of precipitation are the most significant factors that are likely to be affected by climate change. Secondary, but important, factors potentially affected by climate change are changes in temperature and humidity that may alter the levels of evapotranspiration.

Figure 3. Debris from stormwater and flooding in Honey Creek inlet following torrential rains in June 2008. (Photo provided by the Milwaukee Metropolitan Sewerage District)

Stormwater management systems may include components designed 1) for water pollution abatement and control of smaller storms (e.g., storms with average annual occurrence probabilities of 50 percent or greater); 2) to adequately infiltrate, store, and convey runoff during mid-range storms with annual probabilities of occurrence of 10 percent or more; and 3) to adequately store and/or convey runoff during large storms with annual probabilities of occurrence of up to 1 percent or less. Flood mitigation planning and facilities are generally focused on storms, or more appropriately flood events,[3] with annual probabilities of occurrence of 1 percent or less.

Projections developed by the WICCI Climate Change Working Group indicate that, in Southeastern Wisconsin, the number of storms with daily rainfall totals of two inches or more could increase in frequency from the current 12 storms per decade to 14 to 15 storms per decade under currently predicted climate change conditions. Increases in the frequency of larger storms could have the effect of shifting rainfall frequency relationships to some limited degree, resulting in future storms having larger depths for a given probability of occurrence. Depending on the magnitudes of the rainfall events there may be greater flood damages and a need for more costly, larger stormwater management and flood mitigation facilities and/or programs. However, the predicted increases in 2" storm frequencies are modest and uncertain as well but become important considerations when designing a storm management and flood mitigation facility that has a life span of more than 20 years.

The availability of downscaled precipitation data enables the planning and design of stormwater management and flood mitigations facilities and programs to consider the possible future effects of climate change in two ways. First, to compare predictions with existing research on current rainfall-frequency-duration relationships and secondly, directly apply downscaled meteorological data within watershed hydrology models developed for the Milwaukee Metropolitan area by the Southeastern Wisconsin Regional Planning Commission and the Milwaukee Metropolitan Sewerage District (MMSD).[4]

Examples of specific projects or programs that could be affected by climate change, and for which climate change effects based on application of downscaled meteorological data could be considered, include:

[3] *Because the amount and timing of runoff during a storm event is dependent on the volume and time distribution of precipitation and on the antecedent soil moisture conditions, there is not a direct relationship between the probability of occurrence of a given storm and the probability of occurrence of the resulting flow.*

[4] *The WICCI Stormwater Working Group web page provides additional background on general state-wide vulnerability issues and data needs. The Stormwater Group has also prepared an Assessment Report addressing stormwater in depth.*

- Design of flood mitigation projects, such as those undertaken by municipalities and MMSD.[5] Urban flooding is largely controlled by summer storms, and hence may not be much affected by climate change. However, the downscaled data are fairly consistent in predicting increases in winter-spring precipitation and in the portion that is rainfall. This suggests potential increases in the magnitude of floods in large watersheds, such as the Milwaukee River Watershed.
- Future revision of the State of Wisconsin stormwater management performance standards set forth in Chapter NR 151 of the *Wisconsin Administrative Code.* The potentially-affected standards include those related to infiltration of stormwater, control of total suspended solids in runoff from construction sites and existing and new development or redevelopment, and control of the peak rate of runoff from a 24-hour, two-year recurrence interval storm. Such possible revisions would affect the conditions in State of Wisconsin Pollutant Discharge Elimination System permits issued for municipal separate storm sewer systems.

A.2 Groundwater

Groundwater recharge is influenced by a number of factors, including the amount, timing, frequency, and intensity of precipitation; interception of precipitation by the overlying plant canopy; evapotranspiration of water from the ground surface and soil; and soil moisture storage capacity. Climate change may alter the amount of groundwater recharge through at least two pathways: First, changes in the amount, timing, frequency, and intensity of precipitation may alter the amounts of water able to infiltrate into soils through altering the amount of water available for recharge relative to the soil's ability to accept it. Second, changes in temperature and humidity may alter the levels of evapotranspiration. The impacts of climate change upon groundwater recharge will be the result of interactions between these two pathways.

The changes in groundwater quantity resulting from climate-change-related changes in recharge may have a variety of effects upon the human and natural environment. Climate-change-related changes in groundwater quantity may positively or negatively alter 1) the availability of groundwater for use as a source of water supply, and 2) the discharge of groundwater to surface water bodies, potentially resulting in alterations to the quality of habitat available to fish and other aquatic organisms. This may complicate ongoing management and restoration efforts.

