# A Climate Change Vulnerability and Risk Assessment for the City of Atlanta, Georgia

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## Executive Summary

The Southeastern United States will experience several impacts from climate change over the coming decades, including average temperature increases of several degrees, more frequent droughts, and heavier rain and flood events (Diffenbaugh, Pal et al. 2005; Christensen, Hewitson et al. 2007; Karl, Melillo et al. 2009). More intense weather will place stress on Atlanta's infrastructure, affect planning decisions, and increase demands for already scarce natural and financial resources. The impacts will affect the health of Atlantans and test the strength of the local and regional economy. Understanding the future climate and preparing now will help ensure that the city remains an economically viable, healthy, and enjoyable place to live and work.

Twenty-four planning areas in nine sectors that the city can influence were assessed to determine their vulnerability and risk with regard to climate change. The assessments revealed that air quality, water quality, and energy assurance are the most vulnerable, at-risk planning areas in the City of Atlanta. These areas are crucial to the health of citizens and the economic viability of the city. Increasing their resiliency will require significant coordination with all levels of government and the private sector. Failure to properly prepare these planning areas for climate change could result in substantial costs to the city. Several additional planning areas show significant vulnerability and risk. These include: electricity production and demand, affordable housing, disaster response, heat relief, stormwater management, urban forest management, road and bridge maintenance, and air transport. Analysis of vulnerability and risk by sector resulted in similar findings. The sectors of energy, water, and health will be most impacted by climate change over the coming decades. Improving the resiliency of these sectors may be most effectively achieved through measures that focus on strengthening sectors like ecology, transportation, and land use and development.

This study identified recurring barriers that lower the city's adaptive capacity. Lack of program funding and knowledge of climate change - and the impacts - were pervasive. Short planning horizons and

planning efforts based on historical data (or future projections that ignore climate change) are also common and reduce Atlanta's resiliency. Coordination between several planning areas is strong, but could be increased in others such as heat relief and urban planning. Narrow government mandates, like the flood plain ordinance, can limit progress towards climate resiliency. In other cases, strict mandates like those stemming from the CSO Consent Decree have been instrumental to project success.

The results of the following climate change vulnerability and risk assessments are intended to inform the next phase of adaptation planning. This involves setting high-level goals for climate resiliency and outlining the adaptation tactics to achieve them. It is recommended that a diverse, knowledgeable committee of local decision makers and stakeholders be tasked with this challenge. A robust adaptation strategy will place Atlanta in the company of other climate proactive cities that have already created comprehensive adaptation plans, like New York City and Chicago (Friedman, Berstein et al. 2008; New York City Panel on Climate Change 2009).

## Assessment Objectives

Like many cities, Atlanta's municipal government is developing programs and policies that will affect the city in the long-term, and it has not yet created a plan to increase the city's resiliency to the future negative effects of climate change. The intent of this Masters Project is to provide climate change adaptation guidance to local decision makers by identifying vulnerable planning areas within the city and assessing the risks of expected climate impacts. The results of these analyses determined priority planning areas for the city's adaptation focus. In addition, the report outlines a framework for moving through subsequent adaptation planning phases.

# Background

## Climate Change Adaptation: A Literature Review

In 2007, the International Panel on Climate Change (IPCC) concluded that the planet's climate is already changing (International Panel on Climate Change (IPCC) 2007). Since then, climate change response efforts have expanded beyond mitigation to include adaptation. Mitigation efforts include any actions taken to reduce greenhouse gas (GHG) emissions. Adaptation is a set of plans and actions that a community undertakes to reduce vulnerability and increase resiliency to the impacts of climate change (Lowe, Foster et al. 2009). Climate change will affect communities in all corners of the world. Developing countries are especially vulnerable due to a high exposure to climatic events and a lack of financial resources. Although developed nations have greater financial resources, they will also face adverse impacts.

A focus on adaptation has been slow to gain momentum in developed nations like the US, despite the need for adaptation planning resources. Instead, these nations have focused largely on mitigation efforts (Commission of the European Communities 2009; Ki-moon 2009). National climate legislation is especially hard to pass because the US government gives a great deal of power to the states, and many states would be affected by such legislation differently. In 1998, The National Energy Policy Act was introduced to Congress and signed into law four years later. This law called for a national energy policy and reduction of global warming by greenhouse gases (Hecht and Tirpak 1995). Congress has failed to pass numerous climate bill proposals since then. These bills have focused on mitigation measures, with minimal attention on adaptation needs. In what may mark a sea-change in Congress, the Waxman Markey Bill – introduced in the House of Representatives in May 2009 - has provisions that would require federal and state action, as well as make adaptation planning resources available (Pew Center on Global Climate Change 2009). This bill was passed by the House in June 2009 and has lingered in the Senate for months (GovTrack.us 2009).

Even as the federal government struggled to define a course of action throughout the 2000's, many states, cities and counties created GHG mitigation plans and began implementation. A small number of regions, states, and localities assumed the task of adaptation planning. Nine states have completed or begun work to develop adaptation plans, and nine others have climate action plans that recommend the creation of an adaptation plan for critical areas (Pew Center on Global Climate Change 2009). A handful of cities and counties have also completed adaptation strategies, including King County, Washington and Chicago, Illinois.

By the end of 2009, the federal government showed evidence of action. On October 5, 2009, President Barack Obama signed Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance. Under this order, the Council on Environmental Quality (CEQ) was given the duty of organizing the Interagency Climate Change Adaptation Task Force (Obama 2009). Representatives from CEQ were present at the February 2010 Southeast Climate Change Adaptation Workshop, sponsored by the Environmental Protection Agency in Atlanta, Georgia. There, federal, state, and local agencies and universities gathered to discuss the current state of adaptation planning, uncover needs and determine responsibilities. Less than a week after the workshop, the National Oceanic and Atmospheric Association announced the establishment of a new Climate Service office. The NOAA Climate Service will work with "federal, regional, academic and other state and local government and private sector partners" to provide "critical planning information (National Oceanic and Atmospheric Administration 2010)."

While federal direction will provide the impetus for many localities to address adaptation, valuable lessons can be learned from early adopters. Non-governmental organizations have been working hard for several years to cultivate the climate resiliency conversation and encourage localities to begin adaptation planning. Local Governments for Sustainability (ICLEI) provides guidance to its municipal members through an Adaptation Guidebook. The guidebook's thorough explanation of the adaptation

planning process is particularly helpful. This explanation includes the methods and models for climate change vulnerability and risk assessments of planning areas, as well as direction for planning area prioritization (Center for Science in the Earth System (The Climate Impacts Group), Joint Institute for the Study of Atmosphere and Ocean et al. 2007). In addition, the Washington D.C.-based Center for Clean Air Policy (CCAP) has released an adaptation report as a resource for American cities and counties and has presented adaptation concerns and information to Congress (Lowe, Foster et al. 2009).

An adaptation framework is emerging through this growing body of work. The framework includes best practices and institutional structures necessary for creating and establishing successful local adaptation programs. Best practices include involving key stakeholders, identifying systems of vulnerability using actionable science, garnering the support of a champion, and using existing mechanisms to advance adaptation (Lowe, Foster et al. 2009). Other studies draw attention to the importance of an empowering institutional organizational structure and answering the question of how adaptation measures will be funded (Smith, Vogel et al. 2009). An extensive dialogue among the academic, private, government (including local, state, and federal), and community sectors is necessary for the development of adequate and proper adaptation measures, some of which could involve changes to infrastructure and institutions. However, the fact that adaptation measures will likely involve addressing current issues like air pollution and poverty reduction should allow familiar problem-solving approaches in an otherwise unprecedented crisis (Field, Mortsch et al. 2007).

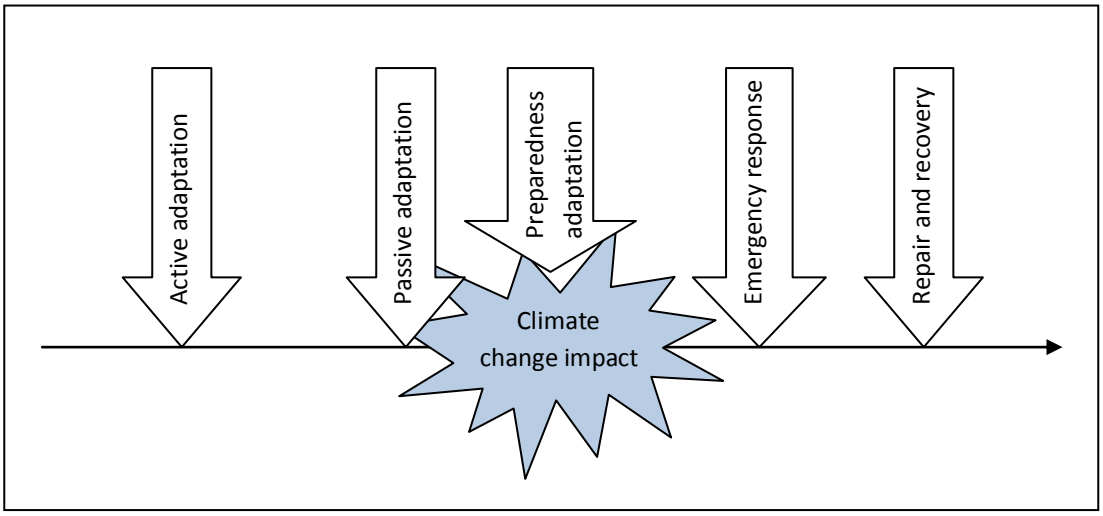
Identifying vulnerable, at-risk planning areas is extremely important in designing effective adaptation strategies. Once these planning areas are identified, a locality must prioritize its efforts and decide what measures to implement. Measures can be differentiated by their degree of responsiveness and timing of implementation. *Preparedness* actions enable a locality to better withstand weather events and other changes, as they occur. These are highly reactionary responses. For example, providing emergency supplies of water would be a preparedness action that Atlantans undertake *during* a

drought. *Passive* adaptation measures involve a slightly less reactionary approach. They are intended to ameliorate negative impacts by ensuring the strength of the existing infrastructure, *as* the climate changes occur. Georgia's water restrictions during droughts are passive adaptation actions. The most aggressive measures are considered *active* adaptation. These measures involve understanding the expected impacts and removing the vulnerable population, or creating infrastructure that will keep them safe *before* any events occur. Active adaptation measures are decidedly more anticipatory in nature. Decreasing Atlanta's day-to-day dependence on water through efficiency programs and water-reuse infrastructure would constitute active adaptation. Additional examples of adaptation measures are provided in Figure 1. Figure 2 describes how varying measures are scheduled in relation to climate impacts.

**Figure 1. Examples of various levels of climate adaptation**

| Preparedness Measures | Passive Measures | Active Measures |
|---|---|---|
| • Replenishing beach sand to ward off winter coastal surges<br>• Stockpiling sandbags before a flood | • Reinforcing levees as floods occur<br>• Retreating from the coast as sea level rises | • Raising levee heights<br>• Relocating development in anticipation of floods or sea level rise |

**Figure 2. Conceptual adaptation planning timeline**



Adaptation measures also vary in their environmental friendliness and contribution to solving the climate problem. The most desirable adaptation measures are those that also contribute to GHG mitigation by reducing GHG emissions, or at least do not increase emissions. The least desirable adaptation measures are those that involve an increase in GHG emissions. For instance, an obvious adaptation to hotter temperatures is the increased use and dependence on air-conditioning. If the electricity production required to power an air-conditioner generates GHG, then the adaptation serves to perpetuate the problem of human-induced climate change and the subsequent need for future adaptation actions. If the air-conditioner is powered by electricity generated by renewable sources and operates efficiently, then its use becomes a doubly beneficial measure.

In many ways, adaptation planning is a responsibility of the locality. Decisions are often influenced by the costs of measures, availability of information, funding, risk of impacts, and alignment with current programs (Lowe, Foster et al. 2009). Although there is perhaps insufficient national direction for climate change adaptation, cities must search out the available resources to prepare for this reality.

## Climate Change in Atlanta

The International Panel on Climate Change (IPCC) has become the clearinghouse for global climate change research. Hundreds of scientific studies have been compiled to provide a comprehensive picture of how climate change will affect the planet. Many of these studies use global climate models, which provide mathematical representations of the planet's climate system. The models used in the IPCC 2007 report provide projections at higher spatial resolution than previous years (New York City Panel on Climate Change 2009). This resolution is strong enough to make reasonable predictions on a regional scale. The 2009 US Global Climate Change report provides such regional predictions, including projections for the Southeastern United States (Karl, Melillo et al. 2009).

By 2080- 2099, the Southeast, including Atlanta, Georgia should expect temperatures to be an average 4.5 – 9˚F warmer than today's averages. Temperature increases will be greater in the summers; while there are around fifteen days per year over 90˚F in recent history, under a high GHG emissions scenario, Atlantans could experience nearly 120 days over 90˚F each year by 2080-2099 (Karl, Melillo et al. 2009). This climate would be comparable to the summers experienced in Houston, Texas (Patz and Kinney 2004). In addition, recent findings suggest that the urban heat island (UHI) effect will amplify IPCC projections of temperature rise in urban areas (Stone 2007). If this proves true, urban Atlanta should expect temperature increases greater than the Southeast predictions of 4.5 – 9 ˚F by 2080- 2099. Increased temperatures will be felt most acutely in the form of severe heat waves and will contribute to an increased number of bad air quality days.

Northern areas of Georgia experience winter temperatures below freezing and between two to six days of snow on average (Center for Integrative Environmental Research 2008). The Southeast is likely to experience a reduction in extreme cold events, as winter temperatures are likely to increase an average of 4.5˚F (Diffenbaugh, Pal et al. 2005). There is currently no information on projections for the number of snowfalls Atlanta should expect in coming decades.

Georgia receives an average of fifty inches of rain per year (Metro Atlanta Chamber of Commerce 2006). Although future precipitation totals may be higher or lower than the current average, the frequency and intensity of precipitation events are projected to change (Christensen, Hewitson et al. 2007). More frequent severe storm events and associated floods are very likely due to enhanced convective potential energy and coastal moisture convergence (Diffenbaugh, Pal et al. 2005). These changes are already becoming apparent; while precipitation averages have been fairly consistent, much of the Southeast has seen a significant increase in heavy downpours since the 1970's (Karl, Melillo et al. 2009).

Atlanta can expect to experience the impacts of more frequent tropical storms because the intensity of Atlantic hurricanes is likely to increase. Since 2002, twelve tropical storms and hurricanes have had impacts on the Atlanta area. While *most* of these storms reportedly caused no damage, this pattern may not prevail with more frequent, intense storms (National Oceanic and Atmospheric Administration (NOAA) Satellite and Information Service and National Climate Data Center 2009).

Drought is a normal occurrence in Georgia climate; historic analysis shows that two-year droughts typically occur every 25 years (Stooksbury 2003). More frequent and longer lasting droughts in the coming decades are very likely (Karl, Melillo et al. 2009). This expectation is in part fueled by the decreased moisture content in soils and plants due to evaporation caused by hotter temperatures (Christensen, Hewitson et al. 2007).

In addition, coastal areas are virtually certain to experience sea level rise by the end of the century and the impacts on Atlanta are currently unknown (Karl, Melillo et al. 2009).

Understanding of the probability of various changes is important for planning purposes. Changes that are "virtually certain" have a greater than 99% chance of occurring. The term "very likely" indicates a greater than 90% chance of occurring. "Likely" changes have a greater than 66% chance of occurring. Other projections are "uncertain" because different climate models have produced divergent results (New York City Panel on Climate Change 2009).

The timeline for climate changes is also crucial. While many changes will occur gradually over this century, others may take place quickly and without warning. Climate changes do not follow a linear pattern and often occur once a "tipping point" is passed. The uncertainty surrounding the timeline of climate change has implications for local governments.

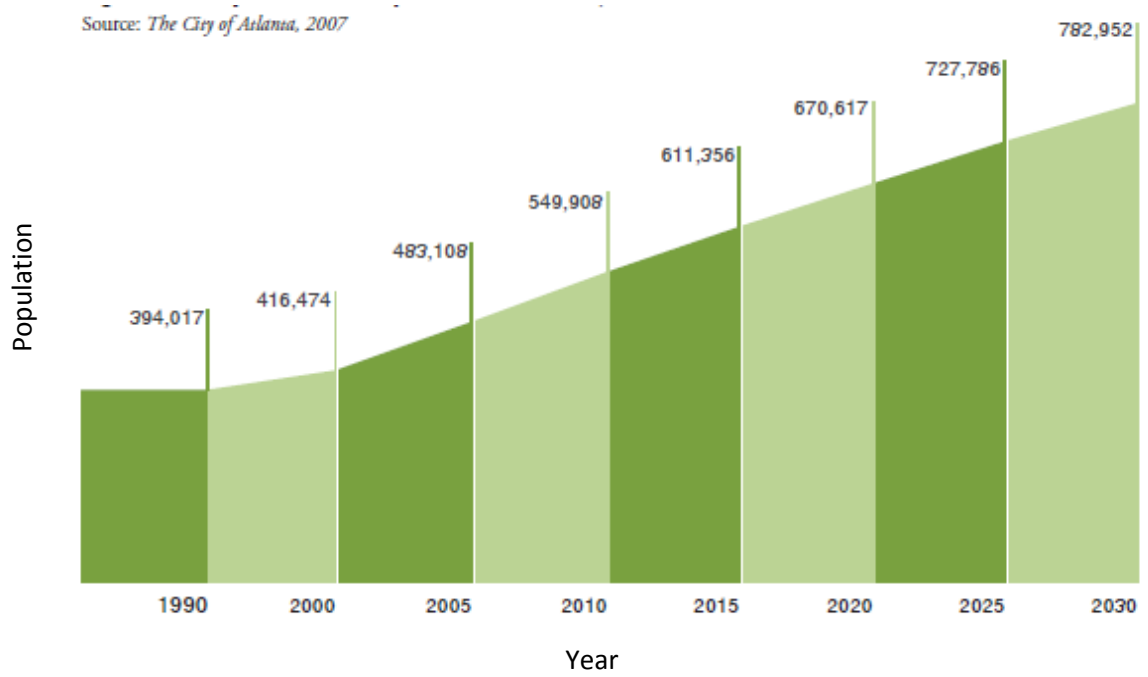
## Background of Atlanta

***Population***

The City of Atlanta has experienced rapid growth that is projected to continue in the next decades (see Figure 3). In the year 2000, the population was 416,267 (U.S. Census Bureau 2000). In just eight years, the city grew by over 100,000 people, to an estimated population of 537,958 (U.S. Census Bureau 2008). According to the Atlanta Strategic Action Plan, a projected 780,000 people will call the city their home by 2030 (Department of Planning and Community Development 2007). With Atlanta's 132 square miles, this will equal an average of 10-25 people per acre (Wallace Roberts & Todd LLC 2008).

