Technical Memorandum

4700 Lakehurst Court
Suite 100
Columbus, Ohio 43016

Prepared for: Mid-Ohio Regional Planning Commission

Project Title: Sustaining Scioto

Project No.: 144491

Technical Memorandum No. 4

Subject: Upper Scioto River Watershed, Adaptation Strategies

Date: December 5, 2014

To: David Rutter, Project Manager, Mid-Ohio Regional Planning Commission

From: Lisa Jeffrey, P.E., Technical Expert, Brown and Caldwell
Kristin Knight, P.E., Deputy Project Manager, Brown and Caldwell

Table of Contents

List of Figures

List of Tables

List of Abbreviations

°F	degree(s) Fahrenheit
µg/L	microgram(s) per liter
AQI	Air Quality Index
ASR	aquifer storage and recovery
BMP	best management practice
CSO	combined sewer overflow
DBP	disinfection by-product
FEMA	Federal Emergency Management Agency
GAC	granular activated carbon
GI	green infrastructure
GCM	global climate model
H_2S	hydrogen sulfide
HSTS	home sewage treatment system
HVAC	heating, ventilation, and air conditioning
I/I	infiltration and inflow
LID	low-impact development
LOS	level of service
mgd	million gallon(s) per day
MORPC	Mid-Ohio Regional Planning Commission
ppt	part(s) per trillion
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
OWDA	Ohio Water Development Authority
PWS	public water supply
SOP	standard operating procedure
SSO	sanitary sewer overflow
TM	technical memorandum
TMDL	total maximum daily load
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WHO	World Health Organization
WQ	water quality
WTP	water treatment plant

Executive Summary

There is substantial concern regarding the potential impacts of climate change to resources, utilities, and economies in the Midwest (Melillo, 2014). National studies indicate that the projected increase in rainfall variability, temperature, and extreme weather may increasingly compromise the ability to effectively manage water supplies, critical water supply and treatment infrastructure, and water quality (USEPA, 2012; Wilbank and Fernandez, 2012; NACWA, 2009; Brekke et al., 2011). Ancillary impacts to water utilities may include increased cost of service, reduced customer confidence, and increased difficulty meeting regulatory compliance requirements.

The Mid-Ohio Regional Planning Commission (MORPC), in partnership with the City of Columbus Department of Public Utilities, Del-Co Water Company, Inc., U.S. Geological Survey (USGS), and Ohio Water Development Authority (OWDA), has initiated a study to evaluate the anticipated effects of climate change on water supply in the Upper Scioto River basin. The primary objective of this project is to develop an adaptive management plan for the region to guide future actions to achieve a resilient water supply system.

This project, named "Sustaining Scioto," includes two phases: 1) evaluating the potential risks associated with climate change; and 2) developing adaptive management strategies to reduce these risks. The first phase entails the development of a watershed model by USGS to predict the impacts of climate change on the water resources of the Upper Scioto River basin through 2090. The second phase of the project includes: development of future water use projections; evaluation of water availability; identification of water supply, water quality, and water and wastewater utility risks; and development of strategies to address these risks through an adaptive management plan.

Using the results of the watershed model, future water use projections, and water inventory, the project team, along with the Stakeholder Advisory Committee, identified key vulnerabilities in the region. The potential risks from changes in temperature, precipitation, and stream flow were assessed and prioritized for nine service sectors based on likelihood of occurrence and severity of impact. These nine service sectors are shown in Table ES-1. Adaptation strategies were then developed to address the highest priority risks identified within each of the service sectors with focus on three: Water Supply/Water Quality; Water Treatment; and Wastewater Treatment.

Table ES-1. Nine Service Sectors

Water supply/water quality	Wastewater treatment
Water treatment	Economy
Environment	Energy
Public health	Transportation
Agriculture	

The adaptation strategies are the focus of this document, Technical Memorandum No. 4 (TM4). For the purposes of this TM, adaptation strategies are divided into three timeframes: 1) Short Term, 2015 to 2025; 2) Mid Term, 2026 to 2045; and 3) Long Term, 2046 – 2090. From 2015 to 2025 climate conditions are expected to be similar to today. Between 2025 and 2045 slightly increased temperatures and more variability in precipitation and stream flows are expected. Between 2045 and 2090 higher temperatures and additional variability in precipitation and stream flows are expected. The adaptation strategies presented in this TM will be used to prepare an adaptive management plan for the region that will provide utilities, developers, agriculture, and industry with an understanding of the risks imposed by climate change and adaptation strategies. This plan is being developed in collaboration with the Water Research Foundation (WRF) and will serve as a guide for future investment and planning for water resource management in the region.

Due to the uncertainty associated with Long Term climate change, it is important to employ an adaptive management approach to strategy implementation. Adaptive management is a flexible approach for developing, evaluating, and making decisions. The basic approach to adaptive management includes understanding and prioritizing risks, developing strategies to reduce risks, implementing strategies, and reevaluating strategies as more information becomes available. Adaptive management's flexible and holistic approach makes it valuable in making decisions in an uncertain environment. It proves especially useful in the context of climate change planning because it is an iterative process. The strategy is periodically modified based on monitoring results and updated climate change projections. New strategies are developed and implemented based on new information and the iterative process continues.

The first step in developing an adaptive management plan is the evaluation of the predicted regional climate changes and corresponding risks. The USGS watershed modeling results predict temperature, precipitation, and stream flow changes in the region due to climate change. TM1, Upper Scioto River Watershed Water Use Projections, includes future water demand projections for the region. TM2, Upper Scioto River Watershed Water Inventory, includes an assessment of future water availability in the region.

ES.1 Prioritization of Climate Change Risks

The next step in developing an adaptive management plan is the identification and prioritization of risks that arise from these changing conditions which may impact the livability of the region. The potential risks were identified and prioritized in TM3, Sustaining Scioto Vulnerability Assessment.

The highest priority risks were defined through an evaluation of their likelihood of occurrence and impact on the region for each service sector. The risks that were highly likely to occur were linked to distinct and consistent trends from the model results and climate data. Examples include those caused by increases in temperature, more extreme variability in precipitation, and decreases in minimum stream flow or reservoir water levels as observed in the model results. These risks were assigned a score of "High". The risks that were moderately likely to occur were linked to model results, but with less distinct trends, such as those associated with development or total annual precipitation. These received a "Medium" score. A "Low" score was assigned to risks which were not directly predicted by the model results and were considered less likely to occur based on the analysis.

The individual risks were then scored based on their potential impact on the region. The risks were categorized similar to likelihood of occurrence with "High", "Medium", and "Low" designations. High priority risks were classified as those that affect the livability of the region by limiting access to basic services such as food production, water treatment and availability, wastewater treatment, or energy production. Medium priority risks affect the quality of life in the region. Basic services would be available, but at a reduced level of service and operational and capital strategies may need to be changed to continue to provide these services. Low priority risks are those that would have only a minor affect on the quality of life in the region or require little or no capital investment to address.

The overall highest priority risks are summarized in Table ES-2. The highest priority risks are identified for each vulnerability scenario and service sector. The water supply/water quality and water treatment sectors have the largest number of highest priority risks. This outcome could be expected given that a safe and reliable water supply is a basic service critical to the livability and economy of the region. The predicted rise in temperatures and greater variability in precipitation increase the potential for additional nutrient and pollutant loadings to surface waters. Additional nutrient and pollutant loadings would degrade surface water quality and increase the need for additional drinking water treatment capabilities. These factors also increase the potential for reduced water supply availability.

Table ES-2. Summary of Highest-Priority Risks by Service Sector and Vulnerability Scenario										
No.	Highest Priority Vulnerability Scenarios	Highest-Priority Risks by Affected Sector								
		Water Supply/ Water Quality	Water Treatment	Wastewater Treatment	Public Health	Agriculture	Environment	Economy	Energy	Transportation
1	Increased air temperatures/increased incidence of heat waves	Increased water demand due to irrigation Increased nutrient/pesticide/ herbicide load due to extended growing season, increased algal blooms	Taste and odor concerns, potential for algal toxins		Increased issues for asthma and allergies Impacts to human mortality; increase in heat illnesses and stresses on health care	Livestock health/mortality Increased need for irrigation and controlled drainage	Increased smog/decreased air quality	Increased service cost for food Increased cost for utility services (water, wastewater, and energy) Decreased human productivity	Increased power disruptions (brownouts)	
2	Increased water temperature	Increased algal blooms including blue-greens (potential for increased toxin release)	Taste and odor concerns, potential for algal toxins	Lower DO/changes in temperature affect wastewater discharge allocation	Increase in waterborne diseases	Increased cost to control water quality from fields			Lack of cooling water could reduce power production	
3	Warmer soil temperatures/decreased soil moisture					Increased need for irrigation and controlled drainage				
5	Higher maximum sustained flow (30- and 7-day higher maximum stream flows)	Increased algal blooms, including blue-greens (potential for increased toxin release) Increased organics, nutrients, turbidity, sediment, and other pollutant loads to surface waters Increased supply management challenges related to greater variability in stream flow Increased watershed and stream bank erosion	Taste and odor concerns, potential for algal toxins Increased treatment cost due to increased pollutant concentrations and increased disinfection by-products (DBPs)					Increased flood damage		
6	Extended dry periods/summer drought (decreased minimum 30-day stream flow)	Decreased reservoir flow/volume and reduced mixing Increased water demand Increased algal blooms, including blue-greens (potential for increased toxin release) Reduced reliability of yield from supply sources	Reduced groundwater supply/recharge Taste and odor concerns, potential for algal toxins; Increased treatment costs due to algae and potentially algal toxins		Increased allergens and dust	Increased demand for irrigation but decreased water availability		Increased food costs due to decreased agricultural production (crop loss)		
7	**Increased intensity of rain and wind events**	Increased watershed and stream bank erosion Increased organics, nutrients, turbidity, sediment, and other pollutant loads	Damage to infrastructure/ infrastructure failure including power outages, flooding, and intake damages	Damage to Infrastructure/infrastructure failure including power outages and flooding Increased CSO/SSO discharges	Loss of electrical/water/ sanitation services during and after event Increased demand on public health services Restricted access to critical care Disaster related injuries/ mortalities			Increased insurance costs; Increased damages due to floods/storms	Increased vulnerability of power supply system	Infrastructure access Infrastructure damage/ failure Interruption to emergency services including the transportation of food and water in critical situations

[This page left intentionally blank.]

ES.2 Climate Change Adaptation Strategies

Climate change presents challenges to water and wastewater utilities and to the other regional service sectors. Challenges include impacts associated with increases in air and water temperature, degraded water quality, increased potential for droughts with longer duration, and increased occurrence of floods associated with more intense rain events. One of the overarching challenges to managing utilities and services in the region is the need to increase flexibility in planning and operations to adapt to the increased variability and extremes of precipitation, stream flow, and water quality.

One of the overarching challenges to managing utilities and services in the region is the need to increase flexibility in planning and operations to adapt to the increased variability and extremes of precipitation, stream flow, and water quality.

The projected climate changes could have a significant effect on facilities and operations, yet the probability and magnitude of these changes are not known with a high degree of certainty. To manage these critical infrastructure systems prudently, utility operators must determine strategies to address the issues that pose the greatest threat and make appropriate investments. They must also determine trigger points using climate and water quality parameters that would initiate further action and monitor these parameters on a regular schedule. This approach will allow utility managers and regional leaders to adapt future planning strategies and investments as climatic conditions change over time.

This TM provides a description of potential adaptation strategies that the utilities and the region may implement to mitigate the risks expected from climate change. Given the objective of this project, strategies for the highest priority risks associated with water quality/water supply, water treatment, and wastewater treatment are the primary focus. The adaptive strategies for each service sector are divided into three categories: planning, operational, and capital improvement. Planning strategies include studies, demand or development planning, and regulatory policy or ordinance changes. Operational changes to reservoir or treatment plant operations, conservation efforts, and other management techniques are operational strategies. Capital improvement strategies include construction of new infrastructure, significant rehabilitation or retrofit of existing infrastructure, and new technologies.

The adaptive strategies for each service sector are divided into three categories: planning, operational, and capital improvement.

Each adaptive strategy is also categorized based on the relative level of investment for the region. Adaptation strategies are divided into three levels of cost. Options that can be funded by the utility or service sector within the typical annual budget are assigned the lowest cost factor, $. Investments that require planning to implement as part of the capital improvement program for the utility or service sector are assigned the cost factor, $$. Projects or improvements that may require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement are given the highest cost factor, $$$.

The associated benefits of each adaptive management strategy to the service sector were considered in conjunction with the benefits related to climate change risk mitigation. In many cases, strategies are identified that provide a significant benefit to the utility or service sector under both the current climate and climate change scenarios. These strategies are labeled throughout the TM as “no regrets” strategies. Implementing such strategies will increase the region’s resilience to climate change while also providing immediate benefits. The “no regrets” actions are not cost-free but do provide benefits to the service sector regardless of future climate conditions.

“No regrets” strategies are strategies that provide benefit under current and potential climate change conditions.

Finally, the strategies were organized by the sequence in which they should occur to provide a clear plan for implementation. Three planning terms were defined: Short Term, which are strategies that should be

Three planning terms:

- Short Term - Strategies that should be implemented between 2015 and 2025
- Mid Term - Strategies that should be implemented between 2026 and 2045 years
- Long Term - Strategies that should be implemented between 2046 and 2090.

implemented between 2015 and 2025; Mid Term, strategies that should be implemented between 2025 and 2045 years; and Long Term, strategies that should be implemented between 2045 and 2090.

It is neither feasible nor necessary to implement all of the adaptive strategies identified in this study immediately. Most of the recommended strategies are "no regrets" and relatively low cost while providing substantial benefits. Implementation of these strategies will require action by local governments in combination with regional coordination.

It is important to note that based on current monitoring results, surface waters in the Scioto basin already contain elevated concentrations of nitrogen and phosphorus. With higher temperatures in the future in combination with additional nutrient loads, algal bloom frequency and intensity is expected to increase. Even under current conditions algal blooms could be more prevalent and intense. Algal blooms can lead to a variety of aesthetic, health, and drinking water issues. For these reasons there is some urgency in identifying and reducing the primary sources of nutrients in the watershed. With new development in the watershed, stormwater runoff nutrient loads are expected to further increase in the future. Minimizing the increase in nutrient and other pollutant loads is essential to protecting surface water quality in the region.

Figure ES-1 includes a summary of the recommended Short Term and Mid Term adaptation strategies and the timeframe in which they should be implemented. Long Term strategies are more likely to change as the climate and the region change over the next 30 years. It is anticipated that the Long Term strategies identified in this study will be refined based on the outcomes from the Mid Term planning studies. Potential Long Term strategies identified during the study are discussed in Sections 3 and 4.

In the Short Term, 10-year planning horizon, the region should implement strategies that focus on:

- Establishing a regional collaborative forum for regional planning for issues related to water supply, water quality, and climate change impacts
- Enhancing public and leadership education regarding water quality, water supply, and climate change
- Increasing emergency preparedness including flood protection for critical assets
- Expanding the monitoring and understanding of pollutant sources and water quality within the watershed
- Establishing reservoir and water treatment standard operating procedures (SOPs) and trigger points for modified treatment based on water quality changes (increased turbidity, nutrient, algae, or organic levels)
- Modifying stormwater and land development ordinances to promote infiltration and reduce impervious areas
- Increasing the use of non-structural best management practices (BMPs) to reduce nutrient and pollutant sources to surface waters
- Developing a cooperative program with agriculture to reduce runoff pollutant loads
- Implementing public low-impact development (LID) retrofit demonstration projects and incentivizing private LID retrofit

In the Mid Term range (30-year planning horizon) strategies should focus on:

- Developing a Regional Water Supply Management Plan
- Water supply planning to establish sustainable groundwater withdrawal rates
- Water reuse planning

- Reservoir capacity planning
- Continuation of watershed management planning and implementation of nutrient/pollutant reduction BMPs (structural and non-structural)
- Reevaluating climate conditions

Developing a more thorough understanding of the watersheds and surface water system through monitoring and analyses would allow the preparation of operational strategies to further improve the reliability and resiliency of the water supply and utility systems and improve future decision making. Additional regional coordination and planning would also enhance system reliability and resiliency. Other strategies, such as the more expensive capital improvements, may not be appropriate under current conditions, but may become necessary as conditions change and more is understood. Once the water supply and watershed planning is completed, capital projects will likely be identified which should be completed in the Mid and Long Terms to improve the resiliency of the water supply system, reduce pollutant loads, improve surface water quality, and reduce drinking water treatment requirements.