The impacts of climate change upon the groundwater system could be estimated using downscaled climate data in existing regional groundwater flow and recharge models developed by the U.S. Geological Survey and the Wisconsin Geological and Natural History Survey as part of the Southeastern Wisconsin Regional Planning Commission's

[5] *Examples of such projects include the proposed MMSD Kinnickinnic River and Wilson Park Creek flood mitigation projects and ongoing Menomonee River flood mitigation and stream rehabilitation/fish passage projects. These projects are in various stages of planning, preliminary engineering, or design, and, depending on implementation schedules, there may be opportunities to refine the project components to reflect hydrologic conditions determined from application of downscaled climate change information.*

water supply planning program. For example, researchers at the Wisconsin Geological and Natural History Survey recently estimated existing groundwater recharge rates for Southeastern Wisconsin using a soil water balance model (SEWRPC, 2008). The results of such an estimate of the impacts of climate change upon groundwater recharge could be used as a first step in designing adaptation strategies.

A.3 Drinking water

The greater Milwaukee area is served primarily by water utilities that utilize Lake Michigan as the source of water supply. In addition, some suburban communities are served by municipal wells, numerous residential developments are served by small well systems, and numerous residences are served by private wells located on these properties. Within Milwaukee County, there are fourteen municipal water utilities. All of these utilities rely on Lake Michigan as their source of supply, either directly or indirectly through wholesale or resale purchase. Five municipal water utilities operate and maintain a total of six Lake Michigan surface water treatment facilities in Milwaukee County. Of the six water treatment plants in the county, one has a conventional treatment process and the others have enhanced disinfection (two use ozone and two use ultraviolet radiation). Climate change impacts could alter the treatability of Lake Michigan water positively or negatively.

At the intakes themselves, lake level has an important effect on pumping requirements, formation of frazzle ice in winter, and the potential for invasive species to impact both water quality and water utility infrastructure. Characteristics of influent water that could impact treatability include water temperature, biological and chemical contaminant types and loads, and amounts and sizes of suspended materials requiring physical removal. Water temperature at the intakes is driven by seasonal change and seiches. 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 in influent water characteristics could complicate treatment and possibly necessitate infrastructure improvements to treatment processes, especially if these changes occur sporadically.

Stressors to the water distribution system could include increased number of freeze-thaw cycles that may cause higher numbers of water main breaks and greater incidences of leaks which could lead to increases in unaccounted for water. Changing water-use patterns within the larger area due to climate change could expand the demand for lake water as a source of potable water, which could then impact decisions related to expanding or replacing infrastructure.

A.4 Wastewater treatment plant infrastructure

Climate change poses potential risks to wastewater treatment agencies in Wisconsin. There is an emerging body of work that is beginning to identify risks and vulnerabilities of climate change as they pertain to wastewater treatment. The Water Environment Research Foundation (WERF) identified four causative influences that may impact wastewater treatment: more intense rainfall events, warmer and shorter winters, warmer and drier summers, and sea level rise (WERF, 2009). The system owned and operated by the MMSD and their contributing satellite communities consists of over 3000 miles of sanitary and combined sewers, two water reclamation facilities, and the MMSD's 521 million gallon Inline Storage System.

The Milwaukee Working group has mainly focused on more intense rainfall events and warmer drier summers as causative influences. These hold the potential to have the most impacts to both MMSD and the general population. More intense rainfall events could result in increased frequency, size, and duration of combined and sanitary sewer overflows, and increased risk of basement backups. In addition, these events could result in physical damage to treatment facilities, short-term loss of treatment capacity, and increased need for inspection and maintenance. Finally, the potential exists for increased risk of losing the biologic mass at water reclamation facilities, which can result in short- and long-term discharge permit compliance concerns (Figure 4).

Warmer and drier summers can result in reduced flows. This could lead to septic conditions and odors, increased sewer pipe corrosion, and an increased risk of sewer blockages (due to stimulated plant growth and material deposition). Varying dry weather followed by extreme precipitation events also pose operational issues for both wastewater collection and treatment systems. These manifest themselves in terms of highly variable wastewater strength and plant loadings, and ultimately to challenges in maintaining discharge permit compliance.