The metropolitan area of thirteen counties is expected to see dramatic growth as well. Nearly four million people lived in the region in 2000, and an estimated six million are expected by 2030 (Atlanta Regional Commission 2009). By this time, one in five residents will be over sixty (Atlanta Regional Commission 2010).

**Figure 3. City of Atlanta population forecasts through 2030.**



***Atlanta City Government***

Atlanta employs a "strong-mayor style" city government with a city council. The fourteen members of City Council represent districts within the city. Policies and programs enacted by the mayor and council are implemented by thirteen city departments chaired by commissioners and directors, which are appointed by the mayor. In addition, dozens of boards, commissions, and agencies operate to fill a variety of niches, represent certain constituencies, and oversee policy implementation. Voter turnout in Atlanta has varied, but the most recent mayoral election saw a low turnout of 24% on November 3, 2009 (Dade 2009).

The majority of the city lies within Fulton County, making a working relationship with this municipality essential. Additional connections to surrounding governments are facilitated by the Atlanta Regional Commission (ARC), the region's Metropolitan Planning Organization (MPO).

***Atlanta's Economy***

Atlanta is one of the leading freight centers in the country, and is home to a vibrant economy. In 2007, twelve Fortune 500 companies had headquarters in Atlanta, taking advantage of the city's status as the second least expensive city for corporate headquarters (Metro Atlanta Chamber of Commerce 2007).

While many businesses thrive, a large portion of the community experiences economic struggles. Twenty-seven percent of Atlantans were estimated to be living in poverty in 2005. Economically disadvantaged areas are generally located to the south and west of the city center, while the north and east have enjoyed recent prosperity and population growth (Department of Planning and Community Development 2007).

***Atlanta's Civil Society***

Atlanta is home to many non-profit organizations like Trees Atlanta, Pathrocks, Meals on Wheels, and more. Private and community foundations often provide important financial support to such

organizations. Community members that are active participants in government meetings and hearings also increase civic participation.

Like most cities in the US, Atlanta is directly influenced by its surrounding metropolitan area, and the region has a great stake in ensuring the success of the city. To advance the success of both, the ARC facilitates a number of conversations among various local governments and citizens. A recent ARC initiative brought together regional leaders and community members to define a positive vision for the region in 2060. This visioning effort, called Fifty Forward, also developed ideas to make that vision a reality (Atlanta Regional Commission 2009). While Fifty Forward did not consider climate change, the initiative created a communication infrastructure that could be valuable as the region faces such planning needs.

## Implications of Climate Change for Municipal Policy

Climate change has already begun to affect municipal policy-making in Atlanta. In 2005, Mayor Shirley Franklin signed the US Mayor's Climate Protection Agreement and publicly stated her aim to make Atlanta a "best in class" city in climate change issues. To make this goal a reality, Franklin established the City's first Office of Sustainability (now the Division of Sustainability)(City of Atlanta 2009), and required all departments to outline GHG emission reduction strategies through the year 2009. A GHG Inventory revealed that Atlanta government operations contributed 540,000 tons of carbon equivalent emissions to the atmosphere in 2007. Mayor Franklin set the target of a 7% government emission reduction from 2007 levels by 2012 when she signed the Mayor's Climate Protection Agreement (City of Atlanta 2009). In doing so, Atlanta has already initiated one of the most preventative adaptation measures by adopting a GHG mitigation target for government operations. A community GHG inventory and emission reduction plan has yet to be created.

While steps to curb emissions are of the utmost importance, understanding the impacts of expected climate change will be a necessity for city leadership, planners, and residents. Climate change will impact the city's infrastructure, influence development and economic choices, and will disproportionately affect certain populations. These impacts will make adaptation action a necessity, and most measures will not be achieved overnight. For example, if Atlanta decides that more shade trees are needed to help mitigate negative impacts, the plans and efforts should be scheduled to allow enough time for the trees to reach an effective size.

The adoption of long-term, transformative municipal programs is not new. Currently adopted programs, like the Atlanta BeltLine Project and Connect Atlanta Plan, will be implemented over the next decades (EDAW, Urban College et al. 2005). These progressive programs may complement future adaptation needs, but were designed without consideration of future climate change impacts. Because project timelines reach decades into the future, project managers will have to deal with the impacts of climate changes whether they realize it now or not.

## Methods

An initial literature review was conducted to understand current best practices for creating adaptation strategies in the US. Most comprehensive adaptation strategies involve an understanding of the vulnerable and at-risk systems – or planning areas –with respect to climate change. Once this information is available, adaptation measures can be defined and implementation can begin. Because Atlanta has not determined its own vulnerability and risk, this report will focus on the initial assessment step.

Nine sectors and 24 planning areas within those sectors were identified for assessment (see Table 1). The nine sectors were: health, water resources, energy, building infrastructure, ecology, transportation,

safety, land use and development, and materials. The twenty-four planning areas were determined using guidance provided by ICLEI's Adaptation Guidebook and cover major issues related to city life. Some planning areas are completely under the jurisdiction of the City of Atlanta (i.e. urban forest management). Others are regulated by the state (i.e. air quality management), are the responsibility of several local governments (i.e. water quality), or are not regulated at all (i.e. outbreak prevention). The diverse planning areas share three things in common: each is important to the success and resiliency of the city; can be impacted by city government; and is likely to be affected by climate change.

**Table 1. Sectors and planning areas assessed in this study**

| Sector | Planning Areas Assessed |
|---|---|
| **Health** | Air Quality; Outbreak Prevention |
| **Water Resources** | Water Quality; Water Supply |
| **Energy** | Energy Production; Energy Demand; Energy Assurance |
| **Building Infrastructure** | Stormwater Management; Building and Energy Code; Building Maintenance |
| **Ecology** | Urban Forest Management; Greenspace; Pest and Invasive Species Management |
| **Transportation** | Public Transit; Paratransit Service; Road and Bridge Maintenance; Air Transport |
| **Public Safety** | Police Services; Fire Safety; Disaster Response |
| **Land Use and Development** | Affordable Housing; Urban Planning |
| **Materials** | Residential Waste Collection |

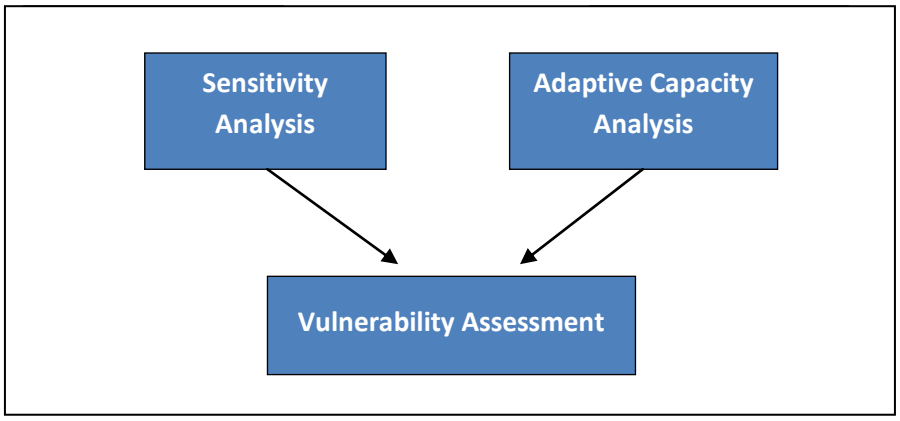
The vulnerability and risk assessments follow the ICLEI model outlined in the Adaptation Guidebook (Center for Science in the Earth System and King County 2007). Relevant data were gathered, including information on current programs and policies of the City of Atlanta, as well as current and future population, industry, and economic status figures. Regional climate change projections were assembled from the 2009 US Global Climate Change report and the 2007 IPCC report. In addition to this research,

informational interviews were conducted. Interviewees reflected a wide variety of expertise, ranging from local city planners and commissioners, to scientists and researchers. The Atlanta Division of Sustainability supplemented these interviews by hosting three discussion-based meetings with a diverse set of experts on February 4, 2010 in City Hall, at which additional information on the planning areas was gathered. In total, 38 individuals were interviewed between July 2009 and February 2010.

***Vulnerability Assessments***

The information gathered from the sources noted above was used to determine the level of vulnerability and risk for each planning area. The vulnerability assessment was conducted in two parts, through a sensitivity analysis and an adaptive capacity assessment as shown in Figure 4.

**Figure 4. Vulnerability assessment flowchart**




The level of climate-sensitivity is influenced by the planning area's current and future stresses, exposure to climate, the relevant expected climate change(s), and the projected impacts of that change in a "business-as-usual" (BAU) scenario. The questions considered for the sensitivity analysis are outlined in Table 2 and were drawn from ICLEI's Adaptation Guidebook. The final sensitivity level was subjectively assigned by the researcher using the information gathered for the sensitivity analysis. A planning area that would experience little to no impact from climate change received a low sensitivity rating, whereas an area that stands to be greatly impacted received a high sensitivity rating.

**Table 2. Vulnerability assessment part I: sensitivity analysis questions**

| SENSITIVITY ANALYSIS | | | | | | |
|---|---|---|---|---|---|---|
| CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | **SENSITIVITY LEVEL (HIGH, MEDIUM, LOW)** |
| | | | | | | |

The second step of the vulnerability assessment was to determine adaptive capacity. Adaptive capacity was estimated by assessing the planning area's ability to absorb the change, as well the barriers and facilitators to improving the area's resiliency. Budget constraints, cultural values, and policies (at any level of government) can help or hinder a community's ability to adapt to climate change, and have been considered in this assessment. The issues taken into account for the adaptive capacity analysis are outlined in ICLEI's Adaptation Guidebook and can be found in Table 3. As in the sensitivity analysis, the adaptive capacity level was determined subjectively by the researcher, based on the information gathered for the adaptive capacity analysis. For example, if the planning area demonstrates the ability to absorb climate impacts well and has few barriers to adapting, it has a high adaptive capacity level. Conversely, a planning area that will not absorb impacts well and faces restrictive barriers that will prevent adaptation displays a low adaptive capacity.

**Table 3. Vulnerability assessment part II: adaptive analysis questions**

| ADAPTIVE CAPACITY ANALYSIS | | |
|---|---|---|
| ABILITY OF PLANNING AREA TO ABSORB EXPECTED CHANGES | BARRIERS AND FACILITATORS TO IMPROVING RESILIENCY | **ADAPTIVE CAPACITY LEVEL (HIGH, MEDIUM, LOW)** |
| | | |

Sensitivity and adaptive capacity levels were placed in a scoring matrix (designed for this study) to provide an overall vulnerability score, as depicted in Table 4. For discussion purposes, planning areas with 4-5 points were deemed highly vulnerable, those with 3 points were deemed moderately

vulnerable, and planning areas with 1-2 points were considered to have low vulnerability. If a planning area has a low sensitivity to climate change and has a high adaptive capacity, it can be concluded this is a planning area of low vulnerability. If the planning area has a high sensitivity to climate change and a low adaptive capacity, its vulnerability is high. A summary table of the vulnerability assessment is located at the end of the written discussion for each planning area in the results section.

**Table 4. Vulnerability assessment scoring matrix**

| | HIGH SENSITIVITY | MEDIUM SENSITIVITY | LOW SENSITIVITY |
|---|---|---|---|
| LOW ADAPTIVE CAPACITY | 5 Points<br>High Vulnerability | 4 Points<br>High Vulnerability | 3 Points<br>Medium Vulnerability |
| MEDIUM ADAPTIVE CAPACITY | 4 Points<br>High Vulnerability | 3 Points<br>Medium Vulnerability | 2 Points<br>Low Vulnerability |
| HIGH ADAPTIVE CAPACITY | 3 Points<br>Medium Vulnerability | 2 Points<br>Low Vulnerability | 1 point<br>Low Vulnerability |

***Risk Assessment***

Risk assessments were conducted by estimating the degree of impact of climate change on each of the planning areas, and by considering the likelihood the change will occur. The probability of impact was determined by the level of certainty for the climate change, as provided by the scientific literature. For those planning areas that will be affected by multiple climate changes with differing probability, the higher probability score was used. The degree of impact was estimated through a consideration of the size of the affected population, whether the impacts could be life-threatening and the general costs associated with impacts. These impacts are roughly quantified using the point system in Table 5 below.

As with the vulnerability assessment, the risk was considered on a high-medium-low scale for discussion purposes. A planning area with 10-12 risk points was deemed high risk. A medium risk designation was given to planning areas with 7-9 risk points, and low risk planning areas were those that had 4-6 points. However, the final prioritization recommendations were determined using only the numerical scores of

the planning areas. A summary table of the risk assessment (like that shown in Table 6) is located at the end each planning area's risk discussion in the results section.

**Table 5. Risk assessment scoring table**

| | 1 point | 2 points | 3 points |
|---|---|---|---|
| **A) Citizens Affected** | Few | Half Atlanta Population | Entire Atlanta Population |
| **B) Life threatening** | No | Uncertain | Yes |
| **C) Cost** | Low *(up to several $ Million)* | Medium *(~several $ Million - $50 Million)* | High *(~$50 Million +)* |
| **D) Probability** | Uncertain | Likely (>66%) | Very Likely (>90%) |

**Table 6. Risk assessment scoring system**

| RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| A + B + C | D | **A + B + C + D** |

***Planning Area Summary***

The planning areas were prioritized using a scoring matrix as illustrated in Table 7 below, and assigned a score (based on vulnerability and risk assessments) denoting the priority level. A high score means that the planning area should be a top priority for climate change adaptation effort while a low score means that the priority level is low. To further sort the planning areas based on their scores, a tier-based scale describes their relative priority level. Planning areas with 17 total points – the maximum - are Tier One, those with 16 total points are Tier Two, and so on, down to Tier Ten. The priority levels are intended to provide the basis by which a high-level strategy to address the top concerns can be defined.

### Table 7. Prioritization scoring matrix for planning areas

| | | VULNERABILITY SCORE | | | |
|---|---|---|---|---|---|
| | | 5 | 4 | 3 | 2 |
| RISK SCORE | 12 | 17 | 16 | 15 | 14 |
| | 11 | 16 | 15 | 14 | 13 |
| | 10 | 15 | 14 | 13 | 12 |
| | 9 | 14 | 13 | 12 | 11 |
| | 8 | 13 | 12 | 11 | 10 |
| | 7 | 12 | 11 | 10 | 9 |
| | 6 | 11 | 10 | 9 | 8 |

Finally, assessment results were organized by sector. This was accomplished through averaging the combined scores of the planning areas within each sector as shown in Table 8.

### Table 8. Scoring system for sectors

| Sector | Planning Area | Vulnerability Score | Risk Score | Combined Score | Sector Average Combined Score |
|---|---|---|---|---|---|
| Sector A | Planning area 1 | $X_1$ | $Y_1$ | $X_1 + Y_1 = Z_1$ | $(Z_1 + Z_2 + Z_3)/ 3$ |
| | Planning area 2 | $X_2$ | $Y_2$ | $X_2 + Y_2 = Z_2$ | |
| | Planning area 3 | $X_3$ | $Y_3$ | $X_3 + Y_3 = Z_3$ | |

# Results

The vulnerability and risk assessments in this study were completed using the Atlanta-specific climate change projections shown in Table 9.