Table ES-3. Recommended Adaptation Strategies for the Upper Scioto River Watershed

Short Term (10 Years) 2015–25	Mid Term (11–30 Years) 2026–45
Regional Collaborative Forum Establish forum for regional collaboration and planning with regard to issues related to water supply, water quality, treatment, and climate change impacts. **Public Education** Implement public education and outreach on sources of pollutants, water quality, supply, and climate change. **Improve Emergency Preparedness Capacities** Develop or update Regional Emergency Preparedness and Response Plans for extreme weather and water quality events. Evaluate and provide flood protection for critical assets. Develop Emergency Power Supply Plans. **Enhance Operational Procedures** Conduct (expand) water quality monitoring throughout supply system and treatment process and identify primary sources of external and internal pollutants. Establish SOPs for modified reservoir and treatment plant operation during high turbidity, algae, and organics events. **Resource Protection** Develop a guide for and promote high-efficiency irrigation systems and low water use landscaping. Modify local stormwater management and land development ordinances to incorporate low-impact development (LID) practices. Develop a cooperative program with agriculture to reduce runoff pollutant loads. Implement public LID demonstration projects and promote/incentivize private LID retrofit. Implement additional non-structural BMPs to reduce nutrient/pollutant loads to surface waters.	**Water Supply Planning** Develop Regional Water Supply Management Plan including sustainable groundwater supply, and irrigation needs. **Groundwater Supply Planning** Conduct a regional groundwater study to assess availability of groundwater for regional growth and irrigation uses. **Water Reuse Planning** Identify areas for water reuse (e.g., irrigation, industrial applications, etc.) to reduce water demands. **Reservoir Capacity Planning** Develop Reservoir Operational Plan for optimizing reservoir capture and reservoir management during drought and high flow conditions. **Nutrient/Pollutant Reduction Planning and Implementation** Continue Regional Watershed Management Planning based on expanded monitoring to identify primary watershed external and internal pollutant loads and protect/improve reservoir water quality. Install structural BMPs to reduce nutrient/pollutant loads to surface waters. Complete necessary in-reservoir treatment to protect/improve reservoir water quality. **Reevaluate Climate Conditions** Continue to monitor and evaluate changes to climate, water demand, and watershed. Update plan as needed.

Additional strategies that may be considered in the Long Term – through the turn of the century have been included for consideration as this plan is updated over time, but have not been highlighted in the table above. **It is anticipated that the Long Term strategies identified in this study will be refined based on updated climate projections and outcomes of the Mid Term planning studies.**

Section 1: Introduction

This introductory section provides a brief summary of the background of this project, describes the project location, and explains the purpose and organization of this Technical Memorandum No. 4 (TM4).

1.1 Project Overview

The Mid-Ohio Regional Planning Commission (MORPC), in partnership with the City of Columbus Department of Public Utilities, Del-Co Water Company, Inc., U.S. Geological Survey (USGS), and Ohio Water Development Authority (OWDA), has initiated a study of the effects of climate change on water supply in the Upper Scioto River basin. The primary objective of this project is to develop an adaptive management plan for the region to guide actions to maintain and protect a resilient water supply system.

There is substantial concern regarding the potential impacts of climate change on utilities, economies, and resources in the Midwest (Melillo, 2014). This project focuses on impacts to water resources and utilities while accounting for climate impacts to all key service sectors within the Scioto River basin. National studies indicate that the projected extreme weather variations and altered patterns of precipitation, stormwater runoff, and dry weather base flow may increasingly compromise the ability to effectively manage water supplies and critical water supply and treatment infrastructure, and water quality (USEPA, 2012; Wilbanks and Fernandez, 2012; NACWA, 2009; Brekke et al., 2011). Ancillary impacts to water utilities may include increased cost for service, impacts to customer confidence, and increased difficulty meeting regulatory compliance requirements.

Land use and water planning are connected, and there is a need to link development to water management (Lee, 2014). MORPC has developed a collaborative initiative, Insight 2050, which aims to help Central Ohio communities proactively plan for development and population growth over the next 30+ years that is expected to be dramatically different from the past by understanding the impact of future land use policies.

The challenges related to the potential impacts of climate change on water and wastewater utilities are exacerbated in central Ohio, where 85 percent of daily municipal water usage is supplied by surface water. With such strong dependence on surface water, there is concern related to the impact of oscillating weather patterns associated with climate change on the reliability of supply sources. In order to maintain a resilient water supply system, utilities must develop a comprehensive understanding of the increased risks to their systems and craft new management strategies to address these risks.

This project, named “Sustaining Scioto,” includes two phases: evaluating the potential impacts associated with climate change through the planning horizon of 2090, and developing adaptive management strategies to reduce these impacts. The first phase entails development of a watershed model for evaluation of the impacts of projected climatologic conditions on the water resources of the Scioto River basin through 2090. The USGS developed this watershed model and has calibrated and validated the results using historical gauging station data. Down-scaled data from the global climate model (GCM) (Source: World Climate Research Programmer’s Coupled Model Intercomparision Project phase 3 multi-model dataset) were developed by USGS for input into the watershed model and also to document predicted changes in temperature and precipitation. This climate change modeling effort is more robust and inclusive than most similar modeling efforts undertaken in the United States. In addition to anticipated changes in climate, changes to water demand due to population growth and build out development are also simulated.

The second phase of the project includes the development of future water use projections, evaluation of the future water inventory, identification of water and wastewater utility vulnerabilities, and development of strategies to address these vulnerabilities through an adaptive management plan. Future development within the region and the associated water demand projections were evaluated based on predicted population growth and commercial and industrial development. A water inventory was prepared for the region based on these demands. Current and future water uses and discharges from the watershed were evaluated to determine potential system risks and provide the framework for future planning. Using the results of the watershed model and the water inventory, the project team, along with a Stakeholder Advisory Committee, identified key vulnerabilities for nine service sectors in the region, listed in Table 1-1. These service sectors were chosen as those that were critical in supporting the region's health and livability. Adaptation strategies were then developed to address the high-priority risks identified within each of the sectors. This information will then be used to develop an adaptive management plan for the region that will provide utilities, developers, agriculture, and industry with an understanding of the both the risks imposed by climate change and the strategies to mitigate such risks. This plan will also serve as a guide for future investment and planning for water resource management.

Table 1-1. Nine Service Sectors

Water supply/water quality	Wastewater treatment
Water treatment	Economy
Environment	Energy
Public health	Transportation
Agriculture	

1.2 Project Location

The Sustaining Scioto project area encompasses the Upper Scioto River basin from its headwaters in northern Ohio to just north of Circleville in the south. A map of the area is shown in Figure 1-1. This 3,200-square-mile watershed provides water to more than 2 million people; encompasses portions of 17counties; and includes the Scioto River, Big Walnut Creek, and Olentangy River. The Upper Scioto River watershed also includes the Griggs, O'Shaughnessy, Alum Creek, and Hoover reservoirs and Delaware Lake. There are nine water treatment facilities drawing a total average flow of 170 million gallons per day (mgd) of surface water from the watershed. There are also 13 wastewater treatment facilities with a combined discharge flow of 190 mgd. The basin is primarily rural, with more development near the city of Delaware; the greater Columbus metro area; and small pockets of urbanization in cities such as Galion, Kenton, Marion, and Marysville.

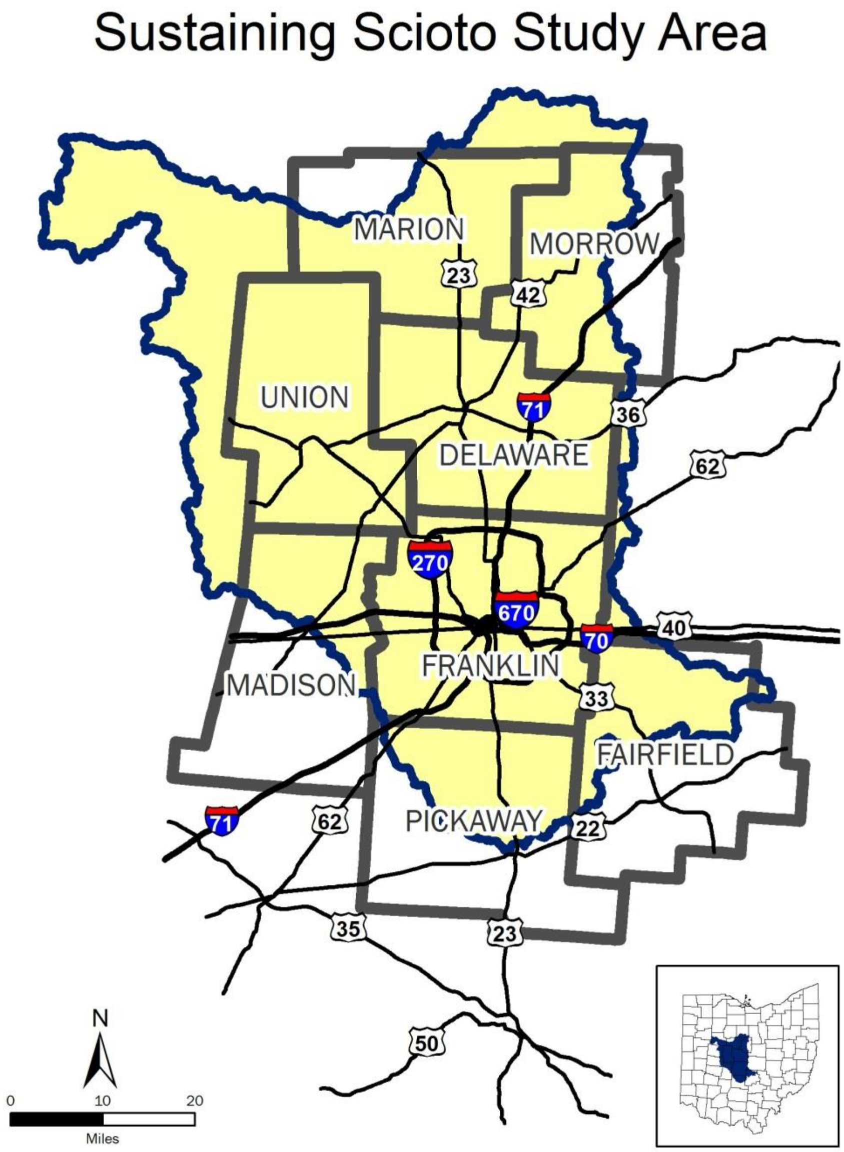

Figure 1-1. Map of the Sustaining Scioto project area

1.3 Purpose and Organization

The purpose of this technical memorandum is to identify adaptation strategies that can be used to address high-priority vulnerabilities and achieve resilient water resources and utilities in the region. The vulnerabilities were identified based on an evaluation of the GCM data and the watershed modeling results provided by USGS. The potential impacts from changes in temperature, precipitation, and stream flow were assessed and prioritized within nine service sectors based on likelihood of occurrence and severity of impact. Adaptation strategies were then developed and prioritized to address the highest-priority risks.

Adaptive management is a flexible strategy for developing, evaluating, and making decisions (EPA, 2012). The basic approach to adaptive management, shown in Figure 1-2, includes understanding and prioritizing risks, developing strategies to reduce risks, implementing strategies, and reevaluating strategies as more information becomes available. Adaptive management's flexible and holistic approach makes it valuable in making decisions in an uncertain environment. It proves especially useful in the context of climate change planning because it is an iterative process. The strategies will be periodically modified based on monitoring results and updated climate change projections. New strategies are developed and implemented based on new information and the iterative process continues.

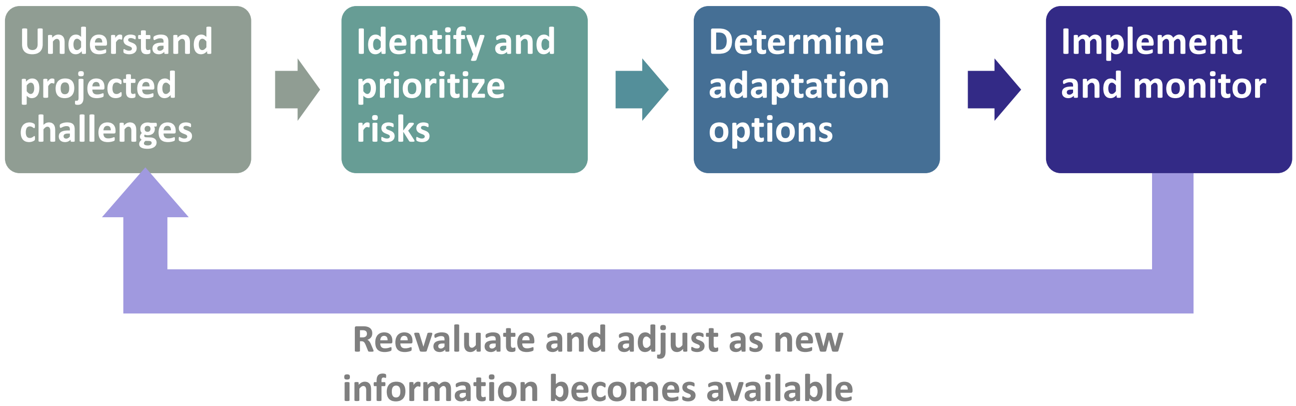

Figure 1-2. Overview of the adaptive management process

The first step in developing an adaptive management plan for climate change is the evaluation of the predicted regional changes and corresponding challenges. The USGS watershed modeling results define potential changes due to climate impacts while TM2, Upper Scioto River Watershed Water Inventory, evaluates the impact of growth and changing water use within the region. The next step in developing an adaptive management plan is the identification and prioritization of vulnerabilities that arise from these changing conditions, which may impact the livability of the region. The potential vulnerabilities were identified and prioritized in TM3, Sustaining Scioto Vulnerability Assessment, based on the climate and watershed modeling results, literature review, and input from regional stakeholders representing the key service sectors. Section 2 includes a brief summary of the Vulnerabilities Assessment results as context for this TM.

The identification of adaptation strategies, as summarized in this document – TM4, is the next step in the development of an adaptive management plan. Section 3 includes the identification of adaptive management strategies to address high-priority risks for each vulnerability scenario by market sector. These were developed by the project team in concert with stakeholder input. Top-priority strategies are summarized in Section 4 and conclusions are provided in Section 5. Pertinent references are included in Section 6.

> Adaptive management's flexible and holistic approach makes it valuable in making decisions in an uncertain environment.

Section 2: Vulnerabilities Assessment Summary

The trends and conditions observed in the watershed model simulations and the predicted changes in temperature, precipitation, water use, and build out can all impact the region. Detailed discussion of the modeling results and associated vulnerabilities is provided in TM3, Sustaining Scioto Vulnerability Assessment. In this section, the potential impacts from these predicted changes are categorized into risk scenarios.

2.1 Prioritization of Vulnerabilities

The results of the climate change and watershed modeling indicate the potential for the following changes in the Upper Scioto River watershed through the end of the century:

- Increase in the mean annual air temperature (up to 10-degrees Fahrenheit [°F] increase by 2090);
- Increase in the variability of precipitation with a slight overall increase in mean annual precipitation;
- Increase in the variability of stream flow including higher maximum flows and lower minimum flows; and
- Longer durations of extended minimum stream flows and reservoir levels.

While results indicate significant Long Term changes in climate, conditions appear to stay within the range of variability we currently experience through 2045. Beyond 2045, the model results indicate that the region will experience higher temperatures as well as greater variability in maximum and minimum stream flows and overall precipitation.

The predicted climatic changes to temperature and precipitation can provide challenges to the region on their own. The combined impacts create inter-related vulnerability scenarios. The identified vulnerability scenarios that may arise from the predicted climate changes are listed in Table 2-1. These scenarios were developed by analyzing the climate projection data and watershed model simulations as well as by performing a review of climate change literature specific to the Midwestern area (USEPA, 2012; Melillo, 2014). The scenarios were then refined in stakeholder meetings with representatives from the planning commissions and key service sectors. Stakeholders from each service sector were invited to participate, and representatives that joined included the Ohio Environmental Protection Agency (OEPA); Ohio Department of Natural Resources (ODNR); water and wastewater utilities; and public health, agriculture, and environmental advocacy groups. Once these risk scenarios were identified, the technical panel and stakeholder group worked together to identify key vulnerabilities by service sector.

This section includes a list of the vulnerability scenarios and most significant risks with an emphasis on water supply/water quality and water treatment. The risks were prioritized based on likelihood and impact, with the most significant risks having both a vulnerability scenario that is likely to occur and a significant impact if they were to occur. For likelihood of occurrence, the vulnerability scenarios were given a ranking of high, medium, or low based on the potential to occur. The specific risks were then assigned a ranking of high, medium, or low based on the expected impact on the region.

The likelihood rankings assigned to the vulnerability scenarios are summarized in Table 2-1. Those that were highly likely to occur were linked to clear trends from the model results and climate data. Examples include those caused by increases in temperature, more extreme variability in precipitation, and decreases in minimum stream flow or reservoir water levels as observed in the model results. These risks were assigned a ranking of "High" and shaded red in Table 2-1. Vulnerability scenarios were categorized as "Medium" and shaded yellow if linked to results that were shown in the models, but with more uncertainty, such as those associated with build out or increased intensity of rain and wind events. A "Low" score was assigned to vulnerability scenarios that were not directly predicted by the model results and were considered less likely to occur based on the analysis. Low-risk vulnerabilities are shaded green in Table 2-1.