MMSD, SEWRPC, and GLWI are planning to specifically study the impact of increased precipitation on combined and sanitary sewer overflows. This is a high priority since sewage overflows pose a serious health risk due to the introduction of pathogens in to the environment. Combined sewer overflows (CSOs) occur when the conveyance system exceeds capacity during periods of heavy rain. Sanitary sewer overflows also may overflow during time of heavy rainfall, resulting in a sanitary sewer overflow (SSO). With projections of increased intensity and frequency of high intensity events, particularly in spring when sewage overflows occur, these alterations in storm patterns could potentially increase the number of sewage overflows despite capital improvements or implementation of management strategies directed at reducing sewage overflows.

This project will specifically examine the stress altered precipitation may have on sewer infrastructure. In the past five years, SEWRPC and MMSD conducted an extensive effort to perform facility planning for sewage treatment through the year 2020 and update the *Regional Water Quality Management Plan* (SEWPRC 2007). This effort included modeling of MMSD conveyance system to evaluate the frequency of CSOs and SSOs and creation of a watershed model to assess pollution sources throughout Milwaukee's watersheds. <u>Importantly, the models used in facility planning relied on current climate conditions</u>. The project will rely upon the same model of the conveyance system used for estimating CSOs and SSOs, but utilize downscaled climate projections generated by the WICCI Climate Working Group. The range of climate projections produced by the various global climate models (GCMs) generates numerous scenarios and there is uncertainty associated the projected increased in the magnitude and frequencies of large rain events; the exception to this is for projected increases in winter/spring rainfall. Therefore, climate projections from two models were chosen that cover a range of projected spring rainfall, e.g. model in the 80th percentile for projected increase and model in the 20th percentile for projected increase.

Figure 4. Jones Island wastewater treatment plant biological treatment aeration beds. High volumes at the plant following storm events may cause these reactors to washout, which would diminish treatment capabilities. Facility designs may need to consider additional capacity if climate changes alters storm patterns.

B. Public Health

A recent report by the National Institute of Environmental Health Sciences identified eleven categories of health effects that are potentially impacted by climate change (Environmental Health Perspectives and the National Institute of Environmental Health Sciences, 2010). Three of these categories are particularly relevant to the urban environment and include (1) asthma, respiratory allergies, and airway diseases; (2) waterborne diseases; and (3) heat related morbidity and mortality. The environmental consequences of climate change include effects on air quality and water resources, which are the primary determinates in pulmonary reactions and waterborne diseases, and may be more pronounced in heavily developed areas. Urban centers such as Milwaukee have high population densities, with sectors of the population especially susceptible to health impacts including the elderly, children, and those with chronic health problems

B.1 Air Quality

Wisconsin (including Milwaukee) currently has areas where the National Ambient Air Quality Standards are not met for either ozone and/or particle pollution. Ozone occurs naturally in the earth's upper atmosphere and shields the Earth's surface from ultraviolet rays from the sun. At ground level, ozone is a harmful pollutant which forms when emissions from automobiles and stationary sources are exposed to heat and sunlight. Particulate pollution (also known as fine particles, particulate matter, or PM) consists of a complex mixture of miniscule solid particles and liquid droplets that are suspended in the air. These particles and droplets come from a variety of sources. Ozone and fine particles can cause a wide range of health effects, particularly for members of sensitive groups, such as active children, active adults, the elderly, and people with existing illnesses, such as asthma, chronic obstructive pulmonary disease (COPD), and heart disease.

Some of the health effects associated with exposure to ozone and fine particles include:

- Increased irritation of respiratory systems,
- Decreased lung function,
- Aggravated asthma,
- Increased susceptibility to respiratory infections that can lead to permanent lung damage,
- Causation or aggravation of chronic lung diseases such as emphysema and bronchitis,
- Reduced ability of the immune system to fight off bacterial infections,
- Causation of irregular heartbeat leading to nonfatal heart attacks, and
- Premature death in people with heart or lung disease.

According to the Wisconsin Department of Health Services, the prevalence of asthma in Wisconsin reached 13% for both adults and children in 2005. For adults, asthma is more prevalent among African-Americans, members of low income households, and women. For children, asthma is more prevalent among African-Americans and boys. From 2003-2005, Milwaukee County had the highest rate of emergency department visits (96.3 per 10,000) in Wisconsin and the second highest rate of hospitalizations for asthma (20.9 per 10,000). Outdoor air pollution, such as nitrogen dioxide, ozone, and fine particles are among asthma related triggers. Major sources of these pollutants include power plants and motor vehicles.