**Table 9. Summary of climate changes expected in Atlanta**

| Climate Condition | Expected Change | Timeline | Probability | Source |
|---|---|---|---|---|
| Average Temperature | Average 4.5 – 9 ˚F warmer than today's averages; heat island effect may amplify this increase | 2080-2099 | Likely | Karl, Melilo et al. 2009; Stone 2007 |
| Extreme High Temperatures | Current: average of 15 days over 90˚F<br>Future: average of 120 days over 90˚F | 2080-2099 | Very Likely | Karl, Melilo et al. 2009; Climate Change Science Program 2008 |
| Extreme Cold Temperatures | Reduction in extreme cold events | End of century | Likely | Diffenbaugh, Pal et al. 2005 |
| Average Precipitation | Current: Georgia receives an average of 50 inches of rain annually<br>Future: future averages may be higher or lower | This century | Uncertain | Metro Atlanta Chamber of Commerce 2006; Christensen, Hewitson et al. 2007 |
| Precipitation Frequency and Intensity | More frequent severe storm events and associated floods; more frequent and longer lasting droughts | This century | Very Likely | Christensen, Hewitson et al. 2007; Diffenbaugh, Pal et al. 2005; Karl, Melilo et al. 2009 |
| Tropical Storms & Hurricanes | Intensity will increase | This century | Likely | Karl, Melilo et al. 2009 |
| Sea Level Rise | Sea level rise up to 2 feet | End of century | Virtually certain | Karl, Melilo et al. 2009 |

## Vulnerability and Risk Assessments

The following sections describe the vulnerability and risk analyses for each of the 24 planning areas, grouped by sector. Each planning area discussion concludes with a short summary that also includes the recommended priority level for adaptation planning. A more detailed summary of the sensitivity,

adaptive capacity, and risk assessments can be found in Appendices A-D, which follows the ICLEI Guidebook methods. An analysis of sectors can be found at the end of the results section.

## Sector: Health

### *Heat Relief*

***Vulnerability Part I: Sensitivity***

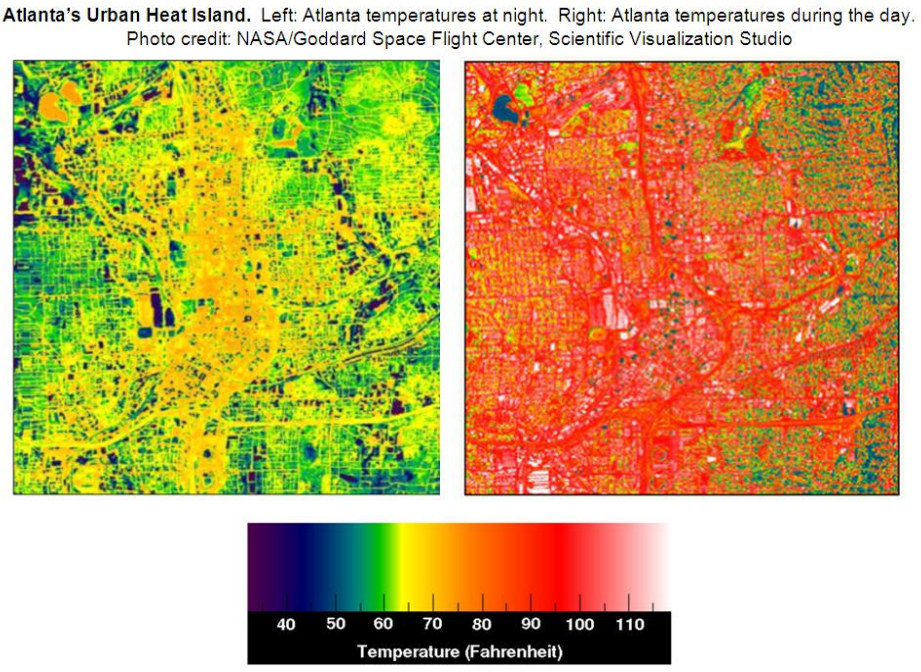
The heat relief planning area currently faces several challenges, some of which are more easily addressed than others. This planning area is important during all times of high temperatures, although relief services are especially important during heat waves. Heat waves are brought about by very high temperatures and are amplified by the Urban Heat Island (UHI) effect, which is well documented in Atlanta. The UHI effect increases with higher building density and more heat-absorbing surfaces, and will worsen with increasing infill development, as well as a lack of shade and surface reflectivity standards. In fact, temperatures within the city are often 2-10 ˚F higher than the surrounding areas. The timing of the UHI effect is also significant; the city retains heat longer, causing higher nighttime minimum temperatures, which have been linked epidemiologically to excess mortality (Luber and McGeehin 2008). Even precipitation events around the city have been intensified by the UHI effect (Dunlap 2009).

At times, heat waves can be categorized as oppressive hot air masses, a phenomenon that is not uncommon in the summer in Atlanta. Oppressive hot air masses are identified when mortality rates are significantly above the summer baseline. Between 1975 and 2004, Atlanta experienced an average 11.3 days of oppressive air masses per summer. Over this time, the mean mortality trend was negative for the city - indicating decreasing vulnerability - likely due to higher saturation of air-conditioners (Sheridan, Kalkstein et al. 2009). The City recognizes these days by declaring heat emergencies using public warning systems. Fan distribution programs organized by community organizations are also common.

**Figure 3: Buildings in Atlanta contribute to the Urban Heat Island (UHI) effect.**

Climate change will have a direct impact on this planning area. The number of heat emergencies is likely to increase as summers become hotter and longer. Southeastern climate projections show that a 4.5 – 9˚F increase in the average temperature is very likely. It is also very likely that Atlanta will deal with summers when there are 120 days over 90˚F. Rising temperatures will lead to a higher demand for heat relief services.

**Figure 4. Atlanta's well documented Urban Heat Island (UHI) effect**




The heat relief planning area demonstrates a high sensitivity level due to Atlanta's current climate and common struggles with very hot days that are intensified by the UHI effect. While the increase in air-

conditioning use has risen over the past decades, rising electricity costs could affect this trend and result in higher exposure to heat impacts.

***Vulnerability Part II: Adaptive Capacity***

A natural response to high temperatures is the increased use of air-conditioners, which can decrease heat stress and serious heat-induced health problems. Although they area a prime example of adaptation, air-conditioners may not be the optimal solution to the heat problem for a number of reasons. Their use leads to higher GHG emissions by fossil fuel burning energy suppliers. Widespread use in an urban area can increase temperatures for those outside or those with no air-conditioner. Moreover, this solution may not be feasible for all populations; studies indicate that increasing energy costs can be a limiting factor in air-conditioner use (Sheridan, Kalkstein et al. 2009). Energy costs have already been on the rise and future energy production regulation may also lead to increased prices, further hindering air-conditioner use by economically stressed households. These circumstances suggest that citizens will have a moderate ability to absorb the impacts of high temperatures through increased air-conditioning.

Besides the high costs of cooling energy, there are few major barriers to adaptation, and several solutions. Resiliency to the impacts of intense heat waves can be improved by increasing the understanding of the UHI effect for the purpose of better forecasting and improved warning systems. Shade tree planting, surface reflectivity changes, fan distribution programs, cooling centers, and outreach efforts focused on vulnerable populations are important solutions that the City could provide assistance with (Gamble, Ebi et al. 2008).

A number of immediate adaptation options tend to work well, but the growing vulnerable population as well as financial restrictions will stretch the capabilities of heat relief efforts. The heat relief planning area is given an adaptive capacity score of medium.

| HEAT RELIEF VULNERABILITY ASSESSMENT | | |
|---|---|---|
| SENSITIVITY SCORE | ADAPTIVE CAPACITY SCORE | VULNERABILITY LEVEL |
| High | Medium | 4 Points: High |

***Risk***

The probability of increased heat emergencies is very likely. Heat waves are felt by all, but many people are able to continue on with daily activities despite the oppressive heat. The homeless, low-income, elderly, and outdoor workers are most vulnerable to these conditions, which can be life-threatening. The costs of heat emergency relief services (including air-conditioning use, fan distribution, cooling centers, and public warnings) can be substantial. Therefore the risk level for this planning area is high.

| HEAT RELIEF RISK ASSESSMENT | | |
|---|---|---|
| DEGREE OF IMPACT OF CHANGE ON SYSTEM | PROBABILITY OF IMPACT | ESTIMATED RISK LEVEL |
| Citizens Affected: Half (2)<br>Life Threatening: Yes (3)<br>Costs: Medium (2) | Very Likely (3) | 10 Points: High |

***Planning Area Summary***

The planning area of heat relief shows both a high level of vulnerability and risk to climate change impacts. The assessment resulted in a total of 14 points out of a possible 17, and on a priority level, heat relief falls into Tier Four.

## *Air Quality Management*

***Vulnerability Part I: Sensitivity***

Atlanta deals with high levels of air pollution, including ozone ($O_3$), particulate matter (PM), nitrogen oxide ($NO_x$), sulfur dioxide ($SO_x$), volatile organic compounds (VOCs), carbon monoxide (CO), and airborne allergens. The majority of these pollutants are produced by fossil-fuel combustion (U.S. Environmental Protection Agency 2008). From a health and regulatory standpoint, ozone has been the

most problematic air pollutant in recent decades. Although unregulated, airborne allergens also pose a significant threat to health and are included in this discussion.

Since 1977, Atlanta has never been in compliance with federal ozone standards. The outward growth of suburban sprawl in the 1980's and 90's, overwhelming traffic congestion in and out of the city, and the ozone emissions from the Hartsfield-Jackson International Airport have led to Atlanta's consistent status as an EPA Non-Attainment zone (Center for Clean Air Policy 2004; Unal, Hu et al. 2005). With an ever-increasing population, municipal and regional transportation planners have struggled with the challenge of creating an accessible city while maintaining or improving air quality. Uncontrollable variables like temperature, humidity, and wind activity directly affect air quality patterns, thus making effective air quality management even more challenging.

Climate change will exacerbate ozone-related air quality problems. Increased ambient temperatures are correlated with increased ground level ozone levels (Liao, Tagaris et al. 2009). Studies show the number of bad air quality days in US cities will continue to increase (Patz and Kinney 2004). According to Bell et al., the average American city will experience increased levels of ozone under predicted future climate conditions. For Atlanta specifically, this will result in more National Ambient Air Quality Standard (NAAQS) exceedance days per summer, as shown in Table 10 (Bell, Goldberg et al. 2007).

**Table 10. Projections of NAAQS ozone annual summer exceedance days in Atlanta**

| | 1990's | 2050's |
|---|---|---|
| Days exceeding NAAQS 1-hour maximum ozone concentration | 4 | 7 |
| Days exceeding NAAQS 8-hour maximum ozone concentration | 28 | 33 |

The impacts of pollen on Atlantans are often overshadowed by concerns over regulated, human-generated air pollution. Outdoor counts for pollens are high in Atlanta, and the allergen often enters the indoors through open windows. Pollen levels are a health concern as sensitization is strongly

associated with respiratory ailments – especially asthma. This is particularly important in Atlanta, where asthma-related hospitalization rates are twice the national average (Carter, Perzanowski et al. 2001). Several studies have also suggested that interactions between air pollutants and allergens can exacerbate respiratory problems (D'Amato, Liccardi et al. 2002).

Expected longer summers due to climate change will allow for longer pollen seasons. Furthermore, pollen loads are expected to increase because of higher temperatures, and possibly higher levels of carbon dioxide. While it is unknown how dependent allergic diseases like asthma are on length of pollen seasons, both are already on the rise (Kinney 2008).

Air quality management efforts have proven challenging in Atlanta. Continued population growth and land use development will make the success of air quality improvement efforts more difficult. These factors, and the fact that air quality is directly affected by climate conditions result in a high sensitivity rating.

***Vulnerability Part II: Adaptive Capacity***

A number of transportation-oriented state, regional, and local programs have been implemented to reduce ozone emissions. The Georgia Regional Transportation Authority (GRTA) was created in 1999 to combat air pollution, traffic congestion, and land use planning in the greater Atlanta region. GRTA has the authority to finance mass transit projects, review major land developments, and approve land use and transportation plans in the region (Center for Clean Air Policy 2004). GRTA's work to alleviate traffic issues has been supplemented by the Metro Atlanta Rapid Transit Authority (MARTA), a public transit system that served more than 150 million riders in 2008 (Metropolitan Atlanta Rapid Transit Authority 2009). The ARC established the successful but underfunded Livable Centers Initiative and updated policies for the Regional Development Plan in 1999 (Center for Clean Air Policy 2004). The City of Atlanta has also joined the effort to reduce air pollution; the recent Connect Atlanta Plan has been designed to reduce vehicle miles traveled (VMT) and increase transportation mode choice. This plan has

been adopted by the City, but is currently unfunded (8/13/2009 interview with Heather Alhadeff). In fact, funding issues exist for nearly all transit systems and air quality improvement projects in Atlanta, which will likely impede progress in air quality management (Center for Clean Air Policy 2004).

Despite all of these efforts, Atlanta is one of several US cities that has demonstrated an increase in ozone concentrations, where most have documented falling levels (U.S. Environmental Protection Agency 2008). As climate change directly and indirectly creates more suitable conditions for air pollution, it seems unlikely that measured pollutant levels will remain the same. Hence, the planning area's ability to absorb the impacts is low.

That so much effort has failed to reduce measured ozone levels may in part be explained by the design of the management programs. Studies suggest that land use planning regulations that aimed at reducing automobile dependence and land use development may be more successful at improving air quality than transportation regulations, which are the dominant focus of current efforts. If this is true, the current regulatory framework is inadequate. The EPA, while charged with enforcing the Clean Air Act, is not permitted to regulate land use planning as a method of decreasing air pollution, although it has provided encouragement for states to do so through State Implementation Plans (SIPs) (Stone Jr. 2005). Additionally, the use of past weather patterns informs current pollution control policies (Kinney 2008). Because a changing climate will mean that past baselines will no longer be indicative of future conditions, successful air quality management stands to become increasingly difficult. For these reasons, policies and programs aimed at reducing air pollution should be designed to account for the impending changes.

The adaptive capacity analysis for addressing airborne allergens is very different since they are completely unregulated and naturally occurring. Nevertheless, there are several ways to reduce the health impacts caused by airborne allergens. An Atlanta-based study found that home visits focused on

maintenance of the indoor environment (visits that included hot washing of bedding, bedding covers, and education) reduced the number of hospital visits by asthmatic children. The study also found that only a fifth of prescriptions for asthma patients on Medicare were for preventative or controller medications (Carter, Perzanowski et al. 2001). Increased education and ability to purchase medications would likely reduce the experience of respiratory symptoms. A less popular adaptation would be to simply stay indoors with the windows closed.

Unfortunately, there seems to be little government action to reduce the problem of airborne allergens in the city and the costs of home visits and preventative prescription medications are often prohibitive. These aspects may act as barriers and reduce the capacity to increase the resiliency of this planning area.

Air quality management efforts focused on pollution must be coordinated by the federal government and state and local governments. While there have been substantial efforts carried out by these governments, Atlanta is still experiencing a growing number of bad air quality days due to pollution. In addition, very little seems to be done to reduce the impact of allergens. The adaptive capacity is low.

| AIR QUALITY VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Low | **5 Points: High** |

***Risk***

Ozone is known to cause inflammation in the deep lung and temporary decreases in lung function. Studies suggest that exposure can increase the risk of asthma-related hospital visits and even premature mortality. The most vulnerable populations are children, outdoor laborers, athletes, asthmatics, and the elderly (Kinney 2008). Bad air quality coupled with higher temperatures is likely to intensify the negative impacts on health, resulting in higher than average expected temperature mortalities, especially as the elderly population increases (Curriero, Heiner et al. 2002). The connections between

air quality, transportation behaviors, and health were demonstrated when asthma-related hospital visits by children plummeted during the 1996 Olympics, when Atlanta highway traffic decreased more than 20% (Friedman, Powell et al. 2001).

Lack of compliance with the National Ambient Air Quality Standard (NAAQS) brings serious economic costs to Atlanta. In 1999, a court ruling terminated federal, state, and local funding for 44 out of 61 planned road construction projects in the city during a conformity lapse period. The original projects would have received $1 billion dollars in federal funding, but the city only saw $300 million dollars, which was channeled toward emission-reducing transportation projects (Center for Clean Air Policy 2004).

Respiratory diseases place a $6 to $14 billion dollar annual drain on the US economy through lost worker productivity and allergies and asthma cost an additional $1 to $4 billion (Fisk 2000). With high rates of asthma already, it is reasonable to assume that Atlanta is currently dealing with the substantial costs of lost productivity, and a lower level of well-being for those affected.

Bad air quality has a high degree of impact on Atlantans, and poses high costs. The probability that climate conditions will worsen is very likely for this planning area. Therefore the estimated risk level is high.

| AIR QUALITY RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: All (3)<br>Life Threatening: Yes (3)<br>Costs: High (3) | Very Likely (3) | **12 Points: High** |

***Planning Area Summary***

The air quality planning area assessment resulted in the highest total score possible (17 points), due to the highest levels of vulnerability and risk. This places the planning area in Tier One in terms of prioritization.

## *Outbreak Prevention*

***Vulnerability Part I: Sensitivity***

Several types of outbreaks present challenges to Southeastern municipalities. These include mold infestations, waterborne pathogenic outbreaks, and Lyme Disease. The occurrences of such outbreaks are often enabled by suitable climactic conditions like severe storms and long summer seasons. While citizens are largely responsible for their own well-being, local governments can play an important role to warm residents of outbreaks.

A humid climate coupled with air-tight buildings has made mold infestations a common challenge in Atlanta. Building practices have resulted in airtight envelopes that effectively "lock in" mold when it occurs (Pouncey, Smith et al. 2004). Mold infestations can be the subject of expensive legal suits hoping to correct personal injury, collateral damage, and/or clean up costs. These suits are directed at property owners, architects, engineers, insurers, lenders, etc (Pouncey, Smith et al. 2004).