Table 2-1. Summary of Prioritized Vulnerability Scenarios

No.	Vulnerability Scenarios	Priority Based on Likelihood of Occurrence
1	Increased summer air temperatures/increased incidence of heat waves	High
2	Increased water temperature	High
3	Warmer soil temperatures/decreased soil moisture	High
4	Increased winter temperature and reduced ice cover	High
5	Higher sustained maximum flow (30- and 7-day higher peak river flows)	Medium
6	Extended dry periods/summer drought (decreased minimum 30-day stream flow)	Medium
7	Increased intensity of rain and wind events	Medium
8	Change in vegetation/animal species composition	Low

Once the vulnerability scenarios were scored based on likelihood of occurrence, the individual risks were ranked based on their potential impact on the region. The risks were categorized based on the severity of their impact, rating each effect with “High,” “Medium,” and “Low” designations, and represented by the colors red, yellow, and green, respectively. The designations and their definitions are shown in Table 2-2. Detailed results of the vulnerability scenario and risk prioritization are provided in Attachment A, Summary of Prioritized Risks by Service Sector.

Table 2-2. Risk Prioritization

Risk Prioritization Designation	Risk Prioritization Definition
High	Risks that affect the livability of the region by impeding access to basic services; e.g., food production, water treatment, wastewater treatment, energy production, access to health care
Medium	Risks that affect the quality of life in the region; e.g., basic services available but at a reduced level of service (LoS)
Low	Risks that have a minor effect on the livability of the region or require little or no investment to address

2.2 Highest Priority Risks

As described above, the highest priority risks were defined through an evaluation of their likelihood and impact for each vulnerability scenario and service sector. The resultant high priority risks are summarized in Table 2-3. As indicated in this table, there were numerous high priority risks identified for each vulnerability scenario and service sector. The largest number of high priority risks is in the water supply/water quality and water treatment sectors. This outcome could be expected given that a safe and reliable water supply is a basic service critical to the livability of the region.

Table 2-3. Summary of Highest-Priority Risks by Service Sector and Vulnerability Scenario

No.	Highest Priority Predicted Changes	Highest-Priority Risks by Affected Sector								
		Water Supply/ Water Quality	Water Treatment	Wastewater Treatment	Public Health	Agriculture	Environment	Economy	Energy	Transportation
1	Increased air temperatures/increased incidence of heat waves	Increased water demand due to irrigation Increased nutrient/pesticide/ herbicide load due to extended growing season, increased algal blooms	Taste and odor concerns, potential for algal toxins		Increased issues for asthma and allergies Impacts to human mortality; increase in heat illnesses and stresses on health care	Negative impact on livestock health/mortality Increased need for irrigation and controlled drainage	Increased smog/decreased air quality	Increased service cost for food Increased cost for utility services (water, wastewater, and energy) Decreased human productivity	Increased power disruptions (brownouts)	
2	Increased water temperature	Increased algal blooms including blue-greens (potential for increased toxin release)	Taste and odor concerns, potential for algal toxins	Lower DO/changes in temperature affect wastewater discharge allocation	Increase in waterborne diseases	Increased cost to control water quality from fields			Lack of cooling water could reduce energy production	
3	Warmer soil temperatures/decreased soil moisture					Increased need for irrigation and controlled drainage				
5	Higher maximum sustained flow (30- and 7-day higher maximum stream flows)	Increased algal blooms, including blue-greens (potential for increased toxin release) Increased organics , nutrients, turbidity, sediment, and other pollutant loads to surface waters Increased supply management challenges related to greater variability in stream flow Increased watershed and stream bank erosion	Taste and odor concerns, potential for algal toxins Increased treatment cost due to increased pollutant concentrations and increased disinfection by-products (DBPs)					Increased flood damage		
6	Extended dry periods/summer drought (decreased minimum 30-day stream flow)	Decreased reservoir flow/volume and reduced mixing Increased water demand Increased algal blooms, including blue-greens (potential for increased toxin release) Reduced reliability of yield from supply sources	Reduced groundwater supply/recharge Taste and odor concerns, potential for algal toxins; Increased treatment costs due to algae and potentially algal toxins		Increased allergens and dust	Increased demand for irrigation but decreased water availability		Increased food costs due to decreased agricultural production (crop loss)		
7	**Increased intensity of rain and wind events**	Increased soil and stream bank erosion Increased organics, nutrients, turbidity, sediment, and other pollutant loads	Damage to infrastructure/ infrastructure failure including power outages, flooding, and intake damages	Damage to Infrastructure/infrastructure failure including power outages and flooding Increased CSO/SSO discharges	Loss of electrical/water/ sanitation services during and after event Increased demand on public health services Restricted access to critical care Disaster related injuries/ mortalities			Increased insurance costs; Increased damages due to floods/storms	Increased vulnerability of power supply system	Infrastructure access Infrastructure damage/ failure Interruption to emergency services including the transportation of food and water in critical situations

[This page left blank intentionally.]

Section 3: Adaptation Strategies

As discussed in Section 2, climate change presents challenges to water and wastewater utilities and to the other regional service sectors. Challenges include impacts associated with increases to air and water temperature, degraded water quality, increased potential for droughts with longer duration, and increased occurrence of floods associated with more intense rain events. One of the overarching challenges to managing utilities and services in the region is the need to increase flexibility in planning and operations to adapt to the increased variability and extremes of precipitation, stream flow, and water quality.

One of the overarching challenges to managing utilities and services in the region is the need to increase flexibility in planning and operations to adapt to the increased variability and extremes of precipitation, stream flow, and water quality.

The projected changes could have a significant effect on facilities and operations, yet the probability and magnitude of these changes are not known with a high degree of certainty. **To manage these critical infrastructure systems prudently, utility operators must determine strategies to address the issues that pose the greatest threat and make appropriate investments.** Utilities must also determine trigger points using climate and water quality parameters that would initiate further action and monitor these parameters on a regular schedule. This approach will allow utility managers and regional leaders to adapt future planning strategies and investments as climatic conditions change over time.

The following sections provide an overview of potential adaptation strategies that the utilities and the region may implement to mitigate vulnerabilities related to climate change. Given the objective of this project, strategies for the high priority risks associated with water quality/water supply, water treatment, and wastewater treatment are the primary focus. A full discussion of strategies for the region's additional sectors, including public health, environment, economy, energy, transportation, and agricultural, are included in Attachment B, Non-water Service Sector Adaptive Strategies.

3.1 Introduction to Adaptation Strategies

This section includes a description of potential adaptation strategies to address the high priority risks identified for the water quality/water supply, water treatment and wastewater utility sectors, as presented in Table 2-3. The adaptive management framework presented in this study assumes that utilities and/or planners will use an iterative approach to planning and implementing strategies for regional climate resiliency. It is recommended that this analysis be revisited regularly as new information is available or when there is capacity to implement additional strategies.

The adaptation strategies for each service sector are divided into three categories: planning, operational, and capital improvement, as described in Table 3-1. In some cases, new planning studies are recommended to evaluate alternative operational or infrastructure investments to mitigate the identified risk. In other cases, infrastructure improvements are recommended including accelerating timing of planned projects.

Table 3-1. Categories of Adaptive Strategies	
Category	**Definition**
Planning	Strategies that include studies, demand or development planning, and regulatory policy or ordinance changes
Operational	Strategies that include operational changes to reservoir or treatment plant operations, conservation efforts, and other management strategies
Capital improvement	Strategies that include construction of new infrastructure, significant rehabilitation or retrofit of existing infrastructure, and new technologies

Each adaptive strategy has also been categorized based on the relative level of investment for the region. Table 3-2 includes a description of the three levels of cost.

Table 3-2. Relative Costs Associated with Adaptive Strategies	
Assigned Cost	**Definition**
$	Options that can be funded by the utility or service sector within the typical annual budget
$$	Investments that require planning to implement as part of the capital improvement plan for the utility or service sector
$$$	Projects or improvements that may require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

The benefits of each adaptive management strategy as associated to each service sector and to climate change risk mitigation were considered. In many cases, strategies are identified that provide a significant benefit to the utility or service sector under both the current climate and climate change scenarios. These strategies are labeled throughout this section as "no regrets" strategies. Implementing such strategies will increase the region's resilience to future climate change while also providing immediate benefits. While these "no regrets" actions are not cost-free, they do provide benefits to the service sector regardless of future climate conditions. "No regrets" activities and adaptation actions are identified for each high-risk potential impact listed in Table 2-3.

> "No regrets" strategies are strategies that provide benefit under current and potential climate change conditions.

3.1.1 Prioritization of Strategies

The strategies in this section have been categorized with regards to timing for implementation, based on the predicted changes from the USGS modeling. Figure 3-1 describes each of the phases and the general classifications of strategies that should be implemented during those timeframes.

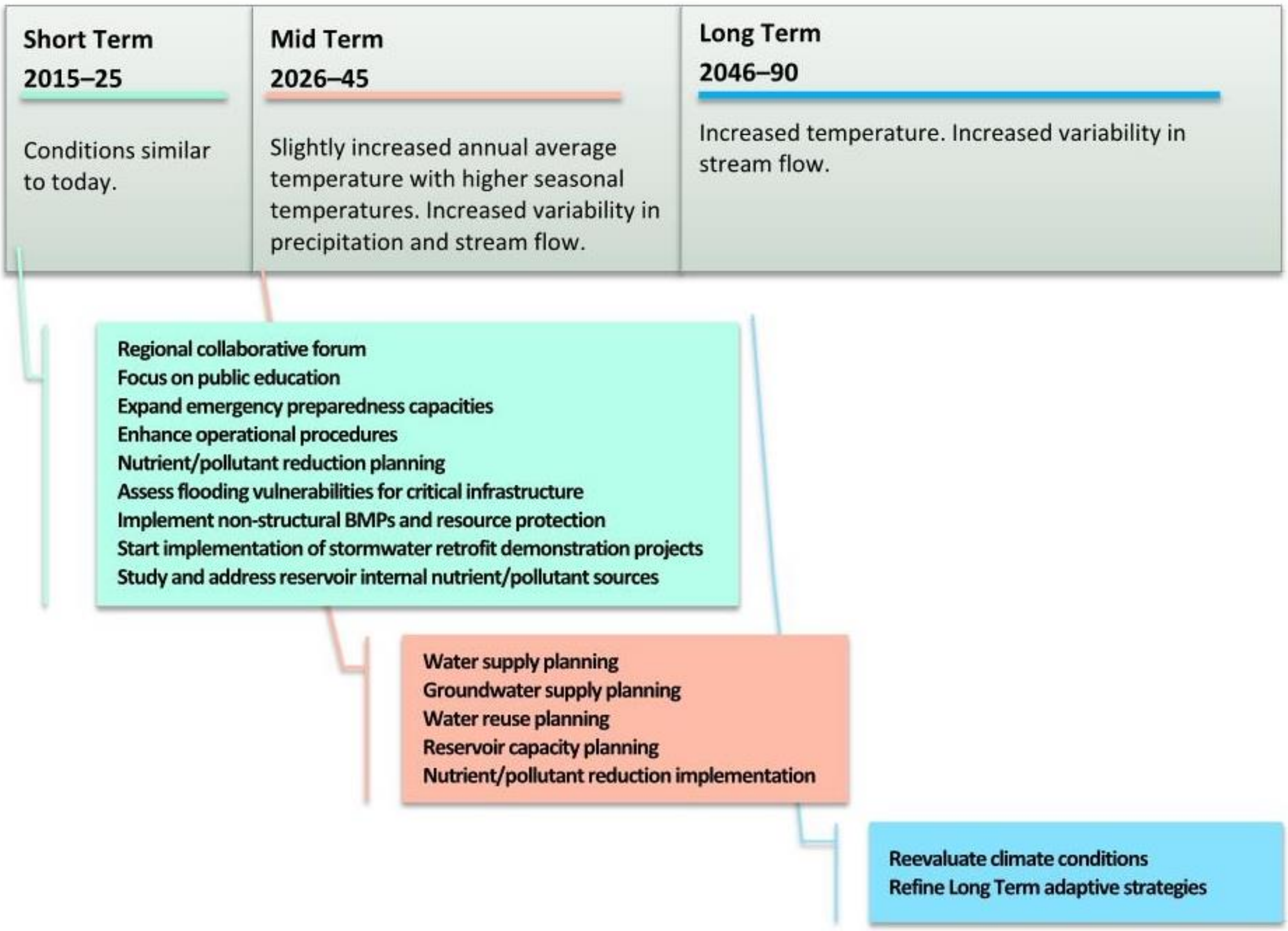

Figure 3-1 Strategy prioritization classification and timeframes

In the Short Term, which consists of the next 10 years, the models predict minor changes, within the level of standard climate variability. During this time frame the region needs to: monitor existing conditions; protect existing resources; enhance operational procedures; initiate regional watershed planning; assess the flooding vulnerabilities of critical infrastructure; implement non-structural best management practices (BMPs) and begin the implementation of stormwater LID retrofit demonstration projects in the watershed to reduce nutrient/pollutant loads; evaluate and address reservoir internal nutrient/pollutant sources; and lay the groundwork for potential regional coordination and collaboration, which may be needed to address regional climate change issues in the future. These efforts need to address both water quantity and water quality. It is recommended that the region's municipal leaders begin to meet to share thoughts on potential implications and begin to consider collaboration with regard to resource planning.

In the Mid Term, which consists of the next 30 years, the models reflect more variability in precipitation and stream flow along with the projected increase in mean annual temperature. During this time frame, the region needs to conduct planning studies to inform and refine Long Term adaptation strategies, continue the implementation of non-structural BMPs, implement stormwater retrofit projects to reduce watershed nutrient/pollutant loads, and improve surface water quality.

Looking out toward the end of the century, the models reflect significant variability with respect to precipitation, but all models indicate a significant increase in temperature. It is anticipated that the Long Term strategies identified in this study will be refined based on outcomes of the Mid Term planning studies. Although the types of projects and activities may change, the need to continue to implement non-structural and structural BMPs is expected to improve water quality. It is likely that there will be additional pollutant of concern that will need to be addressed in the future such as pharmaceuticals and hormones.

In the sections below, the recommended adaptive strategies are discussed in detail. Those that should be addressed in the Short Term (next 10 years) are highlighted in green; those that should be addressed in the Mid Term (11–30 years) are highlighted in pink. Additional strategies that may be considered in the Long Term—through the turn of the century—are included for consideration as this Plan is updated over time, but have not been highlighted in the tables. **It is anticipated that the Long Term strategies identified in this study will be refined based on updated climate projections, outcomes of the Mid Term planning studies, and the effectiveness of structural and non-structural BMPs implemented through 2045.**

A key factor in implementation of all of the strategies is the routine monitoring of climate and risk conditions. Strategies will need to be modified over time as the climate projections are refined. By reviewing updated data on a routine cycle (i.e., every 10 years), the region can monitor what changes are occurring and alter the implementation of strategies accordingly.

3.2 Climate Change Adaptation Strategies by Sector

This section describes adaptation strategies for the highest priority risks by sector: water supply/water quality, water treatment, and wastewater utility. Adaptation strategies for the ancillary service sectors are provided in Attachment B. A detailed discussion of the impacts these risks can have on the region is included in TM3. Many of these strategies are identified as “no-regrets” strategies as they provide improvements which are beneficial under both current and potential future climatic conditions.

3.2.1 Water Supply/Water Quality

The high-priority risks identified for water supply/water quality are listed in Table 3-3. It should be noted that several of these risks also impact the water treatment sector, requiring treatment system adaptations to changing water quality conditions in the source water, as discussed in Section 3.2.2.

Table 3-3. Water Supply/Water Quality High-Priority Risks		
No.	**Vulnerability Scenario**	**High Priority Risks**
1	Increased air temperature	Increased water demand due to irrigation
		Increased nutrient/pesticide/herbicide load due to extended growing season
2	Increased water temperature	Increased algal blooms, including blue-greens (potential for increased toxin release)
5	Higher maximum peak stream flows	Increased algal blooms, including blue-greens (potential for increased toxin release)
		Increased organics, nutrients, turbidity, sediment, and other pollutant loads to surface waters
		Increased supply management challenges related to greater variability in stream flow
		Increased soil and stream bank erosion
6	Extended dry periods/summer drought	Increased water demand
		Reduced reliability of yield from existing water supply sources
		Decreased reservoir inflow/volume and reduced mixing
		Increased algal blooms, including blue-greens (potential for increased toxin release)
7	Increased intensity of wind and rain events	Increased soil and stream bank erosion
		Increased organics, nutrients, turbidity, sediment, and other pollutant loads to surface waters

Several of these high-priority risks are associated with multiple vulnerability scenarios and can be summarized into the following six categories:

- Increased water demand due to increased air temperatures and extended droughts
- Increased algal blooms due to increased air and water temperature, higher maximum stream flows, and extended droughts
- Increased organics, nutrients, turbidity, sediment, and other pollutant loads to surface waters due to increased air temperature, higher maximum stream flows, and more extreme rain and wind events
- Reduced reliability of yield from supply sources due to greater variability in stream flow, higher maximum stream flows, and extended droughts
- Increased soil and stream bank erosion due to higher maximum stream flows and more extreme rain and wind events
- Decreased reservoir inflow/volume and reduced mixing due to extended droughts

Two of the highest priority risks are associated with water demand and water supply reliability and share common strategies. The other four highest priority risks are linked to protecting water quality and also have common mitigation strategies. The following sections summarize the potential adaptation strategies related to planning and policy and operational and capital improvements, along with the relative costs to mitigate the highest priority risks for water supply/water quality, i.e., water demand and water supply reliability, and water quality protection.