An air quality vulnerability assessment of a large urban center such as the Milwaukee area should draw upon the examination of Wisconsin climate change trends, climate forecasts, and assessment of air quality data to evaluate the potential impacts on public health. Assessment and mitigation of air quality impacts is complex, especially in the realm of the totality of greenhouse gases and other criteria pollutants. The vulnerability of large population groups, or subgroups, may be dependent upon the extent of climate change impacts and other human health factors.

Wisconsin has made progress in reducing both ozone levels and frequency of episodes during the summer (ozone) season; however, there are currently concerns about particulate matter, which can reach unhealthy levels at any time of the year. Fine particles can penetrate deeply into the lungs and are linked to a variety of health concerns. Fine particles are also a main component of visible haze or air impairment that cloud over the urban area. Warmer winters coupled with increased water vapor in the air may result in increased concentrations of fine particles. In addition, the recent improvements of ozone levels in Wisconsin may be reversed if increases in summer temperatures or in the incidence of extreme heat events were to occur since heat is a contributing factor in the production of ground-level ozone.

B.2. Waterborne Disease

Previous research has estimated that up to 12% of cases of gastroenteritis in the United States may be due to waterborne disease, with up to 19 million attributable cases annually (Colford et al., 2006; Messner et al., 2006; Reynolds et al., 2008). Drinking water and recreational water exposures are the primary routes of exposure. People may become ill following exposure to pathogens, which can include certain bacteria, viruses, and protozoa. Contamination of water may occur in a variety of ways including stormwater runoff or contamination of wells or distribution pipes in areas of aging infrastructure; and sewage release into waterways in the form of combined or sanitary sewer overflows or sewage blending (Redman et al., 2008; Reynolds et al., 2008). Any of these can introduce human pathogens into ground or surface water sources, with potential health risks (Abbaszagedan et al., 2003; Borchardt et al., 2004; Patz et al., 2008).

Research is being conducted by the Wisconsin Department of Health Services in collaboration with UW-Madison, UW-Milwaukee, Children's Hospital of Wisconsin, and the United States Geological Survey to identify what can be considered "high risk" rain events. The Menomonee River watershed in Milwaukee is being used as a case study to determine the correlation between viruses and climate parameters, including rainfall and temperature. Understanding the pathogen burden associated with certain precipitation patterns will allow for more reliable predictions of waterborne pathogen burdens and risk assessment activities that consider climate change.

B.3 Extreme Heat and Cold

Extremes of heat and cold are two of the most underrated, least understood, and deadly of all natural hazard events that affect urban areas. In contrast to the visible, destructive, and violent characteristics associated with events such as floods and tornadoes, deaths caused by extreme high and low temperatures occur quietly, without headline-making destruction. In particular, the combination of high temperatures and high humidity can create the potential for severe threats to human health. This is because high humidity slows the evaporation of perspiration, which is the body's major cooling process.

Most heat-related deaths occur in cities. Large urban areas become "heat islands." Brick buildings, asphalt streets, and tar roofs store and radiate heat like a slow burning furnace. Heat builds up in a city during the day and cities are slower than rural areas to cool down at night. The worst heat disasters, in terms of loss of human life, happen in large cities when a combination of high daytime temperatures, high humidity, warm nighttime temperatures, and an abundance of sunshine occurs for a period of several days. In addition, socioeconomic factors can place some urban populations at greater risk. The elderly, the disabled, and the debilitated are especially susceptible to heat-related illness and death.

Southeastern Wisconsin generally experiences more heat advisory days than other parts of the State (Figure 5). According to the National Climatic Data Center, Milwaukee County experienced 50 heat-related deaths during the years 1982 through 2008. These numbers are likely to be underestimates due to inconsistent reporting procedures and due to their including only those fatalities in which temperature was the primary cause of death.