More than 60% of the annual load of contaminants in urban watersheds is transported during storm events (Fisher and Katz 1988). It should not be surprising then, that floods and heavy rain events can significantly contribute to the risk of waterborne disease outbreaks (Curriero, Patz et al. 2001). Pathogenic outbreaks following storm events can be difficult to contain. Although current research is insufficient, increased precipitation and runoff may increase the opportunity for *Salmonella*, *Campylobacter*, and *Leptospira* outbreaks in water sources (Gamble, Ebi et al. 2008).

Lyme Disease is the most common vector-borne disease in the US. Long summer seasons and more forest edge habitats promote the growth of tick populations and make Lyme Disease an increased health concern (Gubler, Reiter et al. 2001). According to Paul Shramm of the Center for Disease Control, the escalation of Lyme Disease outbreaks is a very real possibility for Atlanta (2/4/2010 interview with Paul Shramm).

Climate change will create more suitable conditions for each of these health threats. Longer summer periods with lower minimum temperatures will extend the growing season for both mold and ticks. Land use practices will create more suitable conditions for the spread of Lyme Disease. More frequent and intense flood events will likely increase the number of buildings affected by mold and provide more opportunities for pathogenic outbreaks. While there is some emphasis on preventative education, the current coping strategies for mold infestations, Lyme Disease and pathogenic outbreaks tend to be reactionary. These factors result in a high sensitivity ranking.

***Vulnerability Part II: Adaptive Capacity***

Atlantans may have a minimal ability to absorb the impacts of outbreaks, but adaptation and prevention is possible, particularly in the areas of Lyme Disease and waterborne pathogenic outbreaks.

If Lyme Disease or pathogenic outbreaks become a problem, the City of Atlanta could improve detection and public warning systems (Gamble, Ebi et al. 2008). With increased public warning systems, outbreaks may be prevented or mitigated.

Adapting to a more mold-friendly climate may pose greater challenges. Once a building is affected by mold, the remediation process is heterogeneous and subject to an individual building's characteristics. Budgetary constraints can lead to lengthy remediation projects, which may not even be successful. These factors translate into costly problems in terms of financial requirements and health of building occupants (Haverinen-Shaughnessy, Hyvarinen et al. 2008).

Atlantans should be able to adapt to the greater possibility of outbreaks. Adapting to mold infestations will be more difficult and could require different building and site standards. The adaptive capacity for the outbreak prevention planning area is medium.

| OUTBREAK PREVENTION VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Medium | **4 Points: High** |

***Risk***

Children and outdoor workers are particularly vulnerable to Lyme Disease, and those with compromised immune systems and the elderly are vulnerable to waterborne diseases. Many people affected by such diseases go untreated, which can occasionally become life-threatening (Gamble, Ebi et al. 2008). It is unknown how many buildings are impacted by mold.

A greater number of affected individuals will present citizens with more medical bills and reduce the city's economic productivity. Rising mold insurance claims contribute to higher insurance rates, and it is believed that medical costs related to poor indoor air quality are much higher than sickness due to outdoor air quality. Among the worst buildings are schools and government buildings across Atlanta; these buildings typically lack the financial resources to fix mold problems (Miller 2003). The climate conditions that could lead to increased outbreaks are very likely to occur. The estimated risk level is medium.

| OUTBREAK PREVENTION RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Few (1)<br>Life-threatening: Uncertain (2)<br>Cost: Medium (2) | Very Likely (3) | **8 Points: Medium** |

***Planning Area Summary***

The outbreak prevention planning area assessment garnered a high vulnerability rating and a medium estimated risk level. Together, these assessments resulted in 12 total points for the planning area, which places it in Tier Seven for prioritization.

## Sector: Water Resources

### *Water Supply*

#### *Vulnerability Part I: Sensitivity*

Natural and political circumstances of recent years have resulted in a high level of attention on local water supply. The Southeastern US experiences frequent periods of drought. Long term drops in precipitation directly impact the water supply planning area in such a highly populated city. In addition to state-imposed water conservation regulations during these periods, the City of Atlanta Department of Watershed Management successfully implements demand-side conservation efforts to reduce water consumption. These efforts have earned the department Commissioner, Robert Hunter, the 2008 Water Efficiency Leader Award by the EPA (Rose 2008).

To add to drought-caused water supply concerns, Georgia, Alabama and Florida have been entangled in a twenty year tri-state water war over the rights to Lake Lanier water, which is metropolitan Atlanta's only supply of water. In the summer of 2009, a court ruling determined that water supply is not an authorized purpose of Lake Lanier, and the storage of water by the Army Corps of Engineers for supply needs violates the Water Supply Act of 1958 (Dunlap 2009). This ruling presents a challenge to the City of Atlanta's Department of Watershed Management, whose service population will increase from 726,641 to 1,345,500 customers by 2050. The Atlanta Master Plan (which was written prior to the court ruling) identified the need for future increased water allocations from Lake Lanier (Department of Watershed Management 2009), yet the 2009 ruling requires withdrawals from Lanier to return to 1970 levels by 2012. Technological advances and efficiency improvements may make this an attainable requirement for the city. However, some surrounding jurisdictions in the metropolitan area were not allocated any water from Lake Lanier in the 70's and may have to find a completely new source of water (2/4/2010 interview with Melinda Langston). It is obvious that metropolitan Atlanta's needs and plans are not congruent with the legal allowances for use of Lake Lanier water.

Climate change will impact the city's water supply due to longer, more frequent droughts, and hotter days that will speed evaporation. Demand for water will likely climb during the longer, hotter summer period and make conservation efforts more imperative. Flood events may play an important, although unpredictable role in recharging water supply reservoirs. In sum, these impacts will exacerbate the planning area's current and future stresses. Therefore, the planning area of water supply has a high sensitivity with regard to climate change.

***Vulnerability Part II: Adaptive Capacity***

Atlanta continues to develop its water use and conservation strategies. The City has identified water efficiency projects in the Atlanta Master Plan that could save 136 million gallons per day. For example, the Plan includes the Department of Watershed's intentions to complete 13,960 plumbing fixture retrofits annually over a forty year period, beginning in 2015 (Department of Watershed Management 2009). The Department also plans to pursue conservation pricing schemes and rain sensor requirements for outdoor irrigation systems (Metro Atlanta Chamber of Commerce 2006). The City is also working to increase its supply through the BeltLine Project's Bellwood Quarry, which is planned to become a 1.9 billion gallon drinking water reservoir (Mayor's Office of Communications 2006), although it is not clear when. This amount of water could supply the city drinking water for up to twenty days (Atlanta BeltLine Inc. 2008), and should alleviate growing demand and reduced allowances from Lake Lanier.

There is evidence that highly-managed systems (like Atlanta's water supply) that have successfully handled stresses (like extended droughts) can be expected to adapt well to stresses associated with future climate change (Ausubel 1991). However, the legal change in availability of water from Lake Lanier coupled with continued population growth will be new stressors, and may challenge this theory. Funding limitations will also create a barrier to adaptation efforts. Nevertheless, with the anticipated water supply and efficiency projects, Atlanta may be able to handle and absorb changing climate conditions without a problem. Therefore, the adaptive capacity of this planning area is high.

| WATER SUPPLY VULNERABILITY ASSESSMENT | | |
|---|---|---|
| SENSITIVITY SCORE | ADAPTIVE CAPACITY SCORE | VULNERABILITY LEVEL |
| High | High | 3 Points: Medium |

***Risk***

Water supply issues can impact all Atlantans, especially during periods of drought. A drought alone is typically not enough to be life threatening, but when coupled with heat can pose health threats. The costs of a typical drought can be expensive to water-intensive industries and pose small costs to the typical Atlantan. Droughts may also motivate expensive City-funded efficiency projects. The region already experiences droughts and it is very likely that the frequency and intensity of these times will increase. Together, these factors result in a high level of risk.

| WATER SUPPLY RISK ASSESSMENT | | |
|---|---|---|
| DEGREE OF IMPACT OF CHANGE ON SYSTEM | PROBABILITY OF IMPACT | ESTIMATED RISK LEVEL |
| Citizens Affected: All (3)<br>Life Threatening: No (1)<br>Costs: High (3) | Very Likely (3) | 10 Points: High |

***Planning Area Summary***

Although this planning area has a high level of sensitivity to climate change, it also is characterized by a high level of adaptive capacity in Atlanta. Therefore, the vulnerability assessment resulted in a medium level of vulnerability. However, problems with water supply can affect many citizens and the climate change is very likely to occur, so the estimated risk level is high. In sum, the planning area assessment resulted in a total of 13 points, which places water supply in Tier Five for prioritization purposes.

## *Water Quality*

***Vulnerability Part I: Sensitivity***

Water quality in Atlanta has faced major hurdles in recent decades, spurring a concerted effort to remedy environmental harms. The success of these commendable and necessary measures is hindered

by the very difficult physical realities of an expanding urban landscape. Understanding the current and future stresses, the players involved, and their strategies, sheds light on the planning area's sensitivity to climate change.

The Chattahoochee River corridor is a major natural feature in the area, with historic and cultural significance and high ecological diversity. The natural state of the corridor has been altered by decades of land development and invasive species. Urban streams and drainageways are exposed to litter, pollution, and hydrologic impacts due to stormwater runoff (Department of Planning and Community Development 2003). A 2002 United States Geological Survey (USGS) study found that algal, invertebrate, and fish populations in Atlanta area streams showed statistically significant degradation when watersheds were urbanized (Gregory and Calhoun 2007).

The City of Atlanta, the National Park Service, and regional and state actors are working to protect and preserve the corridor against future development impacts (Department of Planning and Community Development 2003). Several efforts are underway to reclaim and protect Atlanta's streams and watersheds, including improved water/sewer infrastructure and increased streamside greenways. These efforts- many of which have been mandated - have been critical to mitigate substantial water quality problems. In the late 1990's the EPA, The Georgia Department of Environmental Protection, the Upper Chattahoochee Riverkeeper Fund, Inc., the Upper Chattahoochee Riverkeeper, Inc., and W. Robert Hancock, Jr. brought an enforcement action against the City for violations of the Federal Water Pollution Control Act and the Georgia Water Quality Control Act. The City settled the matter by signing a Combined Sewer Overflow (CSO) Consent Decree in 1998. This committed the City to several projects that would improve water quality by the year 2007 (Clean Water Atlanta).

In addition to infrastructure improvements, emphasis on water quality monitoring has been considerable. Atlanta has partnered with the USGS to conduct a comprehensive water quality

monitoring project. The City also has a contract with the consulting company CH2MHill to perform biological sampling of streams (2/11/2010 interview with Brian Hughes).

Water quality is significantly affected by climate conditions (like droughts, floods, and heat) and climate change stands to exacerbate current water quality problems (2/11/2010 interview with Brian Hughes). Surface water quality can be degraded during periods of drought, and the degradation is made worse by high temperatures and even when residents construct wells. Residential wells draw down the groundwater table and lower stream water levels which results in higher pollutant concentrations. When coupled with a highly developed landscape, weather events have large impacts on stream ecology. Even moderate storms can create flood conditions that alter the physical hydrology of stream channels. Urban runoff carries an assortment of chemical and trace metal pollutants that affect water chemistry. Together, changing hydrology and water chemistry create habitats suitable to only the most resilient aquatic species. The sensitivity of the water quality planning area to climate change is high.

***Vulnerability Part II: Adaptive Capacity***

Future population growth will likely cause more wastewater production and further land use development that creates more impervious surface. Land use conversions that make the city more resilient to floods and improve water quality will become more difficult and piecemeal to implement. These changing conditions will likely reduce the City's ability to absorb additional impacts brought about by climate change. With that in mind, Atlanta's ability to control and direct land use now can play a significant role in improving water quality of streams today and in the future.

As part of the 1998 CSO Consent Decree, the City of Atlanta acquired more than 120 streamside properties through the Greenway Acquisition Project between 1998 and 2007 (Clean Water Atlanta). Protection of these areas allows the natural filtration process to ensure stormwater that enters streams is clean (Department of Watershed Management 2009). This type of strategy may become more important in the future.

Continued improvements to water infrastructure will improve water quality by decreasing the instances of sewage and stormwater overflows into streams. But these improvements are not cheap; the Metro North Georgia Water Planning District estimates that wastewater and stormwater improvements through 2030 will cost $70 billion. This funding must come from local sources. While ratepayers generate funds for wastewater treatment, the stormwater improvements have no built-in revenue stream (Metro Atlanta Chamber of Commerce 2006). A good deal of funding for water infrastructure improvements comes from the City's General Fund and has been subject to budget cuts. The costly nature of improvements often means that court rulings, and state or federal requirements are the impetus for local action.

Contractual agreements with environmental consulting firms and federal scientific agencies like the USGS allow the city to have an awareness of water quality problems as they occur (2/11/2010 interview with Brian Hughes). These monitoring agreements can be costly, and if they are not mandated, could be discontinued during times of economic stress.

The City's commitment to water quality monitoring and streamside protection will facilitate those working to increase the resiliency of this planning area. City-wide water quality improvements can be achieved by a complex, coordinated effort that often requires substantial funding and political will. Because these critical resources are often unavailable or in short supply, the adaptive capacity is low.

| WATER QUALITY VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Low | **5 Points: High** |

***Risk***

Compromising the health of Atlanta's waterways can translate into higher costs to business, health impacts on citizens, and decreased resiliency of aquatic ecosystems. Water quality affects all Atlantans, not in the least through water treatment costs. City government has already paid a substantial amount

to improve water and sewer systems - the improvements mandated by the Consent Decree cost billions of dollars. Future sewer improvements will likely be paid for by ratepayers, causing water and sewer rates to possibly triple (from annual average $632 in 2002 to $1,776) by 2014 (Department of Watershed Management 2009). In addition, the perception of low water quality could reduce the city's attractiveness to businesses and residents. The climate changes that could decrease water quality are very likely to occur. Therefore, the risk level of water quality to climate change is high.

| WATER QUALITY RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: All (3)<br>Life-threatening: Uncertain (2)<br>Costs: High (3) | Very Likely (3) | **11 Points: High** |

***Planning Area Summary***

Based on the research for this study, the water quality planning area shows a high level of sensitivity and a low level of adaptive capacity. Because water quality can be so highly impacted by climate change and the city has a low capability of adapting to such impacts, this planning area has a high vulnerability rating. The estimated risk level is high, and contributes to the planning area's total score of 16 points. Water quality therefore falls into Tier Two for prioritization purposes.

## Sector: Energy

### *Electricity Production*

***Vulnerability Part I: Sensitivity***

Like the air quality and water-related planning areas, energy planning areas are influenced by a complicated mix of regulations, technologies, and personal behaviors. Unique to the electricity production planning area is the dominating influence of a single company – Georgia Power. A subsidiary of Southern Company, Georgia Power generates and distributes the majority of Atlanta's electricity. The utility is governed by the Georgia Public Service Commission (GPSC), which regulates costs, planning

requirements, and plant projects. Coal combustion and nuclear power generation make up 93% of the company's energy mix, and may be impacted by future federal GHG emission policies. This report will not attempt to guess what policies might be enacted or exactly how electric utilities would be affected. For now, it will suffice to say that regulation of GHG emissions in the future is likely, and any regulation will impact Georgia Power and other electricity producers.

Georgia Power is preparing for a growing population and the associated increased energy demand in the region. The additional base load capacity needed to satisfy the future population will in part be met by two additional nuclear units at an existing plant in the region (Georgia Power 2009).

Advances in coal combustion technology and a stringent regulatory environment over base load generation have lead to large decreases in Atlanta's ambient air pollutant levels like $NO_x$ and $SO_x$ since 1998 (Environmental Protection Agency 2008; Environmental Protection Agency 2008), but carbon emissions have yet to be regulated. Therefore, coal combustion continues to contribute heavily to climate change, with a GHG emission factor of 206.1 (Hong and Slatick 1994). The GHG emissions factor for natural gas is 117.08, which means that it contributes less to climate change than coal (US Energy Information Association 2010). Georgia Power is in the midst of reconstituting several coal power generation plants into natural gas plants (Georgia Power 2009). These conversions will improve regional air quality and help decrease GHG emissions (Georgia Power 2009).

Peak load generation provides energy when demand is unexpectedly high or a base load plant is not operating. Georgia Power produced 41,079 megawatt-hours by operating 31 peak combustion turbines in 2008. This accounted for 0.07% of the company's total generation that year (12/16/2009 email from Steve Ewald). Peak load generation is more expensive and produces more pollutants due to a different generation process, so it is avoided as much as possible.

Electricity production is inextricably linked to temperature. Both high and low temperatures place increased demand on production. According to the US Global Change Research Program, the demand for heating energy will decrease, and the demand for cooling energy will increase in the future, resulting in significant summer electricity use and higher peak demand (Scott and Huang 2007). Climate-induced migration and expected population growth will further increase demand. Hotter temperatures can reduce the efficiency of production in thermal power plants (Karl, Melillo et al. 2009) and affect electricity flow through transmission lines. On the positive side, milder winters could reduce strain on equipment and machinery, and increase their lifetime.

The direct link to climate conditions makes the electricity production planning area highly sensitive to climate change.

