Adaptive Management Planning for Climate Change

November 3, 2014

Lisa Jeffrey, PE
Brown and Caldwell
Agenda

- Model Results – What Does it all Mean
- Adaptive Management Approach
- Vulnerability Assessment
  - Sector based vulnerabilities
  - Risk and Impact Evaluation
- Development of Adaptive Management Strategies
  - Adaptive strategy evaluation metrics, costs, time frame
  - High priority strategies
- Conclusions & Regional Considerations
Sustaining Scioto Partners
Two-Phased Project Approach

- Watershed Model - USGS
- Adaptive management planning
  - USGS Model results
  - Stakeholder Committee
Stakeholder Advisory Committee

- Representatives included:
  - Municipalities, Utilities
  - Agricultural
  - Industrial
  - Regulatory communities
  - Environmental advocacy groups

- Provide input on current and future water needs
- Assess water resource vulnerabilities
- Evaluation of adaptive management strategies.
USGS Modeling

• Develop a hydrologic model for the Upper Scioto River basin
• Calibrate and validate the model with historical observed climate and streamflow data
• Simulate runoff characteristics for climatic conditions that are projected to occur in the future (with and without anticipated population growth and build-out)
Upper Scioto River Basin

- Study watershed is 3,217 mi$^2$ (8,332 km$^2$)
- Eight major contributing sub-basins
- 5 on-stream reservoirs
- Land use spans from highly urbanized to significant agricultural use
Actual vs Projected Annual Mean Temperature (F)
Watershed Modeling Results

- Increase in the variability of stream flow including higher maximum flows and lower minimum flows
- Longer durations of extended minimum stream flows and reservoir levels especially in spring and summer
Climate Model Results

**Short-Term**
- 2015 to 2025
- Climate within normal range

**Mid-Term**
- 2026 to 2045
- Increase in annual average temperature and higher seasonal temp
- Increase variability in flow and precipitation

**Long-Term**
- 2046 to 2090
- Increased uncertainty – regional development as well as climate
- Increased temperature and variability in flow
Additional Model Results

Long-Term

- With projected development, areas where water supply may be inadequate with current operational practices.
- Areas in basin where future water use will be withdrawn from groundwater, discharged to surface water system.
- Areas in basin where significant future irrigation water needs are anticipated, especially related to agricultural practices.
Adaptive Management Approach

Vulnerability Assessment → Prioritize Risks → Evaluate Adaptation Strategies → Adaptive Management Plan → Implement and Monitor

Iterative Approach
Re-evaluate and adjust as new information becomes available
Overall Prioritization Methodology

Predicted Changes
Evaluated changing conditions & ranked based on **Likelihood** of occurrence

Risks
Ranked based on **Impact** on the region

Adaptation Strategies
Ranked based on **Timing** and **Regional Conditions**
Prioritization Methodology: Predicted Changes

- **Highly likely to occur:**
  - Linked to defined trends from the model results and climate data

- **Medium probability of occurrence:**
  - Results shown in the models
  - Less distinct trends
  - Associated with build-out or trends in precipitation

- **Low probability of occurrence:**
  - Not directly predicted by the model results
  - Considered less likely to occur based on the analysis
### Predicted Changes

<table>
<thead>
<tr>
<th>No.</th>
<th>Predicted Changes</th>
<th>Likelihood of Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Increased air temperatures/increased incidence of heat waves</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Increased water temperature</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>Warmer soil temperatures/decreased soil moisture</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Higher sustained maximum flow (30- and 7-day higher peak river flows)</td>
<td>Medium</td>
</tr>
<tr>
<td>5</td>
<td>Extended dry periods/summer drought (decreased minimum 30-day stream flow)</td>
<td>Medium</td>
</tr>
<tr>
<td>6</td>
<td>Increased intensity of rain and wind events</td>
<td>Medium</td>
</tr>
<tr>
<td>7</td>
<td>Change in vegetation/animal species composition</td>
<td>Low</td>
</tr>
</tbody>
</table>
Prioritization Methodology: Risks