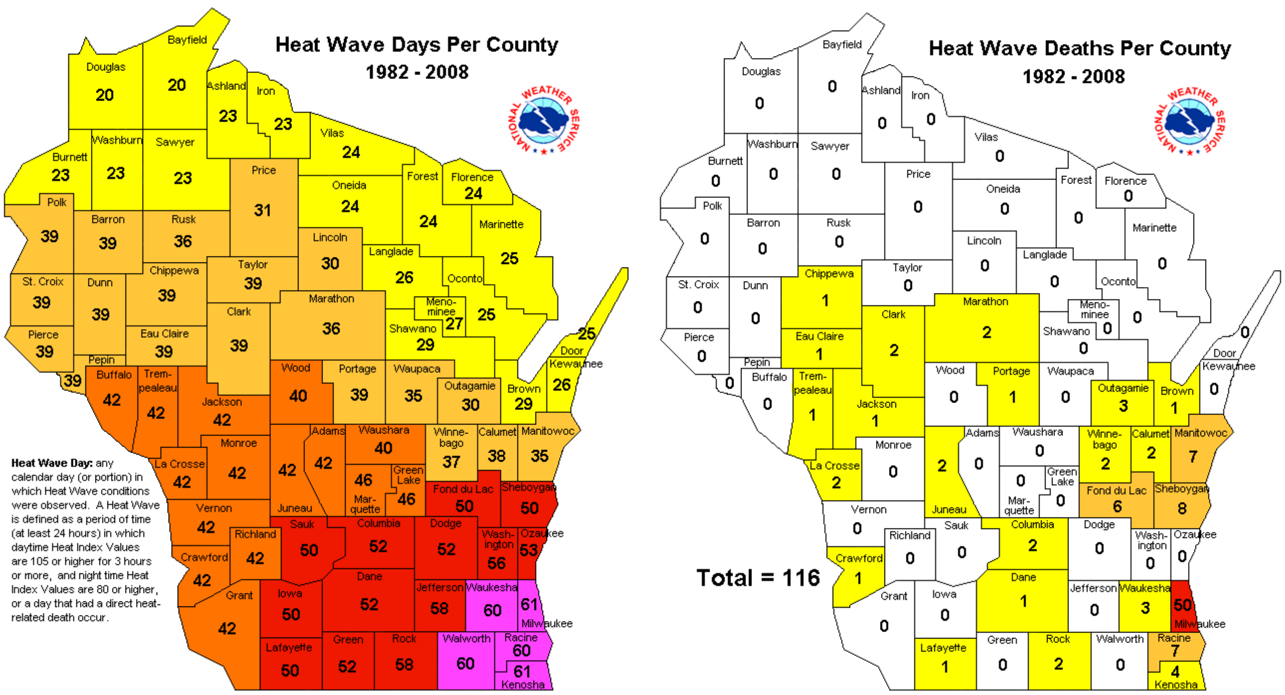

Figure 5. (A) Number of heat advisory days (B) Number of heat related deaths in Wisconsin according to County in 1982-2008. Milwaukee County has a disproportionate number of heat related deaths due to dense population centers. (Source: National Weather Service)

Projected changes in climate may exacerbate problems with heat-related incidents. Current projections include increases in the frequency of days with daily maximum temperatures above 90ºF, increases in average nighttime minimum temperatures, and increase in daily humidity levels. These changes have the potential to cause an increase in the incidence of heat-related injuries and fatalities, especially in highly urbanized areas such as Milwaukee.

As part of activities of the Milwaukee Heat Task Force, the City of Milwaukee Health Department, in cooperation with the Milwaukee County Department on Aging, the Milwaukee County Emergency Management Bureau, and other local agencies and organizations has prepared a plan for excessive heat conditions (City of Milwaukee Health Department, 2009). Under this plan, the issuance of a heat advisory by the

National Weather Service triggers a number of activities, including active surveillance of heat injuries, 24-hour response to heat-related calls, and opening of special congregate cooling sites. Among the potential impacts of the projected changes in climate described above is the likelihood that this program will need to be used more often than it currently is. In addition, it is possible that more resources may be required for this sort of program.

C. Built Environment

The potential impacts of climate change on the built environment are not well established. The Milwaukee WICCI identified a number of structural and materials issues that may require further study, including increased stress to concrete affecting roads, bridges, and buildings, and stress to asphalt roads because of changes in the freeze/thaw cycle.

The American Society for Testing and Materials (ASTM) has established standards for road concrete durability. The standard for highway concrete is that it needs to be durable through 300 freeze/thaw cycles. If downscaled climate data can project the change in freeze/thaw cycles, one could calculate the likely change in the useful life of concrete. An adaptation strategy would be to use new concrete formulations that are more durable through the freeze/thaw cycle because they do not absorb water.