***Vulnerability Part II: Adaptive Capacity***

Georgia Power examines the weather forecasts and predicts when demand will fluctuate. If demand is high, the utility puts as many generating units online as possible, and sometimes uses peak load generators to fill the gaps. These practices result in a power system that can typically absorb changing climate conditions in the immediate future with no problems. However, coal, nuclear, and gas electricity production are all extremely dependent on water use. The high likelihood that water supply and temperature constraints will hinder electricity production by Georgia Power is of great concern.

A main concern for future electricity production is the large increase in demand due to a booming regional population (12/16/2009 email from Steve Ewald). Increasing base load capacity is a time-consuming process that can take many years. Under state law, regulated electric utilities are required to file Integrated Resource Plans (IRPs) with the GPSC every three years (American Council for an Energy-Efficient Economy 2009). This consistent accounting mechanism helps ensure that utilities have accurate projections of energy demand up to twenty years into the future. After the GPSC accepts capacity expansion proposals, construction of new power plants can take several years. Georgia State

law does not require regulated utilities to offer energy efficiency programs, although Georgia Power offers one for residential customers and one for residential builders (American Council for an Energy-Efficient Economy 2009). Energy efficiency programs may decrease the need to build additional base load power plants, although some economists believe that such programs will only make energy easier to afford and use more liberally (Herring 2006) .

There is growing support for the argument that renewable energy will play a vital role in climate change resilience. Atlanta's current renewable energy sources include landfill gas and scattered solar panel installations, with potential for biomass. The amount of renewable energy produced will continue to grow, but it seems it will do so at a slow pace. Georgia Power had planned to convert an old coal plant in Albany, GA into one of the largest biomass plants in the country. The plans are now delayed, with the company citing uncertainty over future federal regulation that would affect the new plant (Markiewicz 2010). Although federal actions have hindered Georgia Power's expansion of renewable energy production, the American Recovery and Reinvestment Act (ARRA) provided $4.5 million to the state of Georgia to fund fourteen solar energy projects through the Clean Energy Property Rebate Program. Several of these projects will take place in Atlanta (Hix 2009).

The production process will be increasingly impacted by changing climate conditions, and building generation capacity takes years due to political and regulatory obstacles. The adaptive capacity of this planning area is low.

| ELECTRICITY PRODUCTION VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Low | **5 Points: High** |

***Risk***

Climate change impacts on electricity production will affect all Atlantans. Increased production is not life-threatening. Peak demand generation is more expensive for the utilities and adding base load

generation capacity is very expensive. The higher temperatures and intermittent drought conditions that will impact energy production are very likely to occur. These factors result in a high risk level.

| ELECTRICITY PRODUCTION RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: All (3)<br>Life-threatening: No (1)<br>Costs: High (3) | Very Likely (3) | **10 Points: High** |

***Planning Area Summary***

The electricity production planning area is highly sensitive to climate, and has a low capability to adapt, which leads to a high vulnerability level. The risk level is also high, and the planning area earned 15 points – enough to place it in Tier Three.

## *Electricity Demand*

***Vulnerability Part I: Sensitivity***

Electricity demand is largely influenced by economic activity and climate conditions (Medlock III and Soligo 2001; Santamouris, Papanikolaou et al. 2001). Although residents in Georgia pay an electricity rate that is comparable to the rest of the country, they use nearly 12% more electricity than the national average (Division of Energy Resources 2005). After a steady 1-2% increase in demand throughout the 1990's and early 2000's, 2008 and 2009 saw a decrease in demand – likely due to the economic recession. Demand is expected to increase again around 2012 (12/9/2009 interview with Steve Ewald). The President and CEO of Southern Company, Georgia Power's parent company, recently stated that "electricity drives the economy; it drives the expansion of the economy. So the demand will increase [once the recession ends] (Athens Banner-Herald 2010)."

Throughout this century, average temperatures in Atlanta will rise – resulting in longer, hotter summers and warmer winters. In general, the demand for energy will increase in the summer, which will be

longer, and may decrease in the winter. Studies show that the demand for cooling energy rises 5-20% for every 1.8 ˚F of warming. Wintertime heating energy demand could decrease 3-15% for the same temperature increase (Scott and Huang 2007). Since conservative estimates suggest temperature increases of 4.5 ˚F by 2080, this will have a substantial impact on the energy consumers (and their above average utility bills).

The electricity demand planning area is given a sensitivity score of high because of its direct connection to climate.

***Vulnerability Part II: Adaptive Capacity***

A number of options exist for customers dealing with a greater dependence on electricity, but financial barriers will likely play the biggest role in reducing adaptive capacity. Spending more on utility bills is one way to deal with increased dependence. For those that cannot afford consistently higher bills, energy efficient products like Energy Star and financial aid programs will facilitate resiliency. For example, in an effort to control energy costs and reduce GHG emissions, Atlanta's municipal government buildings are now able to finance energy efficiency retrofits through a revolving loan fund made possible by the ARRA. But for the large portion of citizens, accepting higher energy bills or investing in retrofits and new efficient appliances will mean a lower ability to purchase other products or services. Cash-strapped families that cannot afford efficiency retrofits may try to reduce bills by not using air-conditioning or cutting usage in other areas. These customers would benefit from weatherization programs, as well as financial support programs offered by Georgia Power. For many, even these programs will not help. It is quite possible that the growing need for electricity will put families out of homes, and small companies out of business.

Georgia Power is currently installing smart meters throughout the region, but the technology's capability is currently limited. Advances in smart meter technology would give customers more real-time information to control their energy usage (Georgia Power Company 2008).

The adaptive capacity of the electricity demand planning area is medium. A number of promising technologies already exist that can help increase energy efficiency and possibly reduce energy demand. However, large scale dissemination of these technologies is the main barrier to adaptation.

| ELECTRICITY DEMAND VULNERABILITY ASSESSMENT | | |
|---|---|---|
| SENSITIVITY SCORE | ADAPTIVE CAPACITY SCORE | VULNERABILITY LEVEL |
| High | Medium | 4 Points: High |

***Risk***

Increased dependence on air-conditioning makes customers more vulnerable to higher energy costs. Since all Atlantans are utility customers, all will be affected. The impacts will generally not be life-threatening, but the costs will be high. The climate conditions that impact this planning area are very likely to change, therefore the risk level is high.

| ELECTRICITY DEMAND RISK ASSESSMENT | | |
|---|---|---|
| DEGREE OF IMPACT OF CHANGE ON SYSTEM | PROBABILITY OF IMPACT | ESTIMATED RISK LEVEL |
| Citizens Affected: All (3)<br>Life-threatening: No (1)<br>Costs: High (3) | Very Likely (3) | 10 Points: High |

***Planning Area Summary***

The planning area of electricity demand is highly sensitive to climate change and has a moderate capability to adapt if needed. Consequently, the vulnerability level is high. The estimated risk level is also high, leading to a total score of 14 points and placement in Tier Four.

## *Energy Assurance*

***Vulnerability Part I: Sensitivity***

The energy assurance planning area focuses on enhancing the reliability of electricity and shortening disruptions in service. Disruptions are caused by local damage to transmission infrastructure or unexpected jumps in energy demand, which are often the result of climate conditions. Climate affects

electricity producers' ability to provide reliable service in a number of ways. Coal and nuclear energy producers are prohibited from releasing heated water into rivers when water temperatures pass a certain threshold. When river temperatures are nearing this threshold, cooling machinery is strained. Droughts and increased ambient air temperature can increase river temperatures so much that electricity production must stop. These occurrences may become more commonplace as extended periods of droughts and high temperatures occur more frequently. Without advances in cooling technology producers will experience a higher risk of power shut-downs on the hottest days, when energy is most needed.

Secondly, as the summer temperatures increase, the dependence on air-conditioning also rises. If power generators fail for any length of time, a large number of citizens will be subjected to dangerously hot environments at the worst, and uncomfortable environments at the least. As the population grows, the number of critical resources that require back-up power generation will also grow. While Georgia Power has many emergency plans and prioritization methods to ensure critical infrastructure has energy first (12/9/2009 interview with Steve Ewald), such plans and methods will likely require expansion as the number of critical resources increase.

Power transmission is also highly exposed to weather (see Figure 4). Power lines are often damaged by high winds, fallen trees, lightening strikes, and other severe weather occurrences. More frequent severe storms and trees weakened by drought could result in more downed power lines. A longer growing season would likely mean a greater need for vegetation clearing from transmission lines to reduce some of these risks. Certain weather events, like flood conditions, make power line repair difficult and slow. Increased power failures could lead to additional cancelled school days, a drain on the private sector, increased costs for residents, compromised emergency services, and higher costs to the power utilities.

The high exposure to climate and dependence on benign weather conditions results in a high sensitivity score for the energy assurance planning area.

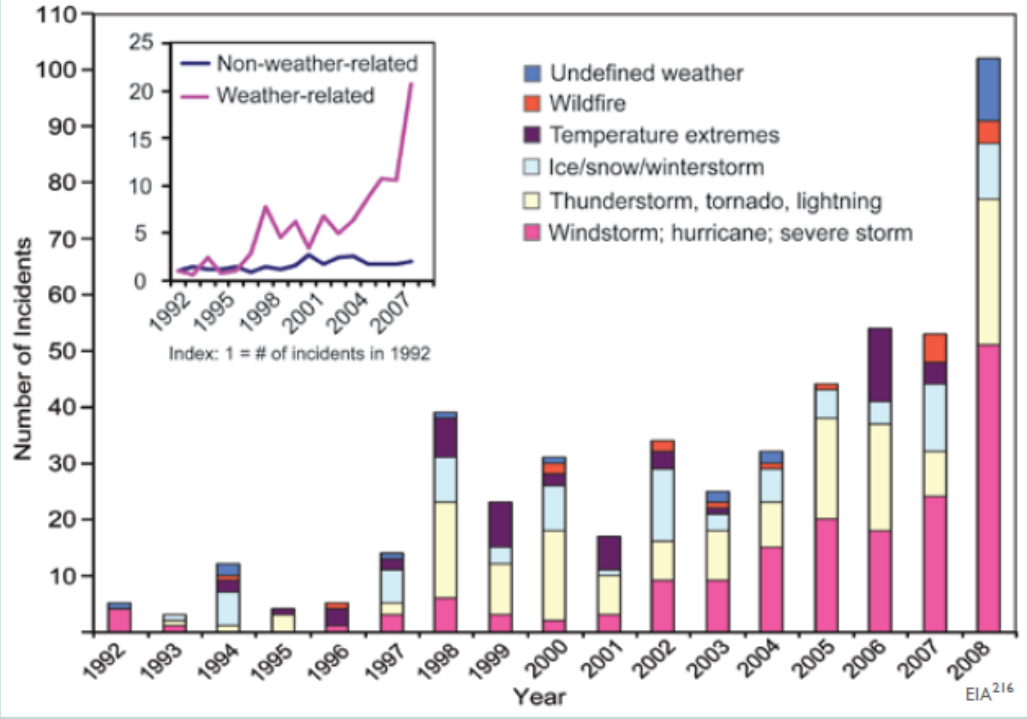
***Vulnerability Part II: Adaptive Capacity***

Georgia Power plans to increase its generation capacity to cover the rising demands of a growing population. By increasing its generation capacity even further and improving demand prediction capabilities the company could reduce the risk of brownouts and blackouts when energy demand is high. However, these capacity increases are expensive, and may not occur. Although only a fraction of Atlanta's current energy mix, renewable energy provides the opportunity for decentralized power generation and could be used to provide energy to critical customers.

Smart grid and smart metering technology would facilitate efforts to increase the resiliency of the energy assurance planning area. More specifically, a smart grid system would reduce the impacts of power outages by containing the disruptions in a small area. Smart meters could reduce energy demand and also provide valuable information that could be used to pinpoint outages more efficiently. Although a smart grid system has yet to be established, Georgia Power began installing its Smart Meter technology in residential homes in 2008 (Georgia Power Company 2008).

A more aggressive strategy to reduce outage involves installing underground power lines. This option removes the vulnerability caused by tree falls and high winds. Installing power lines underground is optional and more expensive, thus occurs rarely. From a business standpoint, it is unclear whether Georgia Power would save money with underground lines through reduced service calls. Large scale outages are a risk, but the southern grid has the capability of separating from the national grid and therefore from feeling effects of other regions' cascade outages (12/9/2009 interview with Steve Ewald).

**Figure 4. Significant Weather-Related US Electric Grid Disturbances (Karl, Melillo et al. 2009)**




The number of incidents caused by extreme weather has increased tenfold since 1992. The portion of all events that are caused by weather-related phenomena has more than tripled from about 20 percent in the early 1990s to about 65 percent in recent years. The weather-related events are more severe, with an average of about 180,000 customers affected per event compared to about 100,000 for non-weather-related events (and 50,000 excluding the massive blackout of August 2003).[201] The data shown include disturbances that occurred on the nation's large-scale "bulk" electric transmission systems. Most outages occur in local distribution networks and are not included in the graph. Although the figure does not demonstrate a cause-effect relationship between climate change and grid disruption, it does suggest that weather and climate extremes often have important effects on grid disruptions. We do know that more frequent weather and climate extremes are likely in the future,[68] which poses unknown new risks for the electric grid.

The adaptive capacity for energy assurance relies largely on one company and the preferences of the Public Service Commission, both entities sharing a high preference for low energy costs. Unfortunately, the technologies that would improve energy assurance are costly. This planning area is therefore considered to have low adaptive capacity.

| ENERGY ASSURANCE VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Low | **5 Points: High** |

***Risk***

Power failures and disruptions in service vary in scale. Small disruptions impact a neighborhood street, while brownouts can impact a large portion of the city. The social impacts of lost power indirectly impact those not directly affected through lost work, changed schedules and fewer services. In this assessment, the number of citizens affected by failures in energy assurance was estimated to be half of the population, due to the possibility of a large number of impacted citizens from any given power failure. The costs can be expensive and include lost work opportunities, high repair costs for power companies, and increased work for emergency personnel throughout the city. Although the typical outage is not life-threatening, outages during heat waves can pose immediate health dangers for residents. The climate changes (namely severe storms and heat waves) that will increase the chance for power failures are very likely to occur. The estimated risk level is high.

| ENERGY ASSURANCE RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life-threatening: Yes (3)<br>Costs: High (3) | Very Likely (3) | **11 Points: High** |

***Planning Area Summary***

The planning area of energy assurance demonstrates the highest level of vulnerability, due to a high sensitivity to climate change and a low capability to adapt. In addition, the planning area has a high estimated risk level, which led to a total of 16 points. These results place the energy assurance planning area in Tier Two for prioritization purposes.

## Sector: Building Infrastructure

### *Stormwater Management*

***Vulnerability Part I: Sensitivity***

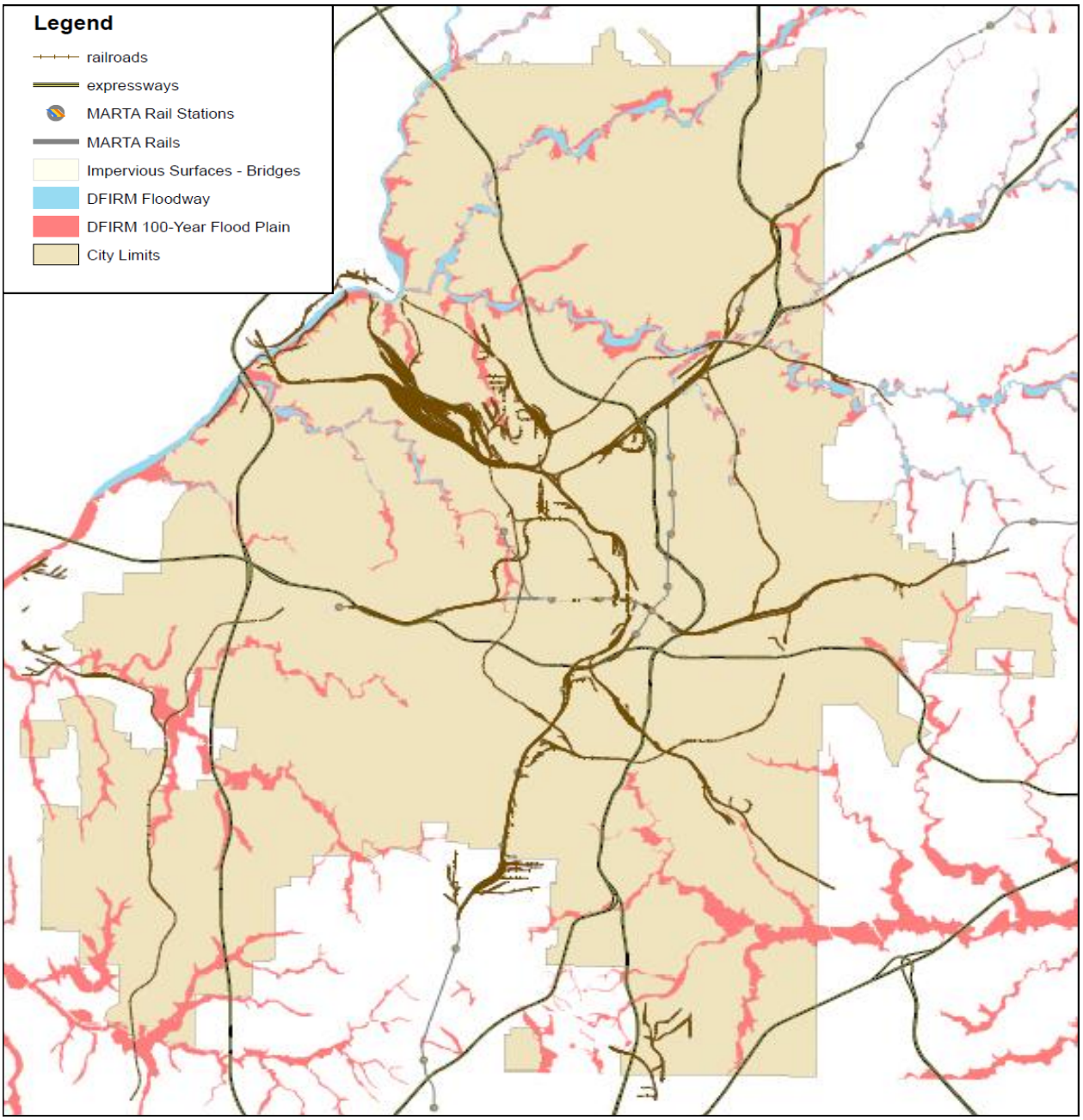
Managing stormwater poses a difficult challenge for any city, and Atlanta is no exception. After precipitation events, Atlanta's streams demonstrate a higher peak level and return to baseline levels quicker than nearby non-urban streams. Both of these phenomena can be attributed to a high level of impervious surface, a typical characteristic of urban areas (Rose and Peters 2001). A city with a high percentage of impervious surfaces will often struggle with flash floods after heavy rain events. In addition to causing water damage to building infrastructure, flash floods can pose a health risk. Pollutants accumulate on impervious surface during dry periods, and flash floods sweep these pollutants and sediments into nearby water bodies.