- **Predicted Changes**
  - Ranked based on **Likelihood** of occurrence

- **Risks**
  - Ranked based on **Impact** on the region

- **Adaptation Strategies**
  - Ranked based on **Timing** and **Regional Conditions**

**Affects Livability of Region**
- High Priority
- Medium Priority
- Low Priority

**Impacts Quality of Life in Region**
- High Priority
- Medium Priority
- Low Priority

**Less Impact on Quality of Life in Region**
- High Priority
- Medium Priority
- Low Priority
Prioritization Methodology: Risks By Sector

Projected or Potential Future Challenges

- Precip.
- Temp.
- Flow

Risks By Sector

- Water Quality / Water Supply
- Water Treatment
- Wastewater Treatment
- Environment
- Public Health
- Economy
- Energy
- Transportation
- Agriculture

SUSTAINING SCIOTO – Mid-Ohio Regional Planning Commission
## Prioritization Methodology: Risks

<table>
<thead>
<tr>
<th>Vulnerability Scenarios</th>
<th>Water Supply/ Water Quality</th>
<th>Water Treatment</th>
<th>Wastewater Treatment</th>
<th>Public Health</th>
<th>Agriculture</th>
<th>Environment</th>
<th>Economy</th>
<th>Energy</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increased Air Temperatures / Increased Incidence of Heat Waves</strong></td>
<td>Increased evaporation, Reduced water volume</td>
<td>Negatively affects water quality</td>
<td>Impacts infrastructure (increased erosion)</td>
<td>Vector Diseases</td>
<td>Vegetation / Animal species shift</td>
<td>Vegetation / Animal species shift</td>
<td>Extended recreational season</td>
<td>Increased energy demand due to air conditioning, increased use of pumps for water/wastewater</td>
<td>Increased use of private vehicles</td>
</tr>
<tr>
<td></td>
<td>Increased water demand and demand due to irrigation</td>
<td></td>
<td></td>
<td>Livestock/health / mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased intra-stream TCO</td>
<td>Increased capital investment due to designing for peak flow factors</td>
<td>Lower flow affects discharge permits and treatment</td>
<td>Increased issues for asthma and allergies</td>
<td>Increased use of herbicides/pesticides/nutrients with longer growing season</td>
<td>Increased smog/Decreased air quality</td>
<td>Increased service cost for food</td>
<td>Increased human productivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased watershed erosion</td>
<td>Taste and odor concerns, potential for algal toxins</td>
<td>Increase need for odor control</td>
<td>Impacts to human mortality, Increase in heat illnesses and stresses on healthcare</td>
<td>Increased need for irrigation and controlled drainage</td>
<td>Increased need for irrigation and controlled drainage</td>
<td>Decreased utility services (water, wastewater, and energy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Increased Water Temperature</strong></td>
<td>Decreased dissolved oxygen</td>
<td>Taste and odor concerns, potential for algal toxins</td>
<td>Increased chlorine demand, Increased DBPs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased release of phosphorus and other pollutants from anoxic zones, sediment</td>
<td>Increased treatment costs due to algal and potentially algal toxins</td>
<td>Lower DOC / changes in temperature affect wastewater discharge allocation</td>
<td>Increase in waterborne diseases</td>
<td>Increased costs to control water quality from fields</td>
<td>Changes in pH and pollutant toxicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decreased mixing</td>
<td>Increased treatment efficiency</td>
<td>Decreased organic at plant due to DBPs</td>
<td>Increased use of disinfectants; Increased DEPs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longer duration of poor water quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased algal blooms including blue green (potential for increased toxins released)</td>
<td></td>
<td></td>
<td>Treatment and disinfection use increases</td>
<td>Negative impact aquatic the diversity and numbers</td>
<td>Increased energy cost due to power plant discharge cooling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Warmer Soil Temperatures / Decreased Soil Moisture</strong></td>
<td>Decreased groundwater base flow to streams</td>
<td>Increased treatment demand due to lower water WQ</td>
<td>Reduced change in vegetative cover</td>
<td>Increased need for irrigation and controlled drainage</td>
<td>Vegetation / Animal species shift</td>
<td>Vegetation / Animal species shift</td>
<td>Increased erosion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased wastewater erosion</td>
<td>Increased use of efficient sludge on farm fields</td>
<td>游览</td>
<td>Impacts to private water systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased in-stream TCO</td>
<td>Change of frequency in water main breaks in winter</td>
<td>Increased soil conservation practices</td>
<td>Increased need for crop insurance</td>
<td>Increase in invasive species</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased sediment deposition / loss of volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SUSTAINING SCIOTO – Mid-Ohio Regional Planning Commission**
## Prioritization Methodology: Risks