3.2.1.1 Increased Water Demand and Waters Supply Reliability Strategies

Recommended adaptation strategies for mitigating increased water demand and reduced water supply reliability are provided in Table 3-4. The strategies have been divided into three relative timeframes for recommended implementation including: Short Term (green highlight); Mid Term (yellow highlight) and Long Term (no highlight). Short Term strategies are recommended in the first 10 years, midterm strategies in the years 11 to 30, and Long Term strategies in years 31 to 75 from 2015.

In the Short Term, it is recommended that the region focus on strategies to increase the resilience of the existing water supply system through demand management and the use of low-impact development (LID) practices. Increased conservation by residential, commercial, industrial, agricultural, and other users will continue to gain importance to reduce overall potable water demands. Water use audits and leak detection studies should be completed to identify areas for conservation. Guidance should be developed to promote the use of high-efficiency irrigation systems, landscaping materials that minimize irrigation needs, and rainwater and stormwater harvesting and reuse for irrigation.

Under current stormwater treatment regulations, new development will degrade surface water quality due to the generation of new pollutant loads from additional impervious surfaces. Local ordinances should be modified to require Low Impact Development (LID, green infrastructure) construction to more closely mimic natural hydrology, improve groundwater recharge throughout the watershed, and reduce pollutant loads. LID practices may include infiltration features, such as bioretention and bioswales. Ponds and tanks can be used to capture and store rainwater from roofs and stormwater runoff from developed areas for irrigation. As conservation is an important element of current utility planning, increased focus on conservation and water use efficiency are considered as “no regrets” strategies for the region.

In the Mid Term, it is recommended that the region collaborate on the development of a Regional Water Supply Management Plan, including the evaluation of water demand, availability, potential new sources, and the identification of emergency supply sources that can be used during drought extreme conditions. Preparation of a Reservoir Operational Plan for each reservoir to optimize operations during both drought and high stream flow conditions is also recommended in the mid-range timeframe. The development of TM2, Water Inventory TM, indicates a regional strategy is needed to evaluate regional water availability and water demand that would result from climate change and future development. The demand should include the future irrigation needs and groundwater usage. Many of the utilities in the region have developed individual water master plans that evaluate potable water needs within their service area. Compilation of these individual plans and expansion to include evaluation of all water needs would provide the region with a more comprehensive understanding of the availability and reliability of this important resource.

The demand projections through build out conditions (2090) presented in TM1 indicated that several utilities in the region plan for increased use of groundwater as a supply source. Evaluation of sustainable groundwater withdrawal rates should be incorporated into the Regional Water Supply Management Plan. The Ohio Department of Natural Resources requires reporting of water withdrawal facilities, both surface water and groundwater, with the capacity to withdraw a minimum of 100,000 gpd. While many residential or agricultural irrigation water withdrawals may be below this threshold, municipal and golf course irrigation withdrawals from groundwater are monitored through the DNR program. Strategies should also be developed in this plan to allow adjacent water suppliers to share water during extended droughts. This will require regional coordination, collaboration, and planning studies to determine feasibility, as well as the construction of water system interties. It is believed that this type of plan would be of value to the region under our current climatic conditions, thereby making this one of the “no regrets” strategies for this sector.

> As a part of the City of Columbus’ Blueprint Columbus project, the City is working to separate downspouts from the sanitary sewer system and routing the rainwater to green infrastructure.

Water reuse should also be considered for future water supply. Up to 50 percent of water demand does not require potable water as it is used for irrigation and toilet flushing (Sharvelle, 2014). Alternative sources for non-potable needs may include groundwater, wastewater reuse, and rainwater and stormwater harvesting and reuse. It will be necessary to determine the potential yield and economical uses of each of these sources prior to implementation.

Potential Long Term capital improvement strategies include the construction of wastewater reuse systems, emergency water system interties, additional water storage/reservoirs, and systems to store and reuse stormwater. Implementation of wastewater reuse may also require improvements at the wastewater treatment facilities to meet reuse water quality requirements. It is important to note that the Long Term impact of wastewater reuse on surface and groundwater quality should be considered during the early planning. Additional water storage tanks and reservoirs may be needed in the watershed to capture stormwater and provide adequate irrigation water during extended droughts. The region may be able to use existing quarries in the area located adjacent to the river for additional water storage. Undeveloped tracts of land adjacent to rivers could be modified to provide water storage and possibly passive treatment. River water could be diverted offline, stored, and released more slowly over time or during periods of drought. These water storage areas could provide additional water supply and could also provide treatment to reduce nutrient and other pollutant concentrations upstream of the reservoirs.

Table 3-4. Recommended Adaptation Strategies for Mitigating Increased Water Demand and Reduced Water Supply Reliability

Strategy	No Regrets	Cost
Planning and Policy		
Increase conservation through residential and commercial rebate programs, device distribution, and public education on efficient irrigation techniques	✓	$
Develop a guide for and promote rainwater and stormwater harvesting/reuse	✓	$
Develop Regional Water Supply Management Plan to identify strategies for extended drought conditions. As part of Regional Supply Management Plan, evaluate alternative sources of water supply, including potential irrigation-only sources	✓	$$
Develop Reservoir Operational Plan for optimizing reservoir management during drought and high flow conditions	✓	$
Identify areas for water reuse (e.g., irrigation, industrial applications, etc.) to reduce potable water demands	✓	$
Conduct study to evaluate sustainable groundwater withdrawal rates	✓	$$
Develop an agricultural water conservation/BMP/reuse program through collaboration with state/local agricultural agencies*	✓	$
Operational		
Conduct water use audits and leak detection surveys to identify areas for conservation	✓	$$
Modify local stormwater management and land development ordinances to require LID, reduce impervious areas, and encourage rainwater and stormwater harvesting/reuse	✓	$
Establish framework for municipal collaboration on climate change and water supply issues	✓	$
Educate/outreach to community on conservation, water supply management & climate change	✓	$
Establish mutual aid agreements that detail water sharing with other municipalities through system interties during emergency or extreme supply situations*		$
Capital Improvement		
Construct emergency water system connections between municipalities in the Scioto watershed, where feasible*		$$
Implement recycled water treatment at the wastewater treatment facility and construct piping for water reuse users*		$$$
Construct larger pump stations to allow capture of peak stream flow*		$$$
Construct additional water storage/reservoirs in the watershed*		$$$
Construct storage ponds/tanks to collect and store stormwater for reuse*		$$
Develop an aquifer storage and recovery (ASR) program		$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

** Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

3.2.1.2 Water Quality Protection Strategies

Recommended adaptation strategies for protecting water quality are provided in Table 3-5. The strategies have been divided into the same relative time frames for recommended implementation. The pollutants of primary concern at this time include: nutrients; organics; sediment; pathogens; and pesticides/herbicides.

Algal blooms have become an increasing problem for surface waters in Ohio. Grand Lake St. Mary in Celina began reporting unsafe levels of microcystin, a toxin released from certain types of cyanobacteria in 2010. The lake is the primary drinking water source for the city of Celina. More recently, the City of Toledo warned 400,000 residents in August 2014 not to drink, cook, or bathe with the water because of potentially harmful levels of microcystin found in the City's drinking water supply. Lakes, reservoirs, and streams in the state have been experiencing an increase in algal blooms for the last decade. Increasing temperatures and higher-intensity rainfall events, which are predicted by the climate model data, will exacerbate the issue by providing ideal temperatures for algal growth and additional food (nitrogen and phosphorus) carried to surface waters by stormwater runoff.

Because of the documented existing water quality impairments and anticipated future trends in the Scioto River watershed, strategies should be implemented to reduce nutrient, organic, sediment, pathogen, and pesticides/herbicides loads to streams and reservoirs (external loads). Reservoir internal nutrient/pollutant loads (i.e., internal recycling of nutrients from the reservoir hypolimnion and sediments) should also be evaluated to determine the affect on surface water quality and addressed based on the study results. Both external and internal nutrient/pollutant loads can be primary sources which degrade surface water quality. Reservoir operational changes may also be warranted to help reduce reservoir pollutant, algae, and cyanobacteria concentrations. In recent years, the Hoover and Alum Creek reservoirs have experienced increasing cyanobacteria densities, which are of immediate concern. Under current conditions surface waters in the Scioto River basin are impaired and could experience the same cyanobacteria bloom and microcystin levels experienced by Celina and Toledo.

Other water quality issues of concern include: drinking water taste and odor; DBPs from the chlorination of reactive organic carbon; and contaminants of emerging concern such as hormones and pharmaceuticals. These are also very important water quality issues that are expected to be of increasing regulatory concern in the future.

Recommended Short Term strategies for protecting/improving water quality include developing and implementing a comprehensive water quality-monitoring program, identifying primary sources of nutrients/pollutants throughout the watershed and reservoirs, and implementing policies and practices to reduce nutrients and other pollutants of concern in the region. Reducing pollutant loads will improve stream and reservoir water quality.

While substantial monitoring is being conducted in the central portion of the watershed, limited data are available on water quality in the headwaters or in the more remote sections of the watershed. The primary specific sources of pollutants and the significance of reservoir internal nutrient/pollutant sources are also not known at this time. A comprehensive Water Quality Monitoring Program is needed to identify the primary sources and magnitudes of nutrients and other key pollutants throughout the watersheds and reservoirs, and evaluate the water quality response in regional streams and reservoirs.

The monitoring program should address in-stream and reservoir water quality during different weather conditions, both wet and dry weather, throughout the year. Analyses to quantify contributions from specific areas and land uses within the study area are needed. Quantifying loads from reservoir bottom sediments and the hypolimnion should also be completed. The monitoring program should also assess the condition of the stream banks and riparian buffers and identify areas with stream bank erosion and loss of natural riparian buffers. The results of the monitoring program should be used to identify primary sources of nutrients, sediment, reactive organic carbon, and other key pollutants that affect drinking water quality and to select the most appropriate strategies to reduce pollutant loads and improve water quality.

The City of Columbus initiated a Watershed Management Plan in 2014 to evaluate sources upstream of its reservoirs on the Scioto River and Big Walnut Creek.

Multiple strategies have been identified to reduce nutrient and other pollutant loads in the region. One strategy involves the development of an agricultural nutrient/herbicide/pesticide/pollutant management program through collaboration with state/local agricultural agencies and soil and water conservation districts. This type of program is one of the many ongoing programs of the local soil and water conservation districts throughout the watershed. It is recommended that additional focus be placed on this important work with the agricultural community in conjunction with increased public education. Stormwater discharges from agricultural land are a primary source of nutrients, organics, pathogens, and herbicides in the study area. The Environmental Quality Incentives Program, EQIP, was successfully implemented in the Hoover Reservoir watershed to reduce atrazine levels for over a decade. Similar approaches could be expanded throughout the watershed to address known water quality issues.

Residents and business owners throughout the watershed need to be educated related to their activities in the watershed and reservoir eutrophication, algal blooms, and other water quality issues. Local regulations can be modified to reduce the application of unneeded fertilizers. In many cases, phosphorus and/or nitrogen fertilizers are applied that are not needed based on existing levels of nutrients in the soil. Fertilizer use in both rural and urban settings is one of the primary sources of nutrients in a watershed, resulting in reservoir eutrophication and algal blooms.

Loss of natural riparian buffers adjacent to streams and stream bank erosion are commonly primary sources of sediment and other pollutants in a watershed. Protection and re-vegetation of riparian buffers and re-vegetation of stream banks is recommended to reduce sediment loads to area streams and reservoirs. Many of the municipal separate storm sewer systems (MS4s) throughout the watershed have adopted riparian buffer protection ordinances. Local governments should be encouraged to protect and maintain natural riparian buffers, wetlands, and floodplains adjacent to streams and reservoirs as development progresses in the watersheds.

MORPC has facilitated the development of Balanced Growth Plans in five Central Ohio watersheds to provide communities with development and conservation tools that best serve the watershed and the region.

The implementation of LID regulations by local governments for new development and redevelopment will reduce the discharge of stormwater runoff to receiving waters, thereby reducing nutrient and other pollutant loads. LID practices retain runoff on site and thereby reduce the volume of runoff and pollutant load leaving a developed site. Stored water can be used for irrigation, reducing the potable water demand in the area. New development and re-development in the watershed can be required to retain a set volume of stormwater runoff on site, typically between 0.5 and 2 inches. A minimum of 1 inch of onsite retention is recommended for this region.

LID retrofit demonstration projects which treat stormwater runoff are **recommended to educate developers, citizens and businesses about the benefits of LID.** Incentives can be provided to local businesses and citizens to implement LID retrofit projects on private property (i.e. rain gardens and cisterns) to further reduce nutrient/pollutant loads in the developed areas of the watershed.

It is important for utilities to prepare for algae blooms and other water quality upsets that could disrupt the supply of drinking water. Operational procedures should be evaluated to determine if operational changes can improve reservoir water quality and reduce the frequency and intensity of algae blooms. Emergency Operational Plans should be prepared with detailed procedures to be put in action in the event of an algae bloom, T&O problem, or other major water quality issue. The plans may include changing operations, treatment, or installing temporary equipment.

In the Mid Term planning horizon, the preparation of a Regional Watershed Management Plan (WMP) is recommended. Watershed planning is currently occurring through multiple organizations and municipalities within the watershed. The next step is to take the information from these individual studies and begin to develop a framework for a regional WMP, including an analysis of information gaps that need to be filled with additional monitoring or studies. Other sources of information that could be used to streamline the development of this Regional WMP include the Olentangy River, Walnut Creek, and other TMDL studies from Ohio EPA.

Watershed Action Plans have been developed for the Upper Scioto River, Upper and Lower Olentangy River, Upper and Lower Big Walnut Creek, Lower Alum Creek, Rocky Fork Creek, Blacklick Creek, and the Darby Accord.

Once the primary sources of nutrients/pollutants are identified, strategies can be developed to reduce the primary sources and maintain acceptable water quality. Strategies are needed to address both watershed (external) and internal surface water pollutant loads. Strategies are needed to manage reservoirs to minimize the occurrence of algal blooms and to provide stream and/or reservoir treatment when necessary to control nuisance blooms (water treatment is discussed in Section 3.2.2).

The WMP should also address other pollutants of concern such as reactive organic carbon and contaminants of emerging concern. Structural and non-structural strategies should be developed and prioritized for controlling the sources of these pollutants in the watershed along with in-reservoir maintenance and operational strategies to protect water quality. Strategies may include purchasing sensitive lands, restoring stream banks and riparian buffers, constructing regional and/or local stormwater retrofit projects to treat stormwater runoff, removing reservoir bottom sediments, and installing in-reservoir treatment systems. Implementation of selected strategies should continue during the Mid Term.

Long Term capital improvements will likely be needed to continue to reduce nutrient and other pollutant loads depending on the Regional Watershed Management Planning results. These improvements may include in-reservoir treatment (e.g., sediment treatment or removal, hypolimnetic oxygenation) and the construction of structural stormwater BMPs in the watershed. Example structural BMPs that can be constructed as retrofits to reduce pollutant loads from existing developed land uses include LID practices (bioretention, storage and reuse), wet detention, gross pollutant removal structures (i.e. baffle box, hydrodynamic separator) and coagulant treatment. Stream and riparian buffer restoration may also be beneficial if stream bank and/or riparian buffer degradation has occurred. Installation of permanent remote sensing in situ water quality sondes is recommended to continuously monitor surface water quality. Using established thresholds and triggers, algal blooms and other severe water quality events can be detected early so that actions can be implemented immediately to resolve the water quality issue.