The amount of permeable surface area will continue to diminish in the region due to increased land development. A 2002 study that analyzed satellite remote sensing data for the thirteen county area predicted that urban land will increase from 1.3 million acres in 2010 to 2.1 million acres in 2050. Forest land is projected to fall from 1 million acres in 2010 to 350,000 acres in 2050 (Lo and Yang 2002). If this occurs, managing stormwater runoff will undoubtedly become more difficult.

To compensate for lost ecosystem services from permeable forest land, the City has created an elaborate wastewater management pipeline system, including 1500 miles of sanitary sewers. These systems are not always adequate. After heavy rain events, sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs) can malfunction and result in the spilling over of untreated sewage into nearby streams. To mitigate this problem, the City recently reduced the number of CSOs by completing three combined sewer separation projects (totaling $1 billion). In addition, two thirds of the sewer system has been analyzed through the Sanitary Sewer Evaluation Survey (SSES). Rehabilitation of these sewers will continue until 2014 and is expected to cost the City $3.8 billion (American Society of Civil Engineers Georgia Section 2009). This project is subject to budget shortfalls and resulting delays.

CNN meteorologist Jacqui Jeras posits that the urbanization of Atlanta and suburban sprawl were key contributors to the September 2009 floods. Instead of hitting soil, the eight-day long rain fell on concrete, draining quickly into overwhelmed rivers and drainage systems (Sutter 2009). Reports suggest

**Figure 5. City of Atlanta waterways and 100-year floodplain, with major transportation routes (Source: Atlanta GIS Department)**



that the recent stormwater systems improvements helped to mitigate the water surge during the flood, but overflows still occurred (Bennett 2009). Climate change is likely to bring about stronger, more frequent heavy rains, exacerbating the stormwater management challenges the city already faces. At times, rain events will be preceded by periods of drought, allowing a greater buildup of contaminants on urban surfaces. When the rains do come, the amount of pollution carried by the water will be greater.

In most cases, stormwater is not problematic, but when it is, the impacts are widespread. The sensitivity of this planning area is medium.

***Vulnerability Part II: Adaptive Capacity***

A city ordinance prohibits the development of property in the 100-year flood plain, and is meant to safeguard future development from the risks of flooding. The 100-year flood plain is defined intermittently by the Federal Emergency Management Agency (FEMA), which updated Atlanta's maps in 2001. Updates are necessary because changing weather patterns and increased surface area of impermeable surfaces change the dynamics of urban flooding (Burby 2006). Depending on the amount of change the city has experienced since 2001, it may be that these maps are already outdated. Of additional concern is the fact that FEMA maps do not factor in climate change projections. If the flood plain maps are already (or will soon be) outdated, this safeguard is not has helpful as it is meant to be.

To further weaken the intent of the flood plain ordinance, there are two instances when it is not observed. First, the Commissioner of Public Works has the ability to override the ordinance and grant permission to build within the flood plain (City of Atlanta 2002). Second, the ordinance does not apply to homes that were in place at the time the ordinance was passed (8/31/2009 interview with Susan Rutherford). This "grandfathering" has allowed several locations to remain especially vulnerable to flood events, including the Vine City and Peachtree Creek areas.

In addition to the flood plain ordinance, Atlanta has taken various approaches to reduce flooding costs, including buying properties or seeking federal grants to elevate structures. These measures are typically responses to recent flood events and undertaken to avoid additional future damages. The following actions taken by Atlanta are prime examples of adaptation measures to increase resiliency to flooding:

- In 2002, a major flood event ravaged the low-income Vine City area (Walker 2003). The damage was so extreme that the Department of Watershed Management decided to purchase the land and homes and converted them to greenspace (08/31/2009 interview with Susan Rutherford).
- In 2007, the City applied for and accepted nearly $2 million dollars from FEMA to elevate seventeen residential structures in the Peachtree Creek area in 2007 because of frequent flooding issues (City Utilities Committee 2007; City Utilities Committee 2007).
- In another area of the city, a faulty culvert system that was supposed to protect two homes in the 100-year flood plain would have cost an estimated $1.7 million dollars to fix. The Department of Watershed Management opted instead to purchase the properties and connected easements and restore the flood plain to its natural condition for under $500,000. This step created more greenspace in the neighborhood and mitigated flooding in other nearby areas (Morris 1996). Both options are examples of adaptation actions, but the action chosen was less expensive and provided co-benefits (increased greenspace and flood protection).
- Greenroofs can mitigate urban stormwater problems. There are no municipal incentives that promote their installation, but the City leads by example with a greenroof on City Hall.

High project costs have presented the most restrictive obstacle to managing stormwater runoff. Atlanta has made futile attempts to cover these costs. One of these attempts was the establishment of a municipal stormwater utility in 1999. This utility was

"funded by annual charges based on the size and use of properties in the City. By calculating fees in this fashion, the utility failed to distribute fees to those that most directly contributed to the problem. Thus, the stormwater utility fee looked more like a general tax than a fee for services and the utility was successfully challenged in *Fulton County Taxpayers Association v. City of Atlanta*. The City was required to return all funds collected back to property owners, with interest (8/31/2009 interview with Susan Rutherford)."

**Figure 5. Greenroof on the roof of City Hall**

According to the 2009 Annual Water Report, the City may revisit this type of strategy to establish a dedicated source of funding for stormwater projects (Department of Watershed Management 2009).

Federal and state mandates have helped stormwater management efforts. The Metropolitan Water District has required the City to strengthen the stormwater ordinance and create a conservation subdivision zoning district. When federal and state regulations have been relaxed, the Bureau of Watershed Protection has a more difficult time enacting programs and policies (2/4/2010 meeting with Kenna Laslavic).

In conclusion, Atlanta improvements to stormwater management typically occur after problems are identified, making progress slow and piecemeal, and in many cases costly. The adaptive capacity is low.

| STORMWATER MANAGEMENT VULNERABILITY ASSESSMENT | | |
|---|---|---|
| SENSITIVITY SCORE | ADAPTIVE CAPACITY SCORE | VULNERABILITY LEVEL |
| Medium | Low | 4 points: High |

***Risk***

Inadequate stormwater management can lead to a number of problems; most notably, floods. Flood damage can bring a heavy cost to citizens and City operations: about half of the floods reported in Atlanta since 1994 caused damages ranging from $2,000 to $1.5 million dollars (National Oceanic and Atmospheric Administration Satellite and Information Service and National Climate Data Center 2009). The most recent flood event occurred in September 2009, and caused preliminary estimates of $61 million in damages to be paid by the City (most of which could be recuperated later through federal emergency recovery programs). The most significant cost was the damage sustained by RM Clayton, Atlanta's largest wastewater treatment facility. Table 11 (below) outlines the initial cost assessment for municipal departments from this flood. In addition to these losses, hundreds of private buildings were damaged, for which the costs have not yet been estimated (Wessels 2009). Additionally, inaccurate flood plain maps can lead to insufficient flood insurance for building owners.

**Table 11. Initial cost estimates as a result of September 2009 flood (Wessels 2009)**

| City of Atlanta Department | Overtime Costs | Damage Costs | Totals |
|---|---|---|---|
| Atlanta Police | $6,066 | - | $6,066 |
| Atlanta Fire Rescue | $17,446 | $55,575 | $73,021 |
| Parks Recreation and Cultural Affairs | $25,579 | $2,390,000 | $2,415,579 |
| Planning and Community Development | None | - | - |
| Office of Enterprise Assets Management | $3150 | $250,000 | $253,150 |
| Aviation | $15,500 | $25,000 | $40,500 |
| Public Works | $156,200 | $5,992,000 | $6,148,200 |
| Watershed Management | $153,852 | $52,076,200 | $52,230,052 |
| Totals | **$377,793** | **$60,788,775** | **$61,166,568** |

Human health is also at risk – flood related deaths are reported every year. Most fatalities occur as a result of drivers being swept away while trying to pass through water-covered roads (National Oceanic and Atmospheric Administration 2006). Health issues also emerge during the recovery period as residents and building owners deal with increased mold outbreaks, which are already a problem in Atlanta (Miller 2003).

Stormwater problems negatively affect homeowners, businesses, and ecosystems. In extreme cases, flooding affects nearly all Atlanta residents and can present life-threatening circumstances. Minor and major flooding can result in very high costs to both the City and individuals. More intense and frequent rain events are very likely. These considerations result in a high risk level.

| STORMWATER MANAGEMENT RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life Threatening: Uncertain (2)<br>Cost: High (3) | Very Likely (3) | **10 Points: High** |

***Planning Area Summary***

The stormwater management planning area demonstrates a medium level of sensitivity to climate, but a low adaptive capacity. Therefore, it received a high vulnerability rating, along with a high estimated risk level. These assessments contributed to the planning area's total score of 14 points, which place it in Tier Four.

## *Building Maintenance*

***Vulnerability Part I: Sensitivity***

Atlanta is home to a large number of residential and high rise commercial buildings. The city's rich history, which stretches earlier than the Civil War, is preserved in many buildings, neighborhoods and

districts. These highly valued historic places are registered by the Bureau of Planning, which evaluates the city's collection of historic places in each Comprehensive Development Plan. Maintenance of the building stock varies by owner and practices are naturally influenced by economic conditions.

More intense, frequent storms and high temperatures may shorten the time between construction and outer building maintenance by making it necessary to paint and repair buildings sooner than expected normally. The biggest concern may be for extreme storm events that result in basement flooding and water damage. While these events are normally infrequent, they are likely to become increasingly common. In fact, internal building operating systems (like water pipes, HVAC systems, etc) may have more impacted (i.e. shorter) life spans because they will be more regularly stressed to provide comfortable conditions for building occupants. Like impacts to building façades, the impacts to interior systems due to climate change will likely be minimal and difficult to measure. The sensitivity score for the building maintenance planning area is low.

***Vulnerability Part II: Adaptive Capacity***

Renovating a building's façade can be an extremely costly and time-consuming process. A notable exterior maintenance project will be that of the Westin Hotel, which sustained damage from the 2008 tornado, and has yet to be repaired. Luckily, the Westin's renovation is an extreme case, as Atlanta's architects have designed most buildings to withstand years of harsh weather and elements (1/29/2010 interview with Robert Reed).

Internal building systems can be retrofitted for a cost and typically are necessary at some point during the life of a building. Retrofits and building system replacements often take place long after the systems have become inefficient, when they have completely failed. The high cost of maintenance and infrequency of projects are barriers that reduce the adaptive capacity of this planning area, and it is therefore given a low adaptive capacity score.

| BUILDING MAINTENANCE VULNERABILITY ASSESSMENT | | |
|---|---|---|
| SENSITIVITY SCORE | ADAPTIVE CAPACITY SCORE | VULNERABILITY LEVEL |
| Low | Low | 3 Points: Medium |

***Risk***

Higher temperatures, stronger and more frequent storms are very likely and may speed up the deterioration of building façades and systems in Atlanta. Apart from minor inconveniences, few citizens are affected by maintenance needs for high-rise buildings. Homeowners may experience a slight increase in required maintenance. Shorter infrastructure lifetimes do not pose a threat to human life if they are replaced. Although the costs of repair can be high, they cannot solely be contributed to climate change as buildings have a natural lifetime that typically involves renovation. Combined, these factors result in a medium risk level.

| BUILDING MAINTENANCE RISK ASSESSMENT | | |
|---|---|---|
| DEGREE OF IMPACT OF CHANGE ON SYSTEM | PROBABILITY OF IMPACT | ESTIMATED RISK LEVEL |
| Citizens Affected: Few (1)<br>Life-Threatening: No (1)<br>Costs: Medium (2) | Very Likely (3) | 7 points: Medium |

***Planning Area Summary***

The assessment for the building maintenance planning area generated a low sensitivity score and a low capability to adapt. These results lead a medium level of vulnerability. This is matched with the estimated risk level, which is also medium. In sum, the planning area had a total of 10 points, giving it a relatively low priority level of Tier Eight for adaptation planning.

## *Building and Energy Code*

***Vulnerability Part I: Sensitivity***

The buildings in America are responsible for more than half of the country's GHG emissions. Residential buildings alone account for more than 20% of US energy use and energy-related GHG emissions (Brown, Chandler et al. 2009). This fact is not lost on engineering and architectural associations, who have committed to reducing the carbon footprint of the sector (Dunlap 2006). This commitment may be manifested through building and energy code changes.

Atlanta's building and energy code is administered by the Bureau of Buildings (Department of Planning and Community Development 2010). Most municipal regulations are adopted from state and national standards. For instance, the design temperature code is taken directly from the American Society of Heating, Refrigerants, and Air-Conditioning Engineers (ASHRAE), and the energy code is follows state standards (1/29/2010 interview with Robert Reed). Georgia has adopted the 2006 International Energy Conservation Code (IECC), opting not to adopt the new 2009 code (Brown, Chandler et al. 2009). Unfortunately, the energy code is complicated and technical, and a lack of institutional capacity has resulted in lax enforcement in the city (and throughout many states)(Brown, Chandler et al. 2009)(1/29/2010 interview with Robert Reed).

While state and national code standards are the norm, local variations in codes are not uncommon. In 2009, the proposed Atlanta Sustainable Building Ordinance (ABSO) attempted to overhaul the City's commercial and multi-family building code. The proposed ordinance garnered the support of many, yet strong opposition by private developers detained the ordinance in committee hearings for over six months (1/19/2009 interview with Charletta Jacks). The proposed ordinance also suffered from a lack of political will and was effectively shelved in December 2009. This ordinance would have improved Atlanta's climate resiliency by requiring a shade percentage and surface reflectivity standard. These changes would help to cool buildings and lower energy needs, thereby decreasing the UHI effect.

Upgrades would be required to be more efficient, thus protecting building occupants from high utility costs and reducing natural resource use (1/29/2010 interview with Robert Reed).

Building and energy codes are influenced by climate and can determine the functionality of buildings. Technical associations like ASHRAE and state lawmakers will likely revise current codes in response to a changing set of climate conditions in the Southeast (Dunlap 2009), although it is unclear whether these will be proactive or reactionary changes. This planning area is given a sensitivity score of medium due to its indirect connection to climate.

***Vulnerability Part II: Adaptive Capacity***

Many players are involved in local reform decisions. The ASBO demonstrated the uphill battle that code reform efforts face. Local code reform requires political will, private sector acceptance and support, and public demand. Absent code reform, private developers can facilitate the market shift and public acceptance of such changes by choosing attributes like those found in ASBO voluntarily, and some do. However, many developers will only choose these design specifications if they are required. Moreover, the City of Atlanta currently does not seem to possess the institutional capacity to ensure that existing codes are followed. The adaptive capacity of the building and energy code planning area is therefore deemed low.

| BUILDING AND ENERGY CODE VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | Low | **4 Points: High** |

***Risk***

Building performance and code changes influenced by climate change will affect all city residents. These impacts will not be life-threatening. The costs could be substantial, but would be spread over time, as the building industry shifts to more climate-friendly practices. Climate change will mean that the city's code enforcement practices will become ever more important. If the City does not possess the capability to successfully ensure codes are adhered to, it will need to build its capacity through

additional staff, better technical training, etc. The building and energy code in Atlanta is at medium risk to climate change impacts.

| BUILDING AND ENERGY CODE RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: All (3)<br>Life-threatening: No (1)<br>Costs: Medium (2) | Likely (2) | **8 Points: Medium** |

***Planning Area Summary***

The planning area for building and energy code will be affected by climate change, but may have difficulty adapting. Therefore the vulnerability level is high. The risk level is medium, leading to the planning area's total score of 12 points, and placement in Tier Six.

## Sector: Ecology

### *Greenspace*

***Vulnerability Part I: Sensitivity***

Greenspace provides essential health, economic and environmental services to urban communities. A connected system of bike and walking trails that are often a part of greenspace provides fitness opportunities to the general population. These services will become more important as population growth and climate change place increasing stress on the urban environment (Wallace Roberts & Todd LLC 2008).