Green infrastructure offers the opportunity for both mitigation and adaptation through reduced energy consumption and deductions in stormwater impacts. Examples include tree planting and rain garden installations. Stormwater trees slow the speed of rainfall, and tree roots appear to provide a conduit which allows rain to percolate through the soil more easily. Trees can also mitigate heat island effects and provide substantial carbon sequestration opportunities, moving carbon into soils and tree tissues. Rain garden installations can also help to reduce stormwater flows. Prairie plants have deep roots that allow rain to seep into the soil. Studies have shown that this can be especially useful during midwinter thaw and early spring thaw, when the ground remains frozen. Prairie plants have also been identified for potential carbon sequestration opportunities.

SENSITIVITY ANALYSIS AND UNCERTAINTIES

The Milwaukee Working group has identified areas that may be sensitive to climate change. Detailed analysis of the level of sensitivity and the projected outcomes need to be identified to aid in development of adaptation strategies. Climate predictions have a degree of uncertainty, which may be different for different parameters. The fact that there is uncertainty needs to be considered, but should not prevent action steps toward adaptation, particularly if it is in a highly vulnerable area, or if there is the potential for large human health impacts or economic losses. The approach used by the Milwaukee working group is to identify the climate parameters that have the largest effect on the area being examined (wastewater conveyance, flooding, air quality) and evaluate a range of climate projections for that parameter. This approach is being taken in a sensitivity analysis of the MMSD conveyance system (see section A.4). Table 1 lists analyses identified by the Milwaukee Working Group as high priority.

Table 1. High Priority Analyses Identified by the Milwaukee Working Group.

Sensitivity	Analysis
CSO/SSO frequency	Number and volume of CSO/SSOs under projected climate scenarios
Flooding	Acreage of land flooded under different climate scenarios
Water Quality	Impact of stormwater and CSO/SSOs
Concrete	Change in number of freeze/thaw cycles per year and change in requirements to meet ASTM standards
Groundwater	Change in recharge volumes and stream baseflow
Economics	Cost of sizing facilities
Air Quality	Consequences of heat, cloud cover, humidity

ADAPTATION STRATEGIES

Milwaukee is already implementing key programs, investments, and practices that will contribute to adaptation and mitigation of climate change:

- In 2008, Milwaukee was selected to be one of the 25 US Solar America Cities by the US Dept. of Energy. In 2009, Milwaukee was awarded an additional $660,000 to continue to promote the use of sustainable solar energy.
- To either mitigate or adapt to greenhouse gases and climate change, the Milwaukee Metropolitan Sewerage District (MMSD):
    - Is in the process of implementing a project that will allow the District to utilize landfill gas in lieu of natural gas at the Jones Island Water Reclamation Facility. This will result in reducing CO_2 emissions by 70,000 metric tons annually.
    - Plans to fund $5 million in stormwater best management practices for the years 2010-2014
    - Since 2002, as part of the Greenseams program, has acquired over 2000 acres of naturalized land along waterways to prevent flooding.
    - Has budgeted $5 million to construct green roofs throughout the region.
- In 2008, the City of Milwaukee launched a “Recycle for Good” campaign for recycling and has won $35,000 from the US Conference for Mayors Cans for Cash recycling program six years in a row.
- Wisconsin DNR Green Tier Program encourages businesses to pursue advanced environmental practices through reduced emissions, waste, etc. Companies in the

- Sustainable Boulevards was adopted in 2007 to increase tree canopy and reduce the amount of resources needed to sustain the landscaping.
- In 2010, the City of Milwaukee proposes to spend $5.8 million on increasing energy efficiency through residential programs, installing LED street lights, and upgrading city buildings.
- The City of Milwaukee has developed a Comprehensive Transit Strategy and is researching alternatives for mass transit such as street cars, commuter rail, and high speed rail.
- Governmental units and transit agencies have received a variety of Congestion Mitigation and Air Quality grants administered by the Wisconsin Department of Transportation. The grant program is aimed at projects that reduce the number of vehicle miles travelled, reduce emissions by improving traffic congestion, and improved vehicle and fuel technologies.
- The MMSD, SEWRPC, and GLWI are cooperatively studying the impact of modeled increased precipitation on the frequency of combined and sanitary sewer overflows and water quality on the Milwaukee region's water resources.

Recommended actions for developing adaptation strategies

Developing adaptation strategies in response to climate change requires a comprehensive multidisciplinary approach, involving all stakeholders and taking into account that the knowledge we have on climate change impacts is limited but evolving rapidly. A step by step approach should be taken to be most effective.