Table 3-5. Recommended Adaptation Strategies for Protecting/Improving Water Quality		
Strategy	**No Regrets**	**Cost**
Planning and Policy		
Develop Water Quality Monitoring Plan to identify primary watershed (external) and reservoir (internal) nutrient and other pollutant sources; include identification of degraded streams and riparian buffers	✓	$
Develop an Agricultural Nutrient Management/BMP/Herbicide/Pesticide Program through collaboration with federal/state/local agricultural agencies	✓	$
Modify local regulations to limit fertilizer use	✓	$
Implement public education and outreach on sources of pollutants and surface water quality/water supply impacts	✓	$
Modify local stormwater management and land development ordinances to promote LID, reduce impervious areas, and encourage rainwater and stormwater harvesting/reuse, thereby reducing runoff volume and pollutant loads	✓	$
Evaluate reservoir operations to improve raw water quality; develop Emergency Operational Plans for reservoir water quality events (i.e. algae bloom; T&O)	✓	$
Assess Regional Watershed Management Plan to reduce nutrient runoff and algal growth	✓	$
Operational		
Conduct Water Quality Monitoring to determine sources and magnitudes of external and internal pollutant sources (nutrients, sediment, T&O compounds, DBP precursors, and algal toxins; identify contributing factors for algae blooms and algal toxin release)	✓	$$
Reduce nutrients/sediment/herbicides/pesticides in runoff from agricultural land through partnerships and agricultural program	✓	$$
Implement increased fertilizer reduction programs, protection of riparian buffers/wetlands/floodplains, re-vegetation of streams and riparian buffer zones, and other non-structural practices to reduce runoff and surface water pollutant concentrations	✓	$$
Begin LID/BMP retrofit demonstration projects on public lands and promote/provide incentives for local businesses and citizens to install LID retrofits	✓	$$
Capital Improvement		
Install permanent in situ water quality monitors for early algal bloom detection*		$$
Implement reservoir capital improvement projects (i.e., sediment removal, hypolimnetic oxygenation)* for internal loads		$$$
Implement pollutant reduction projects (BMPs) to reduce pollutants of concern within the watershed* for external loads		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

3.2.2 Water Treatment

The high-priority risks identified for the water treatment sector are listed in Table 3-6. A number of these risks overlap with those in the water supply section outlined in Section 3.2.1. The discussion below focuses on the treatment strategies related to these same vulnerabilities. The potential adaptation planning and policy, operational and capital improvement strategies, and relative costs to mitigate each of the high-priority risks for water supply/water quality are discussed and summarized in Tables 3-7 through 3-9.

Table 3-6. Water Treatment High-Priority Risks	
Vulnerability Scenario	**Risks**
Increased air temperature	Taste and odor concerns, potential for algal toxins
Increased water temperature	
Higher maximum sustained stream flows	Increased pollutant loads (from increased turbidity, organics, nutrients, microorganisms, and other contaminants) in surface waters
Increased intensity of rain and wind events	Damage to Infrastructure/infrastructure failure including power outages, flooding, and intake damages

3.2.2.1 Increase of Taste and Odor Concerns, Algal Blooms, and Associated Toxins

Warm air and water temperatures are known to cause algal blooms, leading to taste and odor concerns as well as potential algal toxins. Two compounds, geosmin (1,2,7,7-tetramethyl-2-norborneol) and MIB (2-methylisoborneol), are the best-known taste- and odor-causing compounds. Geosmin and MIB are produced by algae (cyanobacteria and actinomycetes). Both geosmin and MIB have extremely low odor thresholds to humans; the average person can often detect the presence of these compounds in the 10 parts per trillion (ppt) concentration range (Crittendon et al., 2005). These compounds are aesthetically unpleasing, but do not represent a serious health concern.

Although not as common as taste and odor compounds, cyanobacteria (also referred to as blue-green algae) toxins are a much greater concern when present in drinking water supplies. These toxins can cause serious health issues including poisoning, impacting the liver and the nervous system, and skin and mucous irritation. Microcystins, a class of natural toxins produced by certain genera of cyanobacteria, are of increasing interest and concern around the world as the number of poisoning incidents associated with cyanobacteria exposure increases, both in inland water bodies and coastal areas (de Figueiredo et al., 2004).

Most of the microcystin toxins are not released until the cell wall is lysed, which occurs when the cyanobacteria die (Heinze, 1999; WHO, 2003; Svircev et al., 2009). A large "die-off" of an algal bloom therefore may result in substantial release of microcystins to the water column. Treatment approaches should be focused on removing microcystin prior to cell lysing or inactivation of the extracellular toxin. The effectiveness of removal/inactivation processes depends on the type, concentration, and location of the toxins. Intracellular toxins are more easily removed because conventional treatment processes can be used for flocculation and coagulation followed by sedimentation and filtration (AWWA, 2010). Extracellular toxins can be oxidized by disinfectants, such as chlorine, but may require advanced treatment, such as reverse osmosis filtration, GAC adsorption, or ozonation (AWWA, 2010).

> The Dublin Road and Hap Cremean WTPs for the City of Columbus are currently constructing ozonation and biologically active granular activated carbon (GAC) treatment processes.

Recommended Short Term strategies for addressing taste and odor concerns and associated algal blooms include developing water treatment goals and water quality monitoring plans to identify taste and odor outbreaks or algal toxin events throughout the treatment process (from reservoir concentrations through finished water production). Finished water quality trigger points for public notification and an emergency management plan in case of an algal toxin event should be developed. Several utilities monitor for microcystin, but there are no U.S. regulatory limits. The World Health Organization (WHO) guideline for a maximum contaminant level for microcystin-LR is 1 microgram per liter (μg/L) (WHO, 1998). WHO terms this guideline as a "provisional value" because data are limited on the toxicity of cyanobacteria toxins. At this time, the region would need to develop trigger points without U.S. water quality regulations in place.

Mid Term strategies include evaluation of reservoir management options including source susceptibility analyses and the identification of alternative sources and treatment processes for use during algal blooms

or taste and odor events. The timing for these planning level studies will be determined by the level of problem being experienced within each source of supply.

Potential Long Term strategies may include implementation of surface reservoir treatment options. Algaecides, destratification/aeration, and watershed management are potential reservoir treatment methods. There are also several options within the water treatment plant (WTP) to modify operation to ensure removal of taste and odor compounds when outbreaks occur by increasing chemical and oxidant dosages.

Treatment plants not designed for enhanced organics removal will have more difficulty removing taste and odor compounds during outbreak events. Water treatment facilities with ozonation and biologically active filtration should be able to remove geosmin and MIB if an adequate ozone dosage is applied and the biofilm on the filter media is well established. If the GAC media has adsorptive capacity, this can be an additional mechanism for removal of these compounds. Geosmin and MIB removal should be monitored.

Table 3-7. Recommended Strategies for Mitigating Impacts related to Taste, Odors and Potential for Algal Toxins

Strategy	No Regrets	Cost
Planning and Policy		
Develop and conduct Water Quality Monitoring Plan to identify taste and odor outbreaks and presence of algal toxins throughout the treatment process (intake to finished water)	✓	$
Establish water quality treatment goals and levels that would trigger treatment modification and levels of contamination in the finished water that would trigger public notification	✓	$$
Develop Emergency Treatment Response Plan for taste and odor/toxic algal events	✓	$
Conduct study to evaluate source susceptibility and identify redundant source options	✓	$
Operational		
Activate additional treatment for facilities with taste and odor/algal toxin treatment options, increase chemical and oxidant dosages during summer and fall seasons when algal outbreaks can occur*	✓	$$-$$$
Implement reservoir treatment strategies or operational changes such as water withdrawal depths*		$$
Capital Improvement		
Install reservoir treatment strategies*		$$-$$$
For water treatment facilitates without a means to remove algal toxins, such as microcystin or taste and odor compounds, construct additional treatment processes*		$$$
Construct emergency water system connections between communities, where feasible*		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

3.2.2.2 Increased Source Water Pollutant Concentrations, Such as Turbidity and Disinfection By-products,

Increased peak stream flow is predicted to increase source water turbidity and disinfection by-product (DBP) levels, as well as other pollutant concentrations. Table 3-8 outlines strategies to address this concern.

Short Term strategies include establishing protocols and standard operating procedures (SOPs) for modified treatment plant operation during high turbidity and organic events to guide operators on chemical dosages, unit process loading rates, and water quality testing requirements. Additional SOPs may include using a secondary coagulant to reduce turbidity/organic levels and reduce or eliminate prechlorination to reduce DBP levels. As noted previously, another Short Term strategy is implementation of a water quality monitoring program.

Mid Term strategies may include evaluation of alternative sources of supply as part of the larger scale resource planning efforts. This could include developing new groundwater sources or implementing an aquifer storage and recovery (ASR) system. ASR is the enhancement of natural groundwater supplies using manmade conveyances, such as infiltration basins or injection wells, that it is stored in the ground for use at a later time (EPA, 2012). ASR can supplement water availability in the summer months when water use is high and naturally most limited. ASR can serve the same purpose as traditional storage in surface reservoirs and has the following benefits of being: less costly because large impoundments are not required; more environmentally friendly because it may reverse declining water levels in aquifers; and lower vulnerability from water quality standpoint due to limited exposure (Ecology, 2014).

In the Long Term (or as needed based on monitoring results), additional treatment processes may need to be brought online or constructed if not available. Ozonation, dosing of powdered activated carbon, and GAC polishing units are treatment processes that are effective at removing already formed DBPs. If chloroform is the main DBP of concern, in-tank aeration can be used in the distribution system to strip chloroform from the water.

Table 3-8. Increased Source Water Pollutant Concentrations, Such as Turbidity and Disinfection By-products Due to Higher Maximum Sustained Stream Flow

Strategy	No Regrets	Cost
Planning and Policy		
Establish water quality monitoring program	✓	$$
Develop alternative source of supply	✓	$$$
Operational		
Establish protocols or SOPs for modified treatment plant operation during high turbidity and organic events	✓	$
Increase water quality monitoring and testing (special testing of additional water contaminants)		$
Reduce prechlorination practices if DBP levels are high and prechlorination is practiced*		$
Use secondary coagulants to reduce high turbidity and organics levels*		$
Bring additional treatment processes online to remove already formed DBPs*		$
Use of alternative sources of supply during high stream flow events*		$
Capital Improvement		
Install reservoir treatment strategies for high turbidity events*		$$-$$$
Install equalization storage upstream of treatment plant*		$$$
Construct additional treatment facilities as needed, such as ozonation and/or GAC filtration*		$$$
Develop alternative source of supply (such as groundwater)*		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

3.2.2.3 Damage to Infrastructure and Infrastructure Failure

Planning, operation, and capital adaptive strategies to mitigate infrastructure damage and failures are summarized in Table 3-9. Based on treatment facilities' close proximity to rivers, plants are at a high risk for flooding. They are also vulnerable to loss of power during extreme events. Additional challenges to water production include increased turbidity and pollutant concentrations following storm events.

Short Term strategies include the development of regional emergency plans that identify key contacts with regulators, health departments, local officials, and special-use customers, such as hospitals and schools. As part of this plan, water utilities should evaluate water system infrastructure vulnerability and define the appropriate level of service for extreme weather events. It is also recommended that utilities establish treatment protocols for operation during high flow events with increased turbidity and organic levels.

Emergency strategies should include plans to provide water in cases of extreme infrastructure failure, including use of tanker trucks with water and use of Federal Emergency Management Agency (FEMA) or Army portable treatment units. These plans should also address backup and alternative sources of power, additional flood protection, and operational planning to restore function of the plant following extreme storm events.

Table 3-9. Damage to Infrastructure and Infrastructure Failure Related to Increased Intensity of Rain and Wind Events		
Strategy	No Regrets	Cost
Planning and Policy		
Develop or Update Regional Emergency Preparedness and Response Plans for extreme weather events	✓	$
As part of emergency plan, evaluate water system infrastructure vulnerabilities and lack of redundancy, and needs for system redundancy/new facilities	✓	$$
Determine appropriate LOS during extreme weather events	✓	$
Operational		
Establish protocols or SOPs for modified treatment plant operation during extreme events with high turbidity and organic levels	✓	$
Use of alternative sources of supply (likely more use of groundwater sources)*		$
Capital Improvement		
Install alternative power sources to provide power during outages (generators, solar or wind generators)	✓	$$-$$$
Install reservoir treatment strategies for high turbidity events caused from increased runoff*		$$
Construct pipelines (and emergency interties) to increase water system redundancy*		$$$
Rehabilitate or replace most vulnerable infrastructure*		$$$
Implement flood control strategies at the WTP*		$
Construct additional treatment facilities as needed (may be onsite treatment system or trailer-mounted treatment system)*		$$-$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

3.2.3 Wastewater Utility

The high-priority risks identified for the wastewater treatment sector are listed in Table 3-10, below. Adaptive strategies to mitigate each of these vulnerabilities are provided in the following tables and discussed in the subsequent paragraphs.

Table 3-10. Wastewater Utility High-Priority Risks	
Vulnerability Scenario	Risks
Increased water temperature	Lower DO/changes in temperature result in more stringent discharge requirements and affect wastewater discharge allocation
Increased intensity of rain and wind events	Damage to Infrastructure/infrastructure failure including power outage and flooding
	Increased CSO/SSO discharges

The potential adaptation planning and policy, operational and capital improvement strategies, and relative costs to mitigate each of the high-priority risks for wastewater treatment are summarized in Tables 3-11 and 3-12. A brief discussion on potential adaptation strategies to mitigate each of the high-priority risks for wastewater treatment follows.

Climate change will impact wastewater utilities in a number of ways. Extreme storm events and increased precipitation may result in increased need for wet weather program enhancements. Both infiltration and inflow (I/I) are expected to increase. Water quality considerations driven by increased temperature may lead to the need for significant investments at treatment plants to incorporate advanced treatment systems. Flood protection measures may also be required to address the increased flood potential associated with extreme precipitation and runoff.

3.2.3.1 Strategies to Mitigate Temperature Impacts

Adaptive management strategies for wastewater utilities to mitigate impacts related to potential changes to wastewater discharge allocations are presented in Table 3-11. It is anticipated that with the changing rainfall/runoff patterns, increased temperature, and the associated degradation of water quality in receiving waters, more stringent requirements may be placed on wastewater discharges. In several parts of the watershed, wastewater discharges represent the majority of the flow to the creeks and streams, especially during drought conditions.

As in the other sectors, Short Term strategies focus on monitoring water quality within the watershed in order to understand where and when current discharges are not maintaining water quality. This monitoring will allow utilities to develop advanced treatment plans and wastewater reuse strategies to mitigate the adverse impact of their discharges on the watershed.

Mid-range strategies include evaluation of reuse feasibility as part of the larger scale resource management planning efforts.

Table 3-11. Wastewater Utility Strategies to address Lower DO and Increased Temperature in Receiving Water

Strategy	No Regrets	Cost
Planning and Policy		
Develop Water Quality Monitoring Plan to identify water quality problems associated with changing DO and temperature	✓	$
Conduct water reuse feasibility study to determine potential customers for reuse water and investments required to implement a reuse program	✓	$
Operational		
Conduct Water Quality Monitoring Program		$$
Establish receiving water quality conditions that could trigger treatment modifications		$$
Capital Improvement		
Implement capital projects to increase treatment and provide needed infrastructure for wastewater reuse*		$$$
Increase treatment capacity to address more stringent treatment requirements*		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

3.2.3.2 Strategies to Mitigate Potential Increases in CSOs/SSOs and Damages to Wastewater Infrastructure

Adaptive management strategies to mitigate potential impacts related to the increased intensity of rain and wind events are presented in Table 3-12. Wastewater infrastructure is particularly at risk to flooding when extreme events occur due to the low elevation of these facilities in the watershed. Wastewater infrastructure close to or crossing streams and rivers is also vulnerable to storm damage. With more intense weather events, stream banks may erode, exposing wastewater infrastructure. Extreme storm events can also cause overflows by overwhelming the capacity of sewer systems, causing physical failures, and interrupting power at key facilities. When an overflow is next to a stream or river, the discharges can erode the stream bank and expose the utility line. Infrastructure along streams and rivers should be routinely inspected and any damage should be repaired immediately before a system failure occurs.

Short–term strategies include emergency planning and vulnerability assessments. Investments to flood-proof the most vulnerable facilities should be included in this planning effort. In some areas, pump stations may need to be flood-proofed or levees built. Additional Short Term strategies include modifying local ordinances to encourage green infrastructure. Wet weather management may be addressed by traditional “gray” infrastructure such as storage tunnels or rapid disinfection processes. Many utilities are incorporating green infrastructure as part of their wet weather management portfolio. Green infrastructure technologies include permeable pavement, bioretention or rain gardens, wetlands, bioswales, and green roofs. These systems can reduce the load on drainage systems, recharge aquifers, and ultimately reduce loading on wastewater collection systems.

Table 3-12. Damage to Wastewater Infrastructure and Infrastructure Failure Due to Increased Intensity of Rain and Wind Events		
Strategy	No Regrets	Cost
Planning and Policy		
Develop or Update Regional Emergency Preparedness and Response Plans for extreme weather events	✓	$
As part of Emergency Preparedness Plan, evaluate wastewater system infrastructure vulnerabilities and lack of redundancy, and needs for system redundancy/new facilities	✓	$$
Establish Emergency Treatment Plan for recovery following extreme storm events – as part of Emergency Preparedness Plan	✓	$$
Determine appropriate LOS during extreme weather events – as part of Emergency Preparedness Plan	✓	$
Develop Emergency Power Plan including alternative power supplies to support operations in case of power loss	✓	$
Evaluate options for increased wastewater/stormwater storage for more extreme storm events as part of resource planning efforts	✓	$
Operational		
Establish protocols or SOPs for modified treatment plant operation during extreme events		$
Modify local stormwater management and land development ordinances to require LID, reduce impervious areas, and use rainwater and stormwater harvesting/reuse, thereby reducing runoff volume and potential I/I	✓	$
Implement backup power supplies at pump stations and treatment facilities including alternative power supply sources such as wind or solar*		$$&
Capital Improvement		
Reduce infiltration and inflow (I&I) to the sewer collection system*	✓	$$
Eliminate CSOs and implement a separate stormwater and wastewater collection system*		$$$
Implement asset management plan to rehabilitate or replace most vulnerable infrastructure		$$-$$$
Set aside land to support future flood-proofing needs (berms, dikes etc.)		$$$
Implement flood control strategies at the wastewater treatment plant, protect vulnerable facilities and infrastructure		$$$
Increase capacity for wastewater and stormwater collection, treatment, and discharge including redundancies for system function with potential infrastructure losses and disruption		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

Section 4: Strategy Prioritization

This section summarizes the methodologies used to develop the strategy prioritization.