Atlanta has over 3200 acres of parkland, representing 3.78% of the total geographic area (Department of Planning and Community Development 2003). It ranks last among cities of comparable size in acres of park land per thousand residents, and next to last in the percentage of the city that is park land (American Society of Civil Engineers Georgia Section 2009).

**Figure 6: Piedmont Park**

The future Westside Park, a part of the BeltLine Project, will add 300 acres to the City's total parkland (Mayor's Office of Communications 2006). This addition will improve the amount of park space, but adds more maintenance needs. Approximately $4700 per acre is spent annually on greenspace maintenance; Ken Gillett, the Director of the Office of Parks estimates this number should be closer to $7700 per acre (12/22/2009 interview).

The current and future stresses surrounding greenspace management are well documented. In 2008, a "State of the City" report summarized Atlanta's strengths and weaknesses. This assessment was used to inform the Project Greenspace plan published in 2009 and uncovered important facts that impact the resiliency of this planning area and others:

- Funding to parks and greenspace has been higher in recent years, but it still low when compared to other cities with "best-in-class" park systems. A sustainable stream of funding is not available.
- An organizational analysis showed that greenspace responsibilities are highly fragmented among city departments and public and private partnerships are not maximized, leading to low levels of coordination.
- The State of the City report asserted that existing municipal regulations could be improved, more incentives provided, and greenspace considerations be incorporated into city-financed development projects.

- A key finding revealed that 59% of Atlanta's residents are "not within an easy walking distance" to a park by a pedestrian-friendly street network.
- A distributional analysis of greenspace showed that some areas of Atlanta are underserved and others are over-served (Wallace Roberts & Todd LLC 2008).

City leaders and officials have demonstrated a committment to improve the quantity, quality, and sustainability of the city's greenspace. Numerous efforts - in the form of strategies, initiatives, projects, and plans - have employed a variety of tactics to achieve similar goals (Wallace Roberts & Todd LLC 2008). While many goals have not been fully realized, the City has meaningfully engaged private sector organizations and citizens to improve the park system (12/22/2009 interview with Ken Gillett).

In 1998, as part of the Consent Decree to improve water quality, Atlanta established the Greenway Acquisition Project. Designed to improve the city for "generations to come", the project called for $25 million to acquire and restore greenways in and downstream of Atlanta. These properties were acquired through donations, outright purchase, or by conservation easements (Department of Watershed Management 2009).

The most recent initiative is Project Greenspace, an element of the Atlanta Comprehensive Development Plan (CDP). Project Greenspace is an update to the City's Parks, Open Space, and Greenways Plan of 1993. The new plan includes a dozen major initiatives designed to grow, manage, and build capacity for greenspace in the city by 2030 (Wallace Roberts & Todd LLC 2009). The proposed framework is comprehensive, but the only project that is certain is the additional park land that will be created by the BeltLine project (12/22/2009 interview with Ken Gillett).

Creating new greenspace and improving its management are important strategies to *mitigate* climate change. Greenspace is often forested, helping to cool urban areas, sequester carbon, improve air quality, and capture and filter stormwater. However, this resource is highly exposed to climate and thus

very sensitive to climate change. Because these areas are dwindling in urban environments, their vulnerability is more pressing. Climate change will directly impact Atlanta's greenspace in several ways:

- A dramatically different climate will lead to altered species composition, and perhaps decrease diversity levels altogether. Small shifts in climate will have a lesser impact on generalist species, like the eastern chipmunk , gray fox, (Castleberry 2005), and number of hardy native and invasive plant species.
- Alternating periods of flood and drought will weaken the resilience of plants to invasive and pest species and to extreme weather (11/24/2009 interview with Ainsley Caldwell). Erosion caused by flooding will also affect the health and topography of greenspace.
- The Department of Parks, Recreation and Cultural Affairs manages important public facilities that are subject to weather damage. Maintenance equipment is also subject to weather damage (12/22/2009 interview with Ken Gillett).
- The greenspace management calendar will lengthen due to longer summers. For the Office of Parks, this means that seasonal staff will be needed longer, equipment will wear out faster (due to more extensive use), and overall materials and expenses will increase.
- Lastly, hotter summers will likely change the habits of citizen use. According to Gillett, park use remains high when temperatures are above 90˚F; many without air-conditioning find refuge in the cooler parks (12/22/2009 interview with Ken Gillett).

The future effects of climate change on Atlanta's greenspace are not explicitly discussed in the Project Greenspace report, or in any other public document. Had this been included, the final report may have included priorities that emphasized pro-active protection and shifting management techniques for the City's current assets. However, the report adequately describes the vital and stabilizing functions and benefits of greenspace. The importance of these functions and benefits will be magnified as climate

instability impacts Atlanta. It is clear that the demand and need for greenspace and its many benefits is not (and will not be) in balance with its supply.

While greenspace has a high exposure to climate and its maintenance is underfunded, the City continues to add acreage and assemble task forces to improve its management. Therefore, the sensitivity score for the greenspace planning area is medium.

***Vulnerability Part II: Adaptive Capacity***

Atlanta seems to possess a keen awareness of the importance of greenspace, as evidenced by the many initiatives that have worked to improve the situation. Task forces have consistently monitored progress towards the identified goals and regularly reassess the problems. This leads one to believe that once climate impacts become noticeable, they will be addressed. In other words, the planning area may be able to absorb the impacts due to consistent oversight.

Land and park managers may need to adopt a flexible management approach to maintain the health of Atlanta's greenspace. Gillett believes that comprehensive forestry, turf management, and integrated pest management programs would transform the health of this necessary resource (12/22/2009 interview with Ken Gillett).

There are several barriers to improving the resiliency of greenspace. Tackling problems requires financing and (often) space – two resources that are scarce today and may not be available in the future. While the ramifications of climate change have been discussed internally among members of the Department of Parks, Recreation, and Cultural Affairs, these concerns have yet to be documented in writing. The political contentiousness of the topic of climate change is one of the main reasons for this. When climate change is discussed, there is the perception that it will be a future issue, not one that will impact the current year. Therefore, department budgetary needs that are based on climate change projections (the majority of which will be gradual) are unlikely to receive funding (12/22/2009 interview with Ken Gillett).

It is likely that climate impacts will require increased budgets for daily and seasonal care and disaster recovery. This budgetary demand will be magnified if Atlanta continues to increase municipal greenspace acreage. Because the Office of Parks is funded through the Atlanta General Fund, and thus subject to economic fluctuations and political will, the ability to respond to the possible impacts of climate change is questionable. Therefore, the adaptive capacity score of the greenspace planning area is medium.

| GREENSPACE VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | Medium | **3 Points: Medium** |

***Risk***

Degradation of the city's greenspace could translate into myriad losses to society, many of which are not fully appreciated, in part due to a lack of monetary value for ecosystem services. While not all citizens will directly experience the ramifications of negative impacts on Atlanta's greenspace, a large portion will. The impacts could reduce the quality of life for citizens by reducing physical health opportunities, social and community values, economic benefits, and environmental services (Bell, Hamilton et al. 2008). Expected climate impacts are not life-threatening to humans. The climate changes that will produce these impacts are very likely to occur, resulting in an estimated risk level of medium.

| GREENSPACE RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life-Threatening : No (1)<br>Costs: Medium (2) | Very Likely (3) | **8 Points: Medium** |

***Planning Area Summary***

The greenspace planning area received a medium score for both the sensitivity and adaptive capacity analyses. Consequently, the planning area demonstrates a medium vulnerability level. The estimated

risk level is also medium. These results lead to a total of 11 points, and the planning area's subsequent placement in Tier Seven.

### *Urban Forest Management*

***Vulnerability Part I: Sensitivity***

Atlanta is known as the "city of trees" and a number of City and public actors work to protect and manage the urban forest to maintain this reputation. The Office of Parks in the Department of Parks, Recreation, and Cultural Affairs is responsible for trees on public areas and in the public right-of-way.

**Figure 7: Street trees**

The Department of Public Works provides support to the Office of Parks when major storms cause a number of hazardous fallen trees. In addition, the Department of Community Development and Planning houses five arborists in the Arborist Division, which is charged with implementing the Tree Ordinance for trees on private property. The Tree Ordinance requires developers to plant new trees or pay a recompense fee for any lost trees due to development. The recompense fee is channeled to the Tree Trust Fund, which is operated by the Office of Parks to pay for tree plantings on public lands (11/24/2009 interview with Ainsley Caldwell). In this way, the Tree Ordinance is a "no net-loss" policy.

The fragmented municipal responsibility for trees within the city is accompanied by active civic organizations like Trees Atlanta. Trees Atlanta is a local non-profit organization that has planted and maintained more than 75,000 trees since 1985 (Trees Atlanta 2009).

The importance of an urban forest cannot be understated: a 1994 study revealed that Atlanta's trees provided $8.3 million worth of pollution removal (Nowack and Dwyer 2007). Urban forests also modify microclimates by transpiring water, altering windspeeds, shading surfaces and changing the storage and exchanges of heat among urban surfaces. A 2002 report revealed that the city's trees stored 1.2 million tons of carbon, making the urban forest a large contributor to GHG mitigation efforts (Nowack and Dwyer 2007). Because of these benefits, there is increased demand for protected, public forests as private forests succumb to development in and around the city. As mentioned earlier, forest land in the Metro Atlanta area is projected to fall from 1 million acres in 2010 to 350,000 acres in 2050 (Lo and Yang 2002).

**Figure 8: Street trees provide multiple benefits to this street and the buildings**

Unfortunately, a clear data set of baseline canopy cover for the City of Atlanta does not exist. Without this data, measuring the true success of Atlanta's goal to maintain or increase the canopy is quite difficult. A recent fly-over to collect arial

images was executed in hopes of translating these images into a GIS layer that can be used with the City's existing database of GIS layers. (11/24/2009 interview with Ainsley Caldwell).

Just as greenspace is highly exposed to climate, urban forests are highly exposed and sensitive to climate changes like floods, droughts, and increasing temperatures. Shifting ecoregions will likely affect the fitness of the current species composition and introduce new competitors (Walther, Post et al. 2002). The current climate projections have not provided strong indications of changes in total precipitation, but if the numbers change dramatically, urban trees will undoubtedly be impacted. Projections show a greater certainty of the likelihood of more frequent and intense droughts and floods. Vulnerability to droughts can vary across species; the white oak, for example, is especially sensitive to drought. Floods cause harm to trees when standing water prevents air from reaching the roots. Alternating periods of drought and floods can present problems as well. Roots contract during droughts, creating space between the root and the soil. If a flood occurs and fills those spaces with water, the root system becomes lubricated and destabilizes the tree. In good weather conditions, healthy trees may withstand wind speeds of 25 mph, but in supersaturated, loose soil, a tree may only withstand 10 mph of wind (11/24/2009 interview with Ainsley Caldwell).

Increased temperatures have direct and indirect effects on trees. Heat can cause trees to drop their leaves and reduce water transpiration. This typically affects younger, recently transplanted trees (11/24/2009 interview with Ainsley Caldwell). Heat and sunlight cause the formation of ozone, which can lower the survivability of sensitive plants, decrease growth, and damage leaves (U.S. Environmental Protection Agency 2008). Ozone levels are high enough in the Atlanta metropolitan region to harm highly sensitive tree species like black cherry, sand blackberry and the winged sumac (Diem and Styers 2008). Table 12 contains a list of the ozone-sensitive tree species that are on Atlanta's Recommended Species List. Visible harm due to air pollution has not yet been observed in Atlanta, but arborists are not collecting information in this area (11/24/2009 interview with Ainsley Caldwell).

**Table 12. Ozone-sensitive plants species (Diem and Styers 2008) which appear on Atlanta's Recommended Species List (Bureau of Buildings Arborist Division 2009)**

| Ozone-sensitive plant species promoted in Atlanta | |
|---|---|
| Eastern Redbud | Flowering Dogwood |
| Sassafras | Sweetgum |
| Red Maple | Loblolly Pine |

In summary, climate conditions have direct impacts on the urban forest, and the City's efforts to protect it have been commendable, but may not suffice under a changing climate. The sensitivity score for this planning area is high.

***Vulnerability Part II: Adaptive Capacity***

Most trees in Atlanta will be able to absorb small, gradual changes in climate, but there is no guarantee that the changes will occur slowly. Atlanta's Tree Ordinance is the main strategy to maintain the city's urban canopy. Its existence provides some insurance against the possibility of a heavily damaged urban forest. The Arborist Division, created to implement and enforce the ordinance, is funded both by the General Fund and by the Tree Trust Fund. It has no equipment and receives $50,000 annually for operating expenses. During times of economic stress, only the three positions covered by the Tree Trust Fund are safe- all other positions are subject to General Fund budget cuts (11/24/2009 interview with Ainsley Caldwell).

The Tree Ordinance's narrow mandate may act as a barrier to improving the resiliency of the city's urban forest. The ordinance aims simply to maintain the urban canopy through a quota-based penalty system. It provides little incentive to promote preservation, conservation, or even healthy trees. Choosing climate resilient trees or those that contribute less to VOC emissions (an air pollutant which can lead to more ozone) is not an explicit part of the Arborist Division's mandate. The Tree Ordinance is currently being analyzed by an external consulting firm. This firm will use best practice research to provide Atlanta with several feasible recommendations to improve the policy (11/24/2009 interview with

Ainsley Caldwell). At this point, it is unclear what the recommendations will be and if they accepted by council and implemented by the Arborist Division. If business continues as usual, the planning area's ability to absorb significant climate change impacts appears low.

In terms of adaptability, there are several opportunities to improve the health and size of the urban forest. The Recommended Species List is updated every five years, providing a relatively consistent opportunity to change the list criteria (11/24/2009 interview with Ainsley Caldwell). An increasingly apparent opportunity to provide habitat for trees are rooftop gardens and parks, often called greenroofs. Although the city has been recognized for its collection of greenroofs, there are currently no municipal financial incentives for private developers to build them.

The changes that may be necessary to ensure a healthy urban forest into the future are not exceedingly difficult, but will require a greater understanding of the importance of city trees and how they must be cared for. A revised mandate for the Arborist Division may be necessary. The adaptive capacity score for the urban forest management system is medium.

| URBAN FOREST MANAGEMENT VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Medium | **4 Points: High** |

***Risk***

All citizens are affected by the diverse benefits provided by Atlanta's trees. Trees provide the city air quality benefits, habitat, and decrease ambient air and building temperatures. Trees can absorb large amounts of water, stop erosion, and increase property values. Reducing the size and health of the urban forest can be a health hazard to citizens and lead to increased stormwater runoff, erosion, and flooding. The costs of maintaining an impaired urban forest could be high. Unhealthy urban forests could also lead to numerous indirect costs, like higher air-conditioning bills and reduced air quality. The climate changes that could produce these impacts are very likely, resulting in a risk level of high.

| URBAN FOREST MANAGEMENT RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: All (3)<br>Life-Threatening: Uncertain (2)<br>Costs: Medium (2) | Very Likely (3) | **10 Points: High** |

***Planning Area Summary***

The urban forest planning area will be highly impacted by climate change and has a medium level of adaptive capacity to withstand and respond to the expected changes. These results lead to a high level of vulnerability. The planning area also demonstrates a high estimated risk level, which lead to the total score of 14 points and placement in Tier Four.

## *Pest and Invasive Species Management*

***Vulnerability Part I: Sensitivity***

The Atlanta region is highly affected by pest and invasive species including kudzu, english ivy, infestations of army worms, and more. The City's Arborist Division does not proactively protect against harmful species, but does respond when they pose a significant threat to an ecosystem. The response often involves removing the affected trees, but if the division discovers a destructive species that cannot be controlled by cutting down a small number of trees, then it will notify the US Forest Service. When citizens call about pest and invasive species that are harming their trees, the Arborist Division provides the private property owner with instructions to fend off the species (11/24/2009 interview with Ainsley Caldwell).

Budget constraints have caused the Office of Parks to take a reactionary approach to fighting pests and invasive species in public greenspace as well. There is no comprehensive pest management program, and actions are only taken when a large stand of trees in public space is threatened. The costly war

against kudzu consists of repetitive herbicide applications over five years (interview with Ken Gillett 12/22/09). This reactive approach does little to remove trees from harm's way.

Climate change will increase the vulnerability of urban ecosystems to the negative impacts of pests and invasives. Reduced health due to changes in temperature and precipitation can lower a plant's resilience to fighting off these species. A 2009 study found that despite climate change, the Southeast will remain a suitable habitat for kudzu (Jarnevich and Stohlgren 2009). A climate shift would likely mean an increase in the number of opportunistic and harmful migrating pest species. This possibility, coupled with the current status of invasive and pest species management in Atlanta, result in a high sensitivity score for the planning area.

***Vulnerability Part II: Adaptive Capacity***

The planning area shows little capacity to absorb the growing impacts of pest and invasive species, and the effects will likely become increasingly apparent as Atlanta's urban environment becomes more suitable for such problems. Reactive approaches without integrative management plans will do little to remove the risk of ecosystem impairment and may need to be reassessed and redesigned to ensure resiliency. Properly

**Figure 9: A common sight in Atlanta: kudzu has taken over this empty lot**

valuing the benefits of healthy ecosystems, and enabling city departments to protect them may be key changes.