<table>
<thead>
<tr>
<th>Vulnerability Scenarios</th>
<th>Water Supply/ Water Quality</th>
<th>Water Treatment</th>
<th>Wastewater Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Air Temperatures / Increased incidence of heat waves</td>
<td>Increased evaporation, Reduced water volume</td>
<td>Negatively affects water quality</td>
<td>Impacts to infrastructure (increased corrosion)</td>
</tr>
<tr>
<td></td>
<td>Increased water demand and demand due to irrigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased in-stream TOC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased nutrient/ pesticide / herbicide runoff due to extended growing season, increased algal blooms</td>
<td>Increased capital investment due to designing for peaking factors</td>
<td>Lower flow affects discharge permits and treatment</td>
</tr>
<tr>
<td></td>
<td>Increased watershed erosion</td>
<td>Taste and odor concerns, potential for algal toxins</td>
<td>Increase need for odor control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased chlorine demand, Increase DBPs</td>
<td></td>
</tr>
<tr>
<td>Increased water temperature</td>
<td>Decreased dissolved oxygen</td>
<td>Taste and odor concerns, potential for algal toxins</td>
<td>Lower DO / changes in temp require affect wastewater discharge allocation</td>
</tr>
<tr>
<td></td>
<td>Increased release of phosphorus and other pollutants from anoxic zones/sediment</td>
<td>Increased treatment costs due to algae and potentially algal toxins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decreased mixing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Prioritization Methodology: Risks

### Water Quality High-Priority Risks

<table>
<thead>
<tr>
<th>No.</th>
<th>Vulnerability Scenarios</th>
<th>High Priority Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Increased air temperature</td>
<td>Increased nutrient/pesticide/herbicide load due to extended growing season</td>
</tr>
<tr>
<td>2</td>
<td>Increased water temperature</td>
<td>Increased algal blooms</td>
</tr>
<tr>
<td>5</td>
<td>Higher maximum peak stream flows</td>
<td>Increased TOC, nutrients, turbidity, sediment, and other pollutant loads to surface waters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased algal blooms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased watershed and stream bank erosion</td>
</tr>
<tr>
<td>6</td>
<td>Extended dry periods/summer drought</td>
<td>Decreased reservoir inflow/volume and reduced mixing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased algal blooms</td>
</tr>
<tr>
<td>7</td>
<td>Increased intensity of wind and rain events</td>
<td>Increased watershed and stream bank erosion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased TOC, nutrients, turbidity, sediment, and other pollutant loads to surface waters</td>
</tr>
</tbody>
</table>
Adaptive Management Strategies

Vulnerability Assessment → Prioritize Risks → Determine and Evaluate Adaptation Strategies → Adaptive Management Plan → Implement and Monitor

Re-evaluate and adjust as new information becomes available
Identification of Adaptation Strategies

- Types of Strategies:
  - Planning
  - Operational
  - Capital Improvement

- Estimate relative costs: $, $$, $$$

- No Regrets Strategies
Prioritization Methodology: Adaptation Strategies

Predicted Changes
- Ranked based on **Likelihood** of occurrence

Risks
- Ranked based on **Impact** on the region

Adaptation Strategies
- Ranked based on **Timing** and **Regional Conditions**

**Short Term**
- **2015 – 2025**
  - Conditions similar to today

**Mid-Range Term**
- **2026 – 2045**
  - Slightly increased annual average temperature but higher seasonal values; more variability in stream flow