1. Involve Stakeholders: Water resource planners and city planners should be involved in the process of identifying vulnerabilities and developing adaptation strategies to increase their knowledge and awareness of climate change and how to protect urban areas from negative impacts. The collaboration between planners and WICCI working groups will strengthen the planners' commitment to considering and incorporating a climate component into management decisions. Several members of the Milwaukee Working Group are involved with urban planning, water and air resource management, and water infrastructure planning. These Working Group members are important conduits for information dissemination back to their respective agencies. Further, several members participate on other working groups (Public Health, Stormwater, and Water Resource Working groups), which provides a cohesive approach to assessing sensitivities and formulation adaptation strategies. Members of the Milwaukee Working Group are also on various committees within the Southeastern Wisconsin Watersheds Trust partnership, which is guiding management and policy within the urban watersheds. The Milwaukee Working Group is actively recruiting members from the city and government agencies to expand the focus of the working group to include energy, economics, and other areas.

2. Perform Detailed Analyses of Sensitivities and Risks: Climate data, trends, and literature should be reviewed to develop a comprehensive risk assessment. The risk assessment would identify high priority vulnerabilities (risks) based on the likelihood that the risk would occur, as well as impacts to public health, environmental health, and the economy. These assessments need to take into account the inherent uncertainties associated with climate projections in general. Prioritizing vulnerabilities is essential in order to allocate funding and develop adaptation and monitoring plans. The Milwaukee Working Group is identifying areas of the urban area that may be sensitive to climate change impacts and are actively seeking grant funding to conduct of detailed assessments of potential risks and consequences.

3. Identify and Implement Adaptation Options: The Milwaukee Working Group has identified some examples for Milwaukee in Table 2. The detailed risk assessments will determine what adaptations are most cost effective and provide the largest benefits. Adaptation options that have no additional costs associated with the potential adaptation benefits should be assessed.

4. Implement Monitoring: A comprehensive approach to developing adaptations to climate change will require complementary monitoring targeting several factors related to climate change, the resulting impacts of climate change, and the associated responses. It is desirable that several different factors be monitored. Factors that it would be useful to monitor include environmental variables such as rainfall, stream flow, lake levels, and water quality; potential impacts of climate change such as the incidence and prevalence of temperature- and air quality-related illness and the occurrence of extreme weather events; and the implementation of practices and projects incorporating strategies for adaptation to projected changes in climate. In addition, it would be useful to assess and monitor the extent to which consideration of projected climate change, climate change impacts, and adaptation strategies have been into decision making.

It is important to recognize that efforts are currently underway to monitor some these factors. Considerable effort is being expended to monitor environmental factors, especially those related to streamflow and water quality, in the Milwaukee area. For example, the Milwaukee Metropolitan Sewerage District monitors surface water quality in streams and the nearshore area of Lake Michigan at an extensive set of sampling stations throughout its service area. Through a cooperative program conducted in conjunction with the Southeastern Wisconsin Regional Planning Commission, the Milwaukee Metropolitan Sewerage District, and several county and local units of government, the U.S. Geological Survey maintains a network of streamflow gages throughout the Southeastern Wisconsin Region. In addition, the Great Lakes WATER Institute in partnership with the United States Geological Survey is monitoring fecal indicator bacteria and viruses in the Menomonee and Kinnickinnic Rivers under both wet- and dry-weather conditions. In addition to providing surveillance, these sorts of monitoring efforts will provide the data necessary to characterize the risks associated with specific types of weather events, improve predictions of the nature and magnitudes of potential impacts of climate change, and set benchmarks for the degree of change that would warrant corrective actions or larger investments.

Table 2: Potential Adaptation Options for Milwaukee. Many of these options have been identified by other major metropolitan cities (Toronto Environment Office, 2008).

Vulnerability	Adaptation Options
Stormwater/flooding	• Conduct public education on water usage, rain barrels, and rain gardens. • Expand capacity of sewers and/or pursue alternative operational procedures for WWTP. • Apply best management practices; stormwater retention, permeable pavement, and buffer strips.
Air Quality	• Increase tree canopy. • Increase transportation alternatives. • Increase use of co-generation for power production. • Lower carbon fuels usage.
Public Health	• Improve warning system for extreme weather events and air quality advisories. • Conduct public education on climate related health threats to urban areas.
Built Environment	• Improve energy efficiency of buildings and homes. • Apply green infrastructure; green roofs and high albedo surfaces. • Ensure buildings, roads, and bridges can withstand extreme weather events.

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