4.1 Adaptation Strategy Implementation

It is neither feasible nor necessary that all of the adaptive strategies identified in this Plan be addressed immediately. Adaptation strategies identified as "no regrets" should be strongly considered and implemented where appropriate to strengthen the reliability and resilience of services and infrastructure within the region.

The strategies identified for the Short Term are those that should be considered in the next 10 years. The models are predicting only minor changes over this period, within the level of standard climate variability. Based solely on the current regional surface water quality conditions summarized in Section 5, watershed pollutant load reductions and reservoir operational strategies are warranted at this time. This is true independent of the future water quality impacts as a result of climate change. The implementation of pollutant load reduction and operational strategies should reduce the potential for drinking water T&O issues and harmful algal blooms, and protect aquatic life and human health.

In the Short Term the region needs to: monitor existing conditions; identify primary external and internal pollutant sources; protect existing resources; enhance operational procedures; initiate regional watershed planning; assess the flooding vulnerabilities of critical infrastructure; implement non-structural best management practices (BMPs) and begin the implementation of stormwater LID retrofit demonstration projects in the watershed to reduce nutrient/pollutant loads; and lay the groundwork for potential regional coordination and collaboration, which may be needed to address regional climate change issues in the future. These efforts need to address both water quantity and water quality. It is recommended that the region's municipal leaders begin to meet to share thoughts on potential implications and begin to consider collaboration with regard to resource planning.

In the Mid Term, which consists of the next 30 years, the models reflect more variability in precipitation and stream flow along with the projected increase in mean annual temperature. During this time frame, the region needs to conduct planning studies to inform and refine Long Term adaptation strategies, continue the implementation of non-structural BMPs, implement stormwater retrofit projects to reduce watershed nutrient/pollutant loads, and improve surface water quality.

The Long Term strategies are strategies that should be implemented from 2045 out to the end of the century. The climate predictions for this period suggest significant variability between the different climate models with respect to precipitation. A significant increase in temperature is predicted during this period by all of the climate models. Because of the variability and uncertainty during this time frame, strategy implementation will have to be reassessed based on the realization of climate changes and updated based on outcomes from the Mid Term planning studies. Although the types of projects and activities may change, the need to continue to implement non-structural and structural BMPs is expected to improve water quality. It is likely that there will be additional pollutant of concern that will need to be addressed in the future such as pharmaceuticals and hormones.

A key factor in implementation of all of the strategies is the routine monitoring of climate and risk conditions. Strategies will need to be modified over time as climate projections are refined. By reviewing updated data on a routine cycle (i.e., every 10 years), the region can monitor what changes are occurring and alter the implementation of strategies accordingly. The strategies and their implementation time frames are summarized in Table 4-1 below.

Table 4-1. Adaptation Strategy Prioritization

Short Term (10 Years) 2015–25	Mid Term (11–30 Years) 2026–45	Long Term (31–75 Years) 2046–90
<u>Regional Collaborative Forum</u> Establish forum for regional collaboration and planning with regard to issues related to water supply, water quality, treatment, and climate change impacts. <u>Public Education</u> Implement public education and outreach on sources of pollutants, water quality, supply, and climate change. <u>Improve Emergency Preparedness Capacities</u> Develop or update Regional Emergency Preparedness and Response Plans for extreme weather and water quality events. Evaluate and provide flood protection for critical assets. Develop Emergency Power Supply Plans. <u>Enhance Operational Procedures</u> Conduct (expand) water quality monitoring throughout the watershed and treatment process and identify primary sources of external and internal pollutants. Establish SOPs for modified reservoir and treatment plant operations during high turbidity, algae, and organics events. <u>Resource Protection</u> Develop a guide for and promote high efficiency irrigation systems and low water use landscaping. Reduce fertilizer use. Modify local stormwater management and land development ordinances to incorporate LID practices. Develop a cooperative program with agriculture to reduce runoff pollutant loads. Implement public LID demonstration projects and promote/incentivize private LID retrofit. Implement additional non-structural BMPs to reduce nutrient/pollutant loads to surface waters.	<u>Water Supply Planning</u> Develop Regional Water Supply Management Plan including sustainable groundwater supply, and irrigation needs. <u>Groundwater Supply Planning</u> Conduct a regional groundwater study to assess availability of groundwater for regional growth and irrigation uses. <u>Water Reuse Planning</u> Identify areas for water reuse (e.g. irrigation, industrial applications, etc.) to reduce water demands. <u>Reservoir Capacity Planning</u> Develop Reservoir Operational Plan for optimizing reservoir capture and reservoir management during drought and high flow conditions. <u>Nutrient/Pollutant Reduction Planning and Implementation</u> Continue Regional Watershed Management Planning based on expanded monitoring to identify primary watershed external and internal pollutant loads and protect/improve reservoir water quality. Install structural BMPs to reduce nutrient/pollutant loads to surface waters. Complete necessary in-reservoir treatment to protect/improve reservoir water quality. <u>Re-evaluate Climate Conditions</u> Continue to monitor and evaluate changes to climate, water demand, and watershed. Update plan as needed.	<u>Reevaluate Climate Conditions</u> Continue to monitor and evaluate changes to climate and watershed. Update plan as needed. <u>Refine Long Term adaptive strategies</u> Refine and implement Long Term strategies based on outcomes of Mid Term planning studies.

[This page left blank intentionally.]

Section 5: Conclusions

There is no question that climate change is occurring. What is less clear are the impacts these changes will have on our region, its people, its environment, and its resources. This project has sought to identify the potential changes in both climate and development that may occur within the region over the next 75 years. These potential changes were evaluated to identify vulnerabilities to water resources, infrastructure, public health, the economy, agriculture, and the environment and to prioritize those vulnerabilities based on their likelihood of occurrence and their impact on livability to the region. Each of the high-priority vulnerabilities was analyzed to develop potential adaptive strategies to address and mitigate the risks. This project provides a solid foundation for future planning within the region with regard to development, infrastructure investment, natural resources, and public health and safety. However, this is an iterative process and analysis of the factors affecting the identified vulnerabilities should continue to be monitored and adaptive strategies refined based on updated data.

It is important to note that based on current monitoring results, surface waters in the Scioto River basin already contain elevated concentrations of nitrogen, phosphorus, and other pollutants of concern. With higher temperatures in the future combined with additional nutrient loads, algal bloom frequency and intensity is expected to increase. Even under current conditions, algal blooms could be more prevalent and intense. For these reasons there is some urgency in identifying and reducing the primary sources of pollutants in the watershed. With new development in the watershed, stormwater runoff nutrient loads are expected to further increase in the future.

Developing a more thorough understanding of the watersheds and surface water system through monitoring and analyses will allow the preparation of operational strategies to further improve the reliability and resilience of the water supply and utility systems and improve future decision making. Additional regional coordination and planning would also enhance system reliability and resilience. Other strategies, such as the more expensive capital improvements, may not be appropriate under current conditions, but may become necessary as conditions change and more is understood. Once the water supply and watershed planning is completed, capital projects will likely be identified that should be completed in the Long Term.

Adaptation strategies identified as “no regrets” should be strongly considered and implemented where appropriate to strengthen the reliability and resilience of services and infrastructure within the region. Most of the “no regrets” strategies are relatively low cost while providing substantial benefits. Implementation of these strategies will require action by local governments in combination with regional coordination.

In the short term, it is recommended that the region focus on establishing a framework for regional collaboration, identify and address immediate water quality concerns, and update or enhance its emergency planning to address more extreme and more frequent storm events.

Regional Collaboration Is Required. The projected impacts to the Scioto River basin associated with climate change are regional and will require regional collaboration and planning. This is a new approach for central Ohio, where the need to collaborate on resource planning has not been required in the past. In the Short Term, it is recommended that the region’s municipal leaders begin by establishing a forum for planning and collaboration, to address and consider the larger-scale issues related to maintaining safe and reliable water resources and water supply systems, both now and in the future.

Water Quality Improvements Are a Key Focus Area. Surface waters in the Scioto River basin already contain elevated concentrations of nitrogen and phosphorus. Higher temperatures in the future, combined with additional nutrient loads, will increase algal bloom frequency and intensity. Algal blooms can lead to a variety of aesthetic, health, and drinking water issues. There is some urgency in identifying and reducing the primary sources of nutrients in the watershed. Minimizing the nutrient and other pollutant loads is essential to protecting surface water quality in the region. A combination of structural and non-structural BMPs is recommended to address the primary external pollutant loads in the watershed. Optimization of reservoir operations and reservoir management is recommended to address primary internal reservoir pollutant loads. Enhanced monitoring is proposed to identify the primary external and internal pollutant loads.

A Robust Emergency Plan Is Critical for the Region. Over the past decade, the region has experienced record-breaking heat, unprecedented flooding, and prolonged periods of drought. Across the United States, we have also seen the impact of extreme weather events on utilities. Fortifying critical water infrastructure and robust emergency planning and preparedness is an important element of this Adaptive Management Plan for central Ohio.

Section 6: References

AWWA. Algae Source to Treatment, 1st ed. AWWA Manual M57. 2010.

Brekke, Levi. Addressing Climate Change in Long Term Water Resources Planning and Management. United States Army Corps of Engineers (US ACOE). 2011.

Brown and Caldwell. Upper Scioto River Watershed Water Inventory. Prepared for the Mid-Ohio Regional Planning Commission. 2014.

Center for Disease Control. Community-Wide Cryptosporidium Outbreak, Utah 2007. Morbidity and Mortality Weekly Report. September 12, 2008.

Center for Disease Control. Recreational Water Associated with Disease Outbreaks – United States, 2009-2010. Morbidity and Mortality Weekly Report. January 10, 2014.

Crittendon, J., Trussel, R., Hand, D., Howe, K., and Tchnobanoglous, G. Water Treatment: Principles and Design. 2nd Ed. John Wiley and Sons, Inc. 2005.

de Figueiredo, D.R., Azeiteiro, U.M., Esteves, S.M., Gonzalves, J.M. and M. J. Pereira. Microcystin-producing blooms—a serious global public health issue. Ecotoxicology and Environmental Safety 59: 151–163. 2004.

Department of Health and Human Services. Climate Change Adaptation Plan. 2012

Ecology. Aquifer Storage and Recovery (ASR) and Shallow Aquifer Recharge (SAR): tools to supplement water supply. State of Washington Department of Ecology website. 2014. http://www.ecy.wa.gov/programs/wr/asr/asr-home.html

Fawell, J.K., James, C.P. and H.A. James. Toxins from blue-green algae: Toxicological assessment of microcystin-LR and a method for its determination in water. Medmenham, Marlow, Bucks, Water Research Centre, pp. 1–46. 1994.

FEMA Ohio Flood Fact Sheet, Spring & Summer Floods. 2011.

Heinze, R. Toxicity of the Cyanobacteria Toxin Microcystin-LR to Rats after 28 Days Intake with the Drinking Water. Environmental Toxicology. Vol. 14, Issue 1, pages 57-60. 1999.

Lee, L. Integrated Water Management: Planning for Future Water Supplies. Santa Clara Valley Water District. WRF Project #04550. August, 2014.

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds. Climate Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program. 2014.

National Association of Clean Water Agencies (NACWA). Confronting Climate Change in Long Term Water Resources Planning and Management. NACWA. 2009.

Natural Resource Defense Council (NRDC). Thirsdy for Answers: Preparing for the Water Related Impacts of Climate Change in American Cities. 2012

Safe Drinking Water Foundation (SDWF). The Effect of Climate Change on Waterborne Diseases. SDWF, Saskatoon, Saskatchewan, Canada. 2010.

Sharvelle, S. Graywater Reuse. Water Research Foundation Integrated Water Management Workshop. August 26/27, 2014.

Svirčev, Z., Krstić, S., Miladinov-Mikov, M., Baltić, V., Vidović. M. Freshwater cyanobacterial blooms and primary liver cancer epidemiological studies in Serbia. J Environ Sci Health C Environ Carcinog Ecotoxicol Rev 27, 1, 36-55. 2009.

United States Department of Agriculture. Climate Change Adaptation Plan. 2012

United States Environment Protection Agency (USEPA). Adaptation Strategies Guide for Water Utilities. Climate Ready Water Utilities EPA. 2012.

USEPA. Climate Impacts and Adaptation Website. http://www.epa.gov/climatechange/impacts-adaptation/water.html USEPA. 2014.

USEPA. National Water Program 2012 Strategy: Response to Climate Change. 2012.

United States Geological Survey (USGS). Hydrological Effects of Potential Changes in Climate, Water Use, and Land Cover in the Upper Scioto River Basin, Ohio. 2015.

Water Environment Research Foundation (WERF), Water Research Foundation (WRF). Responding to Extreme Weather Events: Adaptation Strategies and Information Needs. Fact Sheet. 2013.

WHO. Cyanobacterial Toxins: Microcystin-LR in Drinking Water. Background Document for Development of WHO Guidelines for Drinking Water Quality. Guidelines for Drinking Water Quality, 2nd Edition. Addendum to Volume 2: Health criteria and other supporting information. WHO, Geneva. 1998.

WHO. Algae and Cyanobacteria in Fresh Water. In Guidelines for Safe Recreational Waters, Vol. 1: Coastal and Fresh Waters. 2003.

Wilbanks and Fernandez. Climate Change and Infrastructure, Urban Systems and Vulnerabilities. United States Department of Energy (US DOE). 2012.

Attachment A: Summary of Prioritized Risks by Sector

[This page left blank intentionally.]

Table A-1. Summary of Prioritized Risks by Service Sector

Predicted Changes	Affected Sector								
	Water Supply/ Water Quality	Water Treatment	Wastewater Treatment	Public Health	Agriculture	Environment	Economy	Energy	Transportation
Increased Air Temperatures / Increased incidence of heat waves	Increased evaporation, Reduced water volume Increased water demand and demand due to irrigation Increased in-stream organics Increased nutrient/ pesticide / herbicide runoff due to extended growing season, increased algal blooms Increased soil erosion	Negatively affects water quality Increased capital investment due to designing for peaking factors Taste and odor concerns, potential for algal toxins Increased chlorine demand, Increase DBPs	Impacts to infrastructure (increased corrosion) Lower flow affects discharge permits and treatment Increase need for odor control	Vector Diseases Increased issues for asthma and allergies Impacts to human mortality, Increase in heat illnesses and stresses on healthcare	Vegetation / Animal species shift Negative impact on livestock health / mortality Extended/disruptions to growing season Increased use of herbicides/pesticides/ nutrients with longer growing season Increased need for irrigation and controlled drainage	Vegetation / Animal species shift Increased smog / Decreased air quality	Extended recreational season Increased costs for utility services (water, wastewater, and energy) Increased service cost for food Decreased human productivity	Increased energy demand due to air conditioning, increased use of pumps for water / wastewater Decreased efficiency throughout production as temperature rises Increased power disruptions (brownouts)	Increase in road and bridge repairs and disruptions due to heat stress Increased use of private vehicles Change in construction materials for higher temperatures Extended but less efficient construction season
Increased water temperature	Decreased dissolved oxygen Increased release of phosphorus and other pollutants from anoxic zones/sediment Decreased mixing Longer duration of poorer water quality Increased algal blooms including blue greens (potential for increased toxin release)	Taste and odor concerns, potential for algal toxins Increased treatment costs due to algae and potentially algal toxins Increased treatment efficiency	Lower DO / changes in temp require affect wastewater discharge allocation Decreased organics at plant due to DBPs	Increase in waterborne diseases Increased use of disinfectants; increased DBPs	Increased costs to control water quality from fields Treatment and disinfection use increases Energy use for cooling Livestock management and aquaculture	Changes in pH and pollutant toxicity Negative impact on aquatic life diversity and numbers Decreased dissolved oxygen Increase in algal blooms	Algae growth could impact recreational use Increased energy cost due to power plant discharge cooling	Lack of cooling water could reduce energy production	Limited applicability
Warmer soil temperatures / Decreased soil moisture	Decreased groundwater base flow to streams Reduction/change in vegetative cover Increased soil erosion Increased in-stream organics Increased sediment deposition/loss of volume	Increased treatment demands due to lower water WQ Change of frequency in water main breaks in winter	Increased use of effluent sludge on farm fields	Impacts to private water systems	Increased need for irrigation and controlled drainage Vegetation / Animal species shift Increased soil conservation practices Increased need for crop insurance	Vegetation / Animal species shift Increased erosion Increase in invasive species	Negative impact on winter recreational activities if less snow/ice Higher food prices and potential job losses if results in loss of agricultural crops	Increased albedo; greater urban heat island effect leads to increased cooling demands	Reduced salt usage in winter Embankment erosion and damage due dry soils