**Long-Range Term**
- **2046 – 2090**
  - Increased temperature; more variability in stream flow; Continue to evaluate climate conditions
Actual vs Projected Annual Mean Temperature (F)

Temperature (F)

Year

Calibrated Period

Historical Average Temperature

Short Term 2015-2025

Mid Term 2026-2045

Long Term 2046-2090

Model 1

Model 2

Model 4

Model 5

Model 7

Model 8

Model 10

Model 11

2015-2025

2026-2045

2046-2090

50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67

1985 2005 2025 2045 2065 2085
Actual vs Projected Annual Mean Precipitation (in)

- **Historical Average Precipitation**
- **Calibrated Period**
  - Short Term: 2015-2025
  - Mid Term: 2026-2045
  - Long Term: 2046-2090

Models:
- Model 1
- Model 2
- Model 4
- Model 5
- Model 7
- Model 8
- Model 10
- Model 11

Year:
- 1975
- 1995
- 2015
- 2035
- 2055
- 2075
- 2095
# Prioritization Methodology: Adaptation Strategies

<table>
<thead>
<tr>
<th>Short Term 2015 – 2025</th>
<th>Mid-Range Term 2026 – 2045</th>
<th>Long-Range Term 2046 – 2090</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Expand Monitoring</td>
<td>• Regional Water Supply Plan</td>
<td>• Implement Improvements from Mid-Range Plans</td>
</tr>
<tr>
<td>• Increase Emergency Preparedness</td>
<td>• Groundwater Supply Study</td>
<td>• Re-evaluate Climatic Conditions</td>
</tr>
<tr>
<td>• Source Management (Demand)</td>
<td>• Water Reuse</td>
<td></td>
</tr>
<tr>
<td>• Regional collaboration &amp; public education</td>
<td>• Enhance Reservoir Capacity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Watershed Management Plan (Nutrient/ Pollutant Reduction)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Re-evaluate Climatic Conditions</td>
<td></td>
</tr>
</tbody>
</table>
## Recommended Adaptation Strategies for Protecting Water Quality

<table>
<thead>
<tr>
<th>Strategy</th>
<th>No Regrets</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning and Policy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop Water Quality Monitoring Plan</td>
<td>✓</td>
<td>$</td>
</tr>
<tr>
<td>Develop Regional Watershed Management Plan to reduce nutrient runoff</td>
<td>✓</td>
<td>$</td>
</tr>
<tr>
<td>Develop an Agricultural Nutrient Management Program</td>
<td>✓</td>
<td>$</td>
</tr>
<tr>
<td>Implement public education on water quality, water supply &amp; climate change impacts</td>
<td>✓</td>
<td>$</td>
</tr>
<tr>
<td>Modify local ordinances to promote low impact development, stormwater harvesting/reuse</td>
<td>✓</td>
<td>$</td>
</tr>
<tr>
<td><strong>Operational</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implement increased fertilizer reduction programs, revegetation of riparian buffer zones, and other non-structural practices</td>
<td>✓</td>
<td>$$</td>
</tr>
<tr>
<td><strong>Capital Improvement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implement reservoir capital improvement projects</td>
<td></td>
<td>$$</td>
</tr>
<tr>
<td>Implement pollutant reduction projects (BMPs) to reduce pollutants of concern</td>
<td></td>
<td>$$$</td>
</tr>
</tbody>
</table>
Conclusions

• Results:
  – Increased air & water temperature
  – Degraded water quality
  – Increased potential for both floods & droughts
  – More extreme storm events

• Challenges to Utilities & Region
  – Due to uncertainty - need for flexibility in operations and management
  – Regional issues may require regional collaboration

• Adaptive Planning
  – Update plan over time while preparing with No-Regrets strategies
  – Source resiliency; Monitoring; Emergency Preparedness; Regional Collaboration & Education
Questions?

Lisa Jeffrey, PE
ljeffrey@brwncauld.com
757-518-2423