Table A-1. Summary of Prioritized Risks by Service Sector

Predicted Changes	Affected Sector								
	Water Supply/ Water Quality	Water Treatment	Wastewater Treatment	Public Health	Agriculture	Environment	Economy	Energy	Transportation
Increased winter temperature and reduced ice cover	Increased water temperature Declining water levels due to increased evaporation in winter Earlier spring turnover Longer duration of poorer water quality	Reduced chance of frozen water lines and breaks in winter	Extended season for I/I Warmer water easier to treat Extended season for odor control	Fewer snow/ice related injuries Increase in vector diseases	Increased pests and invasive species Damage to crops that use snow as cover Increased growing season which increases use of nutrients and potential for erosion	Vegetation / Animal species shift Shift in growing seasons Increased evaporation	Increased transportation / navigation season Reduce road salt usage Reduction in winter recreational activities	Lower heating costs	Extended transportation season Reduced use of road salts / snow clearing
Change in vegetation / animal species composition	Reduction/change in vegetative cover which causes loss of stream bank shading and increased water temperature Increased soil erosion Increased sediment deposition/loss of volume Increased in-stream organics Increased nutrient, turbidity, and sediment loads and increased potential for algal blooms	Invasive plant / animals can negatively impact water quality, such as zebra mussels or phragmites	Limited applicability	Change in disease vectors	Increase and change in use of herbicides / pesticides Negative impacts to crop growth	Reduced resiliency of ecosystems Reduced carbon sequestration as forest compositions change	Impacts to agriculture and forestry industries	Limited applicability	Limited applicability
Higher maximum sustained stream flow (30 and 7-day higher maximum stream flows)	Increased organics, nutrient, turbidity, and sediment loads and other pollutant loads to surface water Increased watershed and stream bank erosion Increased algal blooms, including blue greens and potential for increased toxin release Increased sediment deposition/ loss of volume Negatively affects groundwater recharge Increased supply management challenges related to greater variability in stream flow	Increased treatment costs due to increased pollutant concentrations and increased disinfection by-products (DBPs) Increased turbidity Increased potential for viruses and bacteria Taste and odor concerns, potential for algal toxins	Increased treatment demands Reduced effectiveness of stormwater management measures Increased CSO volume and frequency	Increased use of cisterns for drinking water Increased mosquito populations Increase disease spread	Increased soil erosion, Loss of nutrients	Negative impact on aquatic life diversity and numbers	CSO/SSOs increase will increase the cost of treatment to ratepayers Increased flood damage Increase need for social services	Increased energy costs for water treatment	Update design sizes for bridges and culverts to new drainage standards Increase of hazardous drainage issues along highway during storm events

Table A-1. Summary of Prioritized Risks by Service Sector

Predicted Changes	Affected Sector								
	Water Supply/ Water Quality	Water Treatment	Wastewater Treatment	Public Health	Agriculture	Environment	Economy	Energy	Transportation
Extended dry periods / summer drought (Decreased minimum 30 day stream flow)	Decreased reservoir flow/volume and reduced mixing Decreased groundwater flow to streams Increased water demand Increased algal blooms, including blue greens (potential for increased toxin release) Reduction/change in vegetative cover Reduced reliability of yield from supply sources	Taste and odor concerns, potential for algal toxins, Increased treatment cost for algae and potential algal toxins Reduced groundwater supply/ recharge Reduced WQ and dilution of non-point source discharges	Lower flow affects discharge permits and treatment Reduced infiltration into sewers resulting in increased H_2S production Stresses on plants in LID such as rain gardens	Reduction in some vector diseases Increased allergens and dust Impacts to PWS	Lowered crop production Increased demand for irrigation but decreased water availability Vegetation/ animal shifts toward species better adapted to drought conditions	Vegetation / Animal species shift toward those better adapted to drought conditions Negative impact on aquatic life diversity and numbers	Decreased recreation Increased industrial treatment costs Low flow could affect transportation navigation through water Increased food cost due to decreased agricultural production (crop loss)	Increased energy for WWTP requirements Increased pumping costs for water supply	Shipping Impacts
Increased intensity of rain and wind events	Increased in-stream organics, nutrients, turbidity, and sediment and other pollutant loads Increased watershed and stream bank erosion Increased algal blooms, including blue greens (Potential for increased toxin release) Increased sediment deposition/ loss of volume	Reduced treatment capacity due to higher turbidity Damage to Infrastructure / Infrastructure failure including power outages, flooding and intake damages	Increased CSO/SSO discharges Flooding can create solid disposal issues/treatment Increased cost to treat Increased I/I to WWTPs Damage to Infrastructure/ Infrastructure failure including power outages and flooding	Loss of electrical/ water / sanitation services during and after event Increased demand on public health services Restricted access to critical care Septic System Failures Disaster related injuries / mortalities	Crop losses Soil erosion Need additional land set aside for increased flood zones	Soil / Channel Erosion Impacts from flood mitigation structures such as flood walls and increased flood zones Negative impact on aquatic life diversity and numbers	Increased insurance costs; increased damages due to floods/storms Could affect recreational use Increased snow: Expensive to remove	Increased vulnerability of power supply system Increased investment in resilient infrastructure	Infrastructure access Infrastructure damage / failure Inability to transport food and water in critical situations Increased snow: changing fleet needs Increased snow: Increased road deterioration

Attachment B: Non-Water Service Sector Adaptive Strategies

[This page left blank intentionally.]

B.1 Public Health

The high-priority risks identified for the public health sector are listed in Table B-1. The changing climatic conditions projected by the USGS modeling will impact the public health and well-being of the region in a variety of ways. Climate change may worsen existing diseases and conditions and introduce new pests and pathogens into communities (U.S. Department of Health and Human Services, 2012). In addition, increased temperatures and more extreme storms will have a direct negative impact on human mortality. The most vulnerable populations are children, the elderly, the poor, and those with underlying health conditions. The potential adaptation planning and policy, operational and capital improvement strategies, and relative costs to mitigate each of the high-priority risks for public health are summarized in the discussion below and Tables B-2 through B-5.

Table B-1. High-Priority Risks to Public Health

Vulnerability Scenario	Risks
Increased air temperature	Increased issues for respiratory issues among sensitive groups
	Impacts to human mortality, increase in heat illnesses, and stresses on health care
Increased water temperature	Increase in waterborne diseases
Extended dry periods/summer drought	Increased allergens and dust
Increased intensity of rain and wind events	Loss of electrical/water/sanitation services
	Increased demand on public health services
	Restricted access to critical care
	Disaster related injuries/mortalities

B.1.1 Mitigating Impacts from Poor Air Quality

Adaptive management strategies for alleviating the impacts due to poor air quality as related to projected increased temperatures are provided in Table B-2. Strategies focus on decreasing air pollutant levels and mitigating urban dust during extended dry weather. Warmer temperatures could increase the concentration of unhealthy air pollutants, exacerbating health issues for people with asthma and respiratory issues. More than 20 million people in the Midwest already experience air quality that fails to meet national ambient air quality standards, and this number is projected to increase (Melillo, 2014). In addition, warmer temperatures are lengthening the pollen season. Spring is already occurring earlier in the United States, creating longer periods of respiratory issues for people with allergies (USEPA, 2014).

> Columbus, Ohio ranked 34 on the list of 100 most challenging places to live with asthma. –
>
> *Allergy Capitals 2010*, Asthma and Allergy Foundation of America

In the Short Term, public outreach and education is recommended to help keep at-risk groups safer. MORPC has an ongoing public education and monitoring program for ground-level ozone and particle pollution levels (MORPC Air Quality). MORPC issues daily air quality forecasts using the Air Quality Index (AQI) which tells residents how clean or polluted the air is, and the associated health effects. On Air Quality Alert days, sensitive groups including active children, older adults, and those with breathing or heart conditions can reduce their exposure by planning outdoor activities in the morning when ozone levels are generally lower. Besides providing public education, this ongoing program provides good data for evaluating the changes to air quality over time Increasing street sweeping during dry periods is another “no regrets” strategy. Street sweeping significantly reduces the accumulation of dust, debris, and pollutants on streets in urban areas, thereby reducing both air pollution and water pollution from stormwater runoff.

In the midterm, a Regional Transportation plan should be developed. Increased mass transit would reduce overall air pollution. Adoption of low or zero-emitting fuels, such as compressed natural gas or electricity, would reduce air pollution loading. Fleet management policies, such as anti-idling, would also provide air quality benefits.

In the Long Term planning horizon, if air monitoring indicates significant negative changes to regional air quality, other identified strategies such as changing air pollution regulations should be considered. Modifications to zoning and development planning to increase opportunities for pedestrian and bicycle transportation would reduce automobile emissions. Capital improvements that came out of the regional transportation plan would also be implemented during this time period.

Table B-2. Increased Issues for Respiratory Issues Due to Increased Temperature and Increased Summer Drought

Strategy	No Regrets	Cost
Planning and Policy		
Monitor and release information on air quality		$
Develop Regional Transportation Plan to limit pollution related to cars/mass transit		$$
Institute anti-idling policies on fleet vehicles	✓	$
Increase statewide regulations on air pollution *		$$
Implement sustainable development patterns to promote walkable communities*		$$
Operational		
Expand the public outreach and education program using social media throughout the region	✓	$
Increase street sweeping in urban areas	✓	$$
Adopt use of low or zero-emitting fuels at point of use	✓	$$
Capital Improvement		
Implement light rail in municipal areas, rail or other options for regional transit *		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

B.1.2 Mitigating Impacts of Heat on Human Mortality

Public health and human mortality will also be impacted by increasing temperatures and incidences of heat waves. Heat waves and greater temperatures will increase the number of heat illnesses such as heat stroke and dehydration in the region. Heat waves, such as the one that occurred in Chicago in 1995, are projected to significantly increase in the latter half of this century. The 5-day-long heat wave in Chicago peaked at 106°F and resulted in more than 700 deaths (USEPA, 2012). In the United States, mortality increases 4 percent during heat waves compared with non-heat wave days (Melillo, 2014).

In the Short Term, it is recommended to leverage MORPC's existing air quality monitoring public education forum to also communicate the risks of higher temperatures on human health. Conservation measures are also recommended, including incentives for developers to install green roofs and tree planting in an effort to reduce the urban heat island effect.

In the midterm planning horizon, it is recommended to conduct a Community Heat Stress Mitigation Plan to identify at-risk areas where residents may be especially susceptible to heat-related illnesses, and to identify potential access to cooling centers. As heat-related illnesses are already a problem facing the region, it is recommended that at a minimum, the region needs to develop a plan for neighborhood support and for providing access to air-conditioned centers or pools to alleviate heat stress.

In the Long Term, as climate changes and the associated local impacts on health are better understood, capital improvement strategies related to the construction of additional pools and cooling centers and air conditioning of schools should be considered and incorporated into municipal plans. Building standards should be improved to conserve energy. Health services should also be expanded, especially in at-risk areas, to accommodate underserved and critical populations.

Table B-3. Impacts to Human Mortality Due to Increased Temperature

Strategy	No Regrets	Cost
Planning and Policy		
Conduct Community Heat Stress Mitigation Plans to identify potential community cooling centers, splash pads or pools, and to include neighborhood support plan (neighbors check on neighbors) during heat	✓	$
Update building standards to promote better energy usage		$$
Operational		
Implement public education and outreach plans regarding heat stress and hydration (in conjunction with air quality outreach program)	✓	$
Implement incentive program for developers related to use of green roofs in development and re-development projects		
Provide access to cooling centers during summer months, potentially in schools/churches with air conditioning*		$$
Capital Improvement		
Implement tree planting program to increase shade in urban areas		$$
Implement green roofs in urban centers to reduce heat island effect		$$
Construct and maintain neighborhood pools/splash pads*		$$
Expand health services as needed to facilitate response to increased heat related illnesses*		$$
Install air conditioning in neighborhood schools to serve as cooling centers during summer months*		$$
Provide fans and distribute to low income areas*		$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

B.1.3 Increase in Waterborne Disease

The associated increase in water temperatures will likely encourage the spread of waterborne diseases. Warmer water temperatures promote the development of many vector organisms and could also shift additional organisms northward that currently do not exist in the Upper Scioto River watershed. Diarrheal diseases as well as viruses and parasites such as giardiasis and cryptosporidiosis are commonly spread through contact with water (SDWF, 2010; CDC, 2010). As temperatures increase human contact with water generally increases, which creates a rise in the number of waterborne illnesses.

The incidence of cryptosporidiosis peaks in late summer and coincides with the summer swimming season. The number of non-outbreak cryptosporidiosis cases reported nationally increased from 3,411 cases in 2004 to nearly 8,300 in 2007 (CDC, 2008). This substantial increase (143 percent) mirrors the increase in the number of nationally reported cryptosporidiosis outbreaks associated with treated recreational water venues (e.g., pools, water parks, and interactive fountains). This health issue may be exacerbated in the future with increased need for access to public pools for cooling during extended heat waves.

Under current climate conditions, the region is also experiencing increased blooms of blue-green algae associated with nutrient runoff and higher temperatures. These algal blooms pose a health risk to the region. Cyanobacteria (blue-green algae) toxins are a concern when present in drinking water supplies as discussed in Section 3.2. These toxins can also cause serious health issues including poisoning, impacting the liver and the nervous system, and skin and mucous irritation from human or animal contact. The recent toxic algae problem in Toledo, Ohio, reflected the impact this problem is having on municipalities in central Ohio under current climatic conditions. Projected increases in temperature will likely exacerbate this problem associated with algal blooms.

Adaptive strategies that have been recommended to mitigate the health risks associated with waterborne disease and toxic algae are also presented in Section 3.2. Strategies range from planning studies to capital improvements all focused on reducing bacteria and nutrient runoff into streams, rivers, and reservoirs. Many of these strategies are recommended under current conditions to alleviate the nutrient loads from stormwater and septic systems in order to address the growing problems associated with bacteria and algae blooms. **In addition to these strategies, in the Short Term, public outreach could be focused on pet waste awareness, reducing biological pollutant loads.**

In the Mid Term planning horizon, it is recommended that a sewer connection plan be developed to identify aging home sewage treatment systems (HSTS) and where they may potentially be contributing bacteria to water sources. Developing a Regional Watershed Management Plan will identify strategies to improve water quality issues and reduce the potential for spread of many waterborne illnesses.

In the Long Term, it is recommended that HSTSs are inspected frequently and regularly, and eventually eliminated as connections to the sewerage system are made. It is also recommended that the U.S. Department of Agriculture's (USDA's) program that offers grants to farmers to assist with farm fencing is expanded possibly through the Ohio Farm Bureau or the soil and water conservation district offices. This program significantly reduces biological pollutant sources in the watershed.

Table B-4. Increase in Waterborne Disease Due to Increased Temperature		
Strategy	No Regrets	Cost
Planning and Policy		
Conduct Sewer Connection Plan to reduce bacteria in water sources from areas served by aging home sewage treatment systems (HSTS)	✓	$
Develop Regional Watershed Management Plan to identify strategies to improve water quality including focus on land use planning options to reduce bacteria and other potential disease organisms in water	✓	$
Operational		
Implement increased pet waste awareness campaigns	✓	$
Increase frequency of inspections of HSTS*	✓	$
Capital Improvement		
Implement sewer connections to serve areas currently served by HSTS*		$$$
Implement livestock fencing and other measures to reduce non-point source pollution due to animal waste	✓	$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

B.1.4 Impacts to Electrical/Water/Wastewater Services and Critical-Care Facilities

Flooding and storm damage from major storm events can have severe impacts on public health. Flooding can inundate urban areas and disrupt transportation along the region's roads. For example, flooding in the Midwest in 2008 caused 24 deaths and closure of key transportation routes (Melillo, 2014). Flooding and high winds can damage roadways, drainage structures, and power supply equipment, thereby reducing access to health care facilities. It is especially critical for health care facilities and other emergency response infrastructure to incorporate future climate change into their planning for continuous operation during such events. Table B-5 provides the detailed strategies to alleviate impacts to public health associated with increased intensity of rain and wind events.

In addition to the immediate fatalities and injuries associated with extreme storm and flood events, are numerous illnesses and deaths associated with consumption of contaminated water. Floods can lead to transmission of waterborne diseases by contaminating fresh water with untreated and partially treated sewage and indirectly by causing the breakdown of water supply and treatment facilities (NRDC, 2012). An extreme example was the outbreak of cryptosporidiosis in Milwaukee in 1993 when 54 people were killed and over 400,000 illnesses were reported due to water contamination following heavy storms.

In the Short Term, an emergency plan which accounts for vulnerabilities in the transportation, power, and basic utilities and how they impact critical care facilities is recommended. The more prepared the region is to restore these services, the more lives will be saved in the event of an emergency. This emergency plan includes understanding system vulnerabilities including flooding and identifying opportunities for redundancy in critical or isolated parts of the health care network. It also includes developing mutual aid agreements and sharing resources between critical care facilities within the region.

Long term strategies include the implementation of capital improvements as identified in the emergency plan to address vulnerabilities. These improvements could include redundant infrastructure, back-up power, flood-proofing, and elevated roadways.

Table B-5. Impacts to Electrical/Water/Wastewater Services and Critical-Care Facilities Due to Increased Intensity of Rain and Wind Events		
Strategy	No Regrets	Cost
Planning and Policy		
Develop or update Regional Emergency Preparedness and Response Plans including focus on utilities and critical-care facilities including a health care access plan	✓	$
As part of emergency plan, develop regional flooding potential maps for more intense and longer-duration storm events (in excess of the 100-year flood based on past climatic conditions)	✓	$$
Evaluate options for increased wastewater/stormwater storage during storm events	✓	$
Evaluate potential to increase redundancy in systems to allow for sharing resources	✓	$$
Develop mutual aid agreements between critical-care facilities within the region	✓	$
Develop backup power plans to maintain utility service and service to critical-care facilities	✓	$
Capital Improvement		
Invest in alternative power supply options at facilities including generators, solar panels, and wind generators*	✓	$$$
Increase flood-proofing of utilities, roadways, and critical-care facilities*	✓	$$$
Increase spillway capacity and armoring of dams to reduce potential for dam breaks*		$$$
Invest in additional storage capacity in wastewater and stormwater utilities to mitigate flooding*		$$$
Invest in elevated roadways to maintain access to critical-care facilities (as needed per emergency response plan)*		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

*Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning

B.2 Agriculture

The high-priority risks identified for the agricultural sector are listed in Table B-6. Adaptive strategies to mitigate each of these vulnerabilities are provided in the following tables and following paragraphs. It should be noted that many of the risks identified for the agricultural sector have been evaluated in relation to water quality as presented in Section 3.2.1. The potential adaptation planning and policy, operational and capital improvement strategies, and relative costs to mitigate each of the high-priority risks for agriculture are summarized in Table B-7 and in the discussion below.

Table B-6. High-Priority Risks to Agricultural Sector	
Vulnerability Scenario	Risks
Increased air temperature	Negative impact on livestock health and mortality
	Crop die off
	Increased need for irrigation and controlled drainage
Increased water temperature	Increased cost to control water quality from fields
Warmer soil temperatures/decreased soil moisture	Increased need for irrigation and controlled drainage
Decreased minimum 30-day river flows/extended dry periods/summer drought	Increased demand for irrigation with decreased water availability

B.2.1 Strategies to mitigate impacts from increased heat and changes in flow

Increasing temperatures and greater variability in precipitation will impact water availability and quality, crop production, and livestock health and productivity. As stated in the USDA Climate Change Adaptation Plan, "the agricultural sector has a strong record of innovation and adaptability, but the magnitude of climatic changes projected for this century including increased frequency of extreme events, exceed the variations that have been managed in the past and will challenge all elements of agricultural production systems" (USDA, 2012).

As discussed in Section 3.2.1, predicted changes in temperature and precipitation will have a negative impact on water quality and availability within the region. Longer growing seasons and higher-intensity rain events could lead to increased nonpoint pollution from runoff. Longer dry periods could also lead to a need for crop irrigation and increased demand on water sources.

Longer dry periods and greater heat could stress existing crops. Extreme wind and precipitation events can also cause significant damage to crops.

Increased temperatures can have a detrimental effect on the health and productivity of livestock. When experiencing heat stress dairy cattle experience a reduction in the amount of milk produced and beef cattle experience a reduction in growth. Other livestock animals such as pigs and chickens can suffer health effects from heat stress as well. Changes in climate will also have an impact on the production of food for livestock. This reduction in production and animal health has a direct effect on food supply and the economy due to reduced supplies of meat, milk, and eggs and increased food prices.

These vulnerabilities can be mitigated through nutrition and heat management strategies. Agricultural producers can shift the timing of animal feeding to cooler parts of the day, which reduces the animal's core temperature increase as the food digests. Farms can install shade structures for grazing areas with little or no natural shade. The addition of sprinklers and additional water sources also helps to reduce the heat stress experienced by livestock. The costs of these strategies would be borne by the agricultural producers and could be significant depending on the size of the herds being managed.

In the Short Term, mitigation of these vulnerabilities will require a regional approach including public education, partnerships with key stakeholders to develop nutrient management and water sharing plans, as well as agricultural investment in conservation practices. As discussed in Section 3.2.1, the modification of local ordinances to require LID will improve groundwater recharge throughout the region as these practices more closely mimic natural hydrology.

In the Mid Term planning horizon, it is recommended that the region collaborate on the development of a Regional Water Supply Management Plan as discussed in Section 3.2.1,, including the evaluation of water demand, availability, potential new sources, and the identification of emergency supply sources that can be used during drought extreme conditions. Changes in agricultural practices may significantly impact the ability of drinking water utilities to provide sufficient supply for residents. Rather than competing for this potentially limited resource, these two sectors can work together to establish mutually beneficial solutions to meet their water needs. Solutions may include increased use of stormwater harvesting or wastewater reuse to address regional water needs.

In the Long Term, the changing conditions will need to be evaluated and agricultural practices adjusted to fit these needs, including installing high efficiency irrigation systems, water reclamation, controlled drainage, and rotating crops or even developing new crops that will be more successful in this changing climate. Long term investments may also include heat abatement equipment such as fans and sprinklers to maintain livestock health. Based on the results of the Regional Water Supply Management plan, new water supply sources to irrigate may need to be developed.

Table B-7. Strategies to mitigate impacts from increased heat and changes in flow		
Strategy	No Regrets	Cost
Planning and Policy		
Implement public outreach and education on water quality issues: causes and prevention	✓	$
Establish partnerships among key stakeholders: education and information sharing	✓	$
Modify local stormwater management and land development ordinances to require LID, reduce impervious areas, and use rainwater and stormwater harvesting/reuse, thereby reducing pollutant runoff volume		$
Develop Regional Water Supply Management Plan to identify strategies for extended drought conditions including irrigation water needs and water sharing alternative evaluation	✓	$
As part of Supply Plan, determine potential future water needs for agriculture as well as potential for use of recycled water for irrigation		$
As part of Supply Plan, develop guide for and promote rainwater and stormwater harvesting/reuse		$
Operational		
Implement conservation practices; e.g., cover crops, conservation tillage, nutrient management planning, etc.	✓	$-$$
Adjust crop mix and/or planting schedules, as needed*		$
Development of crop insurance programs that would aid in the reduction of chemicals used*		$$
Alter livestock feeding schedules and nutritional balance*		$
Capital Improvement Strategies		
Reduce agricultural water use by working with irrigators to install advanced equipment such as drip or other micro-irrigation systems with weather linked controls*		$$
Installation of controlled drainage in agricultural fields*		$$$
Development of water sources; irrigation, ponds, cisterns*		$–$$
Build systems to reclaim wastewater for energy, industrial, agricultural, or irrigation water use*		$$$
Installation of heat abatement equipment: fans, shade tarps, sprinklers, additional water sources*		$–$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

B.3 Environment

Only one high-priority risk was identified for the environment as listed in Table B-8 below. Adaptive strategies have been evaluated in relation to environmental water quality and water supply and are presented in Section 3.2.1. The strategies related to increased smog and decreased air quality is presented in relation to public health in Sections B.1.

Table B-8. High-Priority Risks to the Environment	
Vulnerability Scenario	Risks
Increased air temperature	Increased smog/decreased air quality (see Section B.1.1)

B.4 Economy

The high-priority risks identified for the economy are listed in Table B-9, below. Adaptive strategies to mitigate each of these vulnerabilities are provided in the following tables and discussed in the subsequent paragraphs. It should be noted that many of the high-priority threats to the economy have also been evaluated in relation to the other service sectors.

Table B-9. High-Priority Risks to the Economy

Vulnerability Scenario	Risks
Increased air temperature	Increased service cost for food
	Increased cost for utility services (water, wastewater, and energy)
	Decreased human productivity
Increased 30-day and 7-day maximum high stream flow	Increased flood damage
Extended dry periods/summer drought	Increased food cost due to decreased agricultural production (crop loss)
Increased intensity of rain and wind events	Increased insurance costs; Increased damages due to floods/storms

B.4.1 Minimizing Economic Impacts

Many of the risks to the other sectors will ultimately have an effect on the economic health of the region. The strategies to minimize the economic impacts are summarized in Table B-10. Decreased water quality and reduced water supplies increase the cost to supply and treat water for human use. Higher temperatures result in the increased use of air conditioning and fans, which increase electrical usage and air pollutant emissions, and drive up energy costs. Finally, increased agricultural costs to bring water to fields and install advanced drainage systems, and loss of production will all increase the cost of food within the region and beyond. The recent drought in northern Georgia provides an example of the impact of increased drought and climate change on the economy of a region. In late spring 2008, Lake Lanier, the region's major water supply, was at 50 percent of its storage capacity. This drought, combined with record high temperatures, resulted in an estimated $1.3 billion in economic losses related to impacts to industries, decreased agricultural production, and reductions to water utility revenues related to increased conservation (WERF, WRF, 2013).

Storm damage and the disruption of service associated with increased incidence and intensity of weather events not only represents a cost to the region associated with cleanup, repair, or replacement of infrastructure but also economic and social impacts as the supply chains are disrupted, economic activities are suspended, and social well-being is threatened. The impacts to the economy associated with increased flooding are well documented by FEMA in relation to response to recent floods across the country. In Ohio, $240 million in damages were caused in just over one week by severe storms and flooding in several counties including Allen, Crawford, and Hardin (FEMA, 2011). Flooding presents urgent challenges to all sectors during a flood event as well as Long Term recovery efforts that result in large capital costs related to damages to communities, infrastructure, and industries.

In the Short Term, strategies such as energy and water conservation that will also impact this sector have largely been addressed under the other sectors in this TM. Increased focus on planning for increased heat-related problems such as health effects and power supply, which has also been discussed throughout this TM, will also mitigate the impacts of climate change on the economy. Critical to mitigating economic damages is developing or updating a regional emergency preparedness and response plan. The more prepared the region is to deal with an extreme weather event, the faster key processes can be restored, and the faster economic losses can be recovered. Similar emergency planning is recommended for most other sectors in this TM.

Mid Term planning includes conducting a regional health care access plan and regional energy study. These plans will help mitigate disruptions to key service while identify out the most affordable regional improvements.

Long Term efforts include adjusting working strategies and capital investments to reduce impacts on the economy.

Table B-10. Minimizing Economic Impacts		
Strategy	No Regrets	Cost
Planning and Policy		
Develop or Update Regional Emergency Preparedness and Response Plans for extreme weather events	✓	$
Conduct Regional Energy Study to evaluate alternatives to increase peak energy capacity to minimize brownouts and	✓	$
Develop Regional Health Care Access Plan to evaluate stress on health care systems related to increased heat related disease and illnesses	✓	$
Conduct Utility Rate Studies to evaluate impact of utility rate changes on regional industries and the economy*		$
Operational		
Implement energy conservation practices	✓	$–$$
Adjust working hours due to lower productivity during high heat*		$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

B.5 Energy

The high-priority risks identified for the energy sector are listed in Table B-11. The potential adaptation planning and policy, operational and capital improvement strategies, and relative costs to mitigate each of the high-priority risks for the energy sector are summarized in the discussion below and in Table B-12.

Table B-11. High-Priority Risks to Energy Sector	
Vulnerability Scenario	Risks
Increased air temperature	Increased power disruptions (brownouts)
Increased water temperature	Lack of power plant cooling water could reduce power production
Increased intensity of rain and wind	Increased vulnerability of power supply

The effects of climate change on the energy sector will be felt on both supply and demand. Increased variability in water quantity and timing due to projected changes in the frequency and timing of precipitation will have impacts on hydropower. The likely increase in heat waves will result in more peak load demands, stresses on energy distribution systems, and more frequent brownouts or blackouts. These will also have negative impacts on public health and the economy. The energy required by the water sector is a significant percentage of the overall energy use in a region. Municipal water processing and transport consumes about 4 percent of the nation's electricity. Increased treatment requirements for both wastewater and water would further increase energy use for treatment. These impacts will be most significant during summer months when water quality is typically degraded, treatment requirements increased, and water and energy demands both peak.

B.5.1 Minimizing Power Disruptions

Energy supply systems are also at risk from severe weather events. Increased temperatures result in powerline sagging, degradation of conductor insulation, increased voltage drop and increased transmission losses. In some areas the existing transmission and/or distribution systems are already operating at or above capacity. At times of peak demand this is exacerbated, and may result in outages due to overloaded transformers. Severe weather such as lightning and wind can have devastating effects on energy supply infrastructure, resulting in power loss to customers.

In the Short Term, public education on energy conservation combined with incentive plans to encourage conservation practices will help to reduce system demands. Performance of a regional energy study would help energy distributers understand critical needs as well as identify the best areas for capital investment in energy production. Developing a regional emergency preparedness and response plan is critical to quickly restoring service during an extreme weather event. As part of this emergency plan, infrastructure assessments should be conducted to provide energy producers with an understanding of existing assets and potential vulnerabilities.

In the midterm, investments should be made to energy infrastructure based on the results of the regional energy study including increased deployment of distributed renewable energy systems.

Potential Long Term strategies would include implementing micro-grids with all energy needs produced locally with renewable energy; increased redundancy in transmission and distribution infrastructure, particularly to critical facilities; deploy distributed battery storage systems to supply power during peak demand periods and to reduce the capacity of standby generation that is needed; decommissioning high-pollutant power generating facilities (i.e. coal-fired power plants) and replacing them with lower-polluting (combined-cycle natural gas) or renewable (solar, wind) central plants.

Table B-12. Minimizing Power Disruptions		
Strategy	No Regrets	Cost
Planning and Policy		
Implement public education on power consumption and conservation	✓	$
Maintain/Expand incentive plans for high-efficiency HVAC, appliances, insulation, etc.	✓	$$
Develop/or update of Regional Emergency Preparedness and Response Plans		$
As part of emergency plan, evaluate vulnerability of existing infrastructure	✓	$
Conduct Regional Energy Study to evaluate alternatives to increase peak energy capacity to minimize brownouts and to evaluate potential sources for additional power sources including wind and solar alternatives		$
Adopt Architecture 2030 for the design of new publicly-funded buildings with the goal of achieving net-zero energy and carbon emissions*		$$$
Operational		
Implement energy conservation		$
Develop revised infrastructure design standards*		$
Capital Improvement		
Upgrade critical infrastructure to withstand increased demands and storm events*		$$$
Construct alternative and back-up power supply sources including solar and wind generation with battery storage at critical facilities including health care, water/wastewater treatment, and pumping stations*		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*

B.6 Transportation

The high-priority risks identified for the transportation sector are listed in Table B-13. The potential adaptation planning and policy, operational and capital improvement strategies, and relative costs to mitigate the high priority risk of damage from increased intensity of rain and wind events is summarized in Table B-14 and in the discussion below.

Table B-13. High-Priority Risks to the Transportation Sector	
Vulnerability Scenario	Risks
Increased intensity of rain and wind events	Infrastructure access/infrastructure damage/failure
	Interruption to emergency services including the transportation of food and water in critical situations

B.6.1 Increasing the Resilience of the Transportation System

Existing transportation infrastructure is designed to handle historical precipitation and temperature ranges. These design parameters could allow roadway drainage to be overwhelmed by higher-intensity rain events and roadways to become impassible and potentially damaged by fast-moving floodwaters.

In the Short Term, it is recommended that a regional emergency preparedness and response plan be developed or updated. Transportation is a critical piece to the preparedness of the rest of the region – without the ability to transport goods, services, and repair crews, the region will not be able to recover from a severe event. Failure of the transportation system limits the ability to respond to emergencies and provide essential supplies and services, which can cost lives in a critical situation. As part of this emergency plan, transportation infrastructure assessments should be conducted to provide energy producers with an understanding of existing assets and potential vulnerabilities. Critical transportation routes and infrastructure and alternative routing should be identified in case of a failure.

Interstates 70 and 75 near Dayton, Ohio were closed due to flooding after a rain event in May, 2014 that dropped almost four inches of rain in four hours. This event stranded motorists on the interstates and prevented traffic access for six hours on several major roadways.

In the Long Term, it is recommended that upgrades and improvements be made to the infrastructure as well as design standards that are based on changing conditions. The existing transportation system should be assessed for performance based on potential future storm events.

Table B-14. Increasing the Resilience of the Transportation System

Strategy	No Regrets	Cost
Planning and Policy		
Development/update of Regional Emergency Preparedness and Response Plans	✓	$
As part of emergency preparedness plan, evaluate transportation system vulnerability to assess existing transportation infrastructure based on potential storm events	✓	$
Operational		
Develop revised transportation drainage infrastructure design standards*		$
Capital Improvement		
Upgrade critical transportation infrastructure to withstand greater storm events*		$$$

$ - Can be funded by the service sector within the typical annual budget

$$ - Require planning to implement as part of the capital improvement plan for the service sector

$$$ - Require significant bonding, federal or grant funding, or changes to utility rates to implement the improvement

**Long Term strategies need to be refined based on updated climate projections and outcomes of the Mid Term planning*