Current mandates and funding constraints for the Office of Parks and the Arborist Division have created a barrier to proactively safeguard the city's ecological systems from invasive and pest species. The current adaptive capacity to minimize the impacts of pests and invasive species is very low. This is apparent by the many areas in the city that have been overrun by such species. Therefore, the adaptive capacity score for this planning area is low.

| PEST AND INVASIVE SPECIES MANAGEMENT VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Low | **5 Points: High** |

***Risk***

The number of citizens that could be impacted by a growing pest and invasive species problem is difficult to estimate. Many homeowners are already affected, and other residents will be indirectly affected by ailing ecosystems. Species that decrease the health of trees can make them unstable and dangerous, so the problem could be life-threatening in rare instances. The municipal costs of the current pest and invasive species management techniques (which are often inefficiently designed) are small. Nevertheless, inefficient management programs place a crippling drain on the Office of Parks and Arborist Division and decrease their ability to reach their goals. A reduction in ecosystem services will result in growing future costs for the City, the public, and the private sector. Projected changes in climate conditions that could worsen the problem are likely. The estimated risk level is medium.

| PEST AND INVASIVE SPECIES MANAGEMENT RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life-Threatening: Uncertain (2)<br>Costs: Medium (2) | Likely (2) | **8 Points: Medium** |

***Planning Area Summary***

With a high sensitivity to climate change and a low adaptive capacity, the pest and invasive species management planning area demonstrates a high level of vulnerability. The medium level of risk contributes to the planning area's total score of 13 points. Hence, the planning area falls in Tier Five.

## Sector: Transportation

### *Road and Bridge Maintenance*

***Vulnerability Part I: Sensitivity***

Atlanta's roads are some of the most congested in the country. A recent report by the Texas Transportation Institute indicates that Atlanta's traffic demand is surpassing road capacity growth by 45% (American Society of Civil Engineers Georgia Section 2009). High usage has resulted in municipal roadways that are in constant need of repair. The 2008 Transportation Metropolitan Atlanta Performance Report stated that Atlanta area pavement conditions had degraded drastically in the past three years (American Society of Civil Engineers Georgia Section 2009). Former Commissioner of the Department of Public Works, Joe Basista, has explained the department's operating budget does not cover the annual road maintenance needs of the city (8/12/2009 interview with Joe Basista).

Roads and bridges have a high exposure to climate conditions. Flood events damage and cause delays on public transit systems and low-lying roadways and can lead to erosion and subsidence of road bases, rail beds, and bridge support. The integrity of pavement can be reduced by long periods of extreme heat; asphalt can soften, and traffic can cause rutted roads. Bridge joints and paved surfaces can expand, increasing maintenance needs (Transportation Research Board 2008). Road construction projects are also subject to weather conditions and are hindered by severe storms, floods, and extreme high and low temperatures.

The projected climate changes (floods, storms, and increasing temperatures) will create more road and bridge problems, accelerate degradation, and hinder maintenance efforts. A positive impact of increased temperature may be the reduction of road damage associated with freezing and refreezing of surfaces, although winter precipitation projections are unclear.

Despite the high exposure to climate, roads and bridges in Atlanta are drivable, and a number of funding streams exist to ensure that this remains the case. The sensitivity score for this planning area is medium.

***Vulnerability Part II: Adaptive Capacity***

When roads and bridges are damaged by disasters, federal funds may help finance permanent restoration. In most cases, money is granted by the Federal Highway Administration (FHA) through the Emergency Relief Program. FEMA's Public Assistance (PA) Program cannot fund road and bridge restoration, even if money is not available from the Emergency Relief Program. If immediate threat is demonstrated, FEMA can assist with limited emergency and debris clearance on a case-by-case basis (Federal Emergency Management Agency 2007).

If business continues as usual, a growing population and accelerated weathering of roadways and bridges will continue to reduce the health and safety of the existing and future transportation infrastructure. The City cannot cover the costs of annual road maintenance needs today, so increasing the number of projects is unlikely. The adaptive capacity of this planning area is low.

| ROAD AND BRIDGE MAINTENANCE VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | Low | **4 Points: High** |

***Risk***

Damaged and blocked roads and bridges can affect a large number of Atlantans. During the flood of September 2009, the city's main highway arteries were impassable for hours. Smaller inconveniences

due to damaged and blocked roads occur on a frequent basis throughout the city. At times, climate impacts could result in life-threatening conditions, although not often. The additional costs on road and bridge infrastructure may be steep and will exacerbate the unmet needs that already exist. If roads are left in a state of disrepair, it will create costs to individual drivers through greater vehicle repair needs. The risk score is high.

| ROAD AND BRIDGE MAINTENANCE RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: All (3)<br>Life-Threatening: Uncertain (2)<br>Costs: Medium (2) | Very Likely (3) | **10 Points: High** |

***Planning Area Summary***

The planning area of road and bridge maintenance has a medium sensitivity to climate, and a low capacity to adapt to changing conditions. For those reasons, the planning area has a high vulnerability to climate change. The risk level is high and contributes to the total score of 14 points. This score results in the planning area's placement in Tier Four.

## *Public Transit*

***Vulnerability Part I: Sensitivity***

The City of Atlanta is served by four main public transit systems: the Metropolitan Atlanta Rapid Transit Authority (MARTA), Cobb County Transit, Gwinnett County Transit, and Xpress (American Society of Civil Engineers Georgia Section 2009). All of these systems are comprised of bus service, with MARTA adding a unique rail system.

The MARTA rail is the busiest public transportation system in Atlanta; 150 million riders took advantage of the service in 2008 (Metropolitan Atlanta Rapid Transit Authority 2009). Between the years of 2001-2005, MARTA provided the region a three to four-fold return on investment. Despite the economic

benefit, no regional transit funds were appropriated in 2008 besides a one cent sales tax revenue from Fulton and Dekalb Counties. As a result, MARTA reported a $60 million shortfall that year (American Society of Civil Engineers Georgia Section 2009). In 2010, budget shortfalls continue to plague MARTA, and the company expects to cut services to survive (Hart 2010).

**Figure 10: MARTA's east-west rail line**


The MARTA rail system is characterized by two major arteries; a north-south line and an east-west line. While complexity can often be the source of vulnerability, here, MARTA's heavily used two-artery system can have a great impact on public transit options for citizens. If flooding or tree falls block a rail line, MARTA can reroute buses to transport riders around the impaired rail section. If this adaptive measure is not possible, a major transit resource is lost until the problem can be remedied. Conversely, MARTA's bus routes are changeable and can therefore still operate if the original route has become impassable.

Transportation modes in Atlanta are characterized by varying degrees of exposure to climate and will therefore be impacted differently by climate change. Even under current climate conditions, transportation modes are commonly impaired or destroyed by natural disasters or neglect of maintenance. Most travelers can adapt by changing their mode of transportation. In response to a growing population, the City is placing increasing emphasis on adding transit capacity and providing a variety of viable options, including promoting biking and walking – both of which are highly exposed to

weather. Public transit options like buses and rail services have an intermediate level of exposure to climate events. While operable during most conditions, these services can experience direct impacts during extreme weather events. Intense storms and floods can lead to disruptions and route changes. Heat waves increase the instance of breakdowns. Positive impacts are possible; public transit may be more effective in future winters due to fewer icy conditions that impede bus routes and rail lines.

Climate change may have indirect impacts on public transit through storm-caused fuel disruption and behavioral changes by patrons. Transit riders change their ridership habits if they are exposed to harsh elements while waiting for buses and trains. In addition, operational practices may also contribute to patron discomfort. For instance, chillers in MARTA's subterranean train stations, which were intended to counteract the additional heat emitted by air-conditioned trains, have been discontinued to save money. This cost-cutting strategy has made passengers subject to uncomfortable temperatures on hot days (2/12/2010 interview with Paul Grether).

All together, the projected climate changes may lead to more disruptions and increased maintenance costs for public transit, and the planning area is given a sensitivity score of medium.

***Vulnerability Part II: Adaptive Capacity***

Just as different transportation modes have varying levels of exposure to climate, they also demonstrate varying capabilities to adapt to a changing climate. MARTA's rail system is characterized as well-engineered and resilient (2/12/2010 interview with Paul Grether), and the bus systems are flexible to changing conditions. These characteristics will allow the planning area to absorb many of the impacts of climate change and continue with current practices. Nevertheless, adapting public transit to climate change may still be necessary. This could involve full replacement of infrastructure, like rail lines and bridges, or altered maintenance and repair procedures. Adaptation may also mean changing and adding bus routes.

Adaptive infrastructure changes could logically be included in transportation planning documents, which typically use planning horizons that are under 30 years. While this timeline is not problematic on its face, these plans are often made with the assumption that any climate changes will be felt after that time period, resulting in plans that do not account for these changes (Neumann and Price 2009). This is true for transportation plans created for Atlanta. The ARC's Freight Mobility Plan looks 25 years into the future, and makes no mention of changing weather patterns or climate change (Atlanta Regional Commission 2007). The Connect Atlanta Plan also takes a "long range vision" of 25 years, and does not explicitly address climate change implications. Federal standards dictate what questions are answered in the ARC's regional transportation plans, which look 30 years into the future (2/12/2010 interview with Paul Grether). Federal, state, and local mandates to include climate change implications could ensure that transportation plans, including MARTA projects, are designed to be resilient.

It is relevant to note that planning horizons of 25-30 years are not congruent with the lifetime of most public transit infrastructure. Atlanta's rail system is built to last 100 years (although some systems could require reconditioning before that time)(2/12/2010 interview with Paul Grether). It is therefore subject to many of the expected climate changes throughout this century.

MARTA's current funding structure – namely its dependence on state and federal funds - provides another barrier to increasing public transit service and ensuring climate resilient transit to Atlantans. In fact, this funding structure makes MARTA more vulnerable to service reduction.

Providing citizens with a more diverse set of transportation modes may reduce the importance of MARTA's success and ensure easy mobility of citizens. Creating more connected, walkable and bike-friendly streets is a main goal of the Connect Atlanta Plan (Atlanta Transportation Planning Group 2008). Whether the Plan's goals will be obtained is unclear: it is currently unfunded, and the Department of Public Works lacks the funds to ensure complete maintenance of existing road and sidewalk

infrastructure (8/13/2009 interview with Heather Alhadeff; 8/12/2009 interview with Joe Basista). Even if the Connect Atlanta Plan is completed, and citizens have the choice of rail, bus, walking or biking, they will have to overcome harsh weather conditions to make use of these options.

While there are a variety of options and opportunities to increase the resiliency of the public transit planning area, they require sufficient funding and are therefore less likely to be taken. The adaptive capacity score is medium.

| PUBLIC TRANSIT VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | Medium | **3 Points: Medium** |

***Risk***

Public transit systems affect the entire landscape and vitality of a city. As more projects and plans are developed for Atlanta's growing population, public transit will play an increasing role. However, many Atlantans cannot or choose not to use public transit, so impacts on the system will not directly affect everyone. The possible impacts of climate change are not life-threatening, but could result in costly repairs – some of which will be passed on to riders and citizens. Public transit in Atlanta is at a medium risk level to climate change.

| PUBLIC TRANSIT RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life-threatening: No (1)<br>Costs: High (3) | Very Likely (3) | **9 Points: Medium** |

***Planning Area Summary***

The planning area of public transit generated medium scores for sensitivity and adaptive capacity, so it has a medium level of vulnerability to climate change. The risk level is also medium. Consequently, the planning area falls into Tier Six, with 12 points total.

### *Paratransit Service*

***Vulnerability Part I: Sensitivity***

The disabled and elderly populations have lower functional capacity outside the home than inside, so they are more dependent on affordable, reliable, and accessible mobility service. Their dependence on services outside of the home makes this an important source of vulnerability, especially during disasters (Fernandez, Byard et al. 2002).

In accordance with regulations in the Americans with Disabilities Act of 1990, MARTA offers complimentary paratransit service to individuals that cannot board regular MARTA bus or rail services. This service, called MARTA Mobility, is available within a ¾ mile radius of bus routes and rail stations, on a comparable schedule (Metropolitan Atlanta Rapid Transit Authority 2009). The number of service trips increased by 10.9% from 2007 to 2008 (Metropolitan Atlanta Rapid Transit Authority 2009). Demographic projections predict that the elderly population will grow in the coming decades, likely meaning the demand for this service will continue to increase.

The MARTA paratransit system has similar exposure to climate as the bus system. MARTA uses 175 lift-equipped vans that operate well in most climate conditions. The most common weather concerns occur as a result of icy conditions and severe storms that can impact routes and may lead to route and service disruptions. Climate projections indicate that severe storms and extreme heat will have the most detrimental impacts on this planning area. Extreme heat conditions can place stress on the vehicles and shorten the lifetime of equipment. These impacts are likely to be minor, and the paratransit service planning area is given a sensitivity score of low.

***Vulnerability Part II: Adaptive Capacity***

MARTA is required to offer paratransit service, which is adaptable and expandable. These characteristics are fortunate; changes in demographics over the coming decades will likely result in increased demand for the paratransit service. The ability to absorb climate impacts will be vital to

providing adequate service. The main barrier that could reduce the planning area's adaptive capacity appears to be budget constraints in the face of rising demand and increased maintenance needs. Therefore, the adaptive capacity score of the paratransit service planning area is medium.

| PARATRANSIT SERVICE VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Low | Medium | **2 Points: Low** |

***Risk***

A small but growing number of citizens are dependent on the paratransit service. Efficient and dependable operations are important to the quality of life and even the health of the disabled and elderly. For this reason, it is uncertain whether negative impacts on paratransit service will be life-threatening. The overall costs of the program are marginal compared to the rest of the MARTA transit system (but are higher per trip), so the impacts will likely have low costs as well. The climate changes that stand to impact this planning area are very likely. These factors translate to a medium risk level.

| PARATRANSIT SERVICE RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Few (1)<br>Life-threatening: Uncertain (2)<br>Costs: Low (1) | Very Likely (3) | **7 Points: Medium** |

***Planning Area Summary***

The paratransit service planning area had a low sensitivity score and a medium level of adaptive capacity, which results in a low level of vulnerability. The estimated risk level is medium. In sum, the planning area has 9 points and is placed in Tier Nine, one of the lowest priority levels for adaptation planning purposes.

## *Air Transport*

***Vulnerability Part I: Sensitivity***

Over ninety million passengers passed through the Atlanta Hartsfield-Jackson International Airport in 2008 (City of Atlanta 2009). As the busiest passenger airport in the country, this airport plays a major role in the economic success of the region (Center for Integrative Environmental Research 2008).

The airline industry is highly exposed to weather. Flights take off on time if local conditions and destination conditions allow. High temperatures, storms and ice are the most commonly cited factors that cause delays and cancellations. Climate change will have ripple effects on the airline industries in the form of direct and indirect impacts. The Hartsfield-Jackson International Airport will likely experience increased disruptions and delays in air service and experience periodic airport closures due to the increased intense precipitation events in Atlanta and elsewhere (Transportation Research Board 2008). Hotter air masses reduce aircraft lift, which could result in payload restrictions, flight cancellations, and possibly the need to extend runway lengths. In addition, flights connecting to more vulnerable coastal airports would be more susceptible to weather-related delays (Transportation Research Board 2008). Conversely, warmer winters could reduce the need for de-icing and other runway clearing machinery.

Air transportation is impacted by climate conditions, although serious flight disruptions are typical only in extreme weather events. The planning area of air transportation service is therefore given a sensitivity score of medium.

***Vulnerability Part II: Adaptive Capacity***

The airline industry is completely intertwined and dependent on the climate conditions of locations around the world. There is little room to change operations in order to minimize weather-related delays and cancellations. The state of current technology as well as safety concerns result in little flexibility to work around severe storm and heat conditions. The adaptive capacity score is low.

| AIR TRANSPORT VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | Low | **4 Points: High** |

***Risk***

With ninety million passengers passing through the airport, the number of Atlantans impacted by climate change would be large. The impacts should not be life-threatening, but more severe weather events increase the opportunity for equipment problems and errors by air traffic controllers, pilots, etc.

Additionally, the impacts could be quite costly to the airport, airlines, and passengers. The inability to complete international cargo transfers could result in high fees to the airport (2/4/2010 meeting with Janelle Lyons). A 1989 study revealed that fog and thunder related delays at the Atlanta airport have relatively low individual costs, but can have a very large cumulative effect. One airline documented an annual average of 2,750 hours of delay, costing the airline more than $6 million in operating expenses (this is equivalent to $10,443,580 today) at Atlanta each year (Robinson 1989). Flight delays and cancellations create a cost to society as well. The Air Transport Association calculated the average 2008 value of a passenger's time was $37.18 per hour (Air Transport Association of America 2010). A single plane with two hundred passengers that was delayed thirty minutes cost society $223,080. The climate changes that will impact air transport in these ways are very likely. These factors result in an estimated high risk level.

| AIR TRANSPORT RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: All (3)<br>Life-threatening: Uncertain (2)<br>Costs: High (3) | Very Likely (3) | **11 Points: High** |

***Planning Area Summary***

The air transport planning area has a medium level of sensitivity to climate, and a low capacity to adapt to change, which results in a high vulnerability level. In addition, the estimated risk level is high, leading to a total of 15 points and placement in Tier Three for prioritization planning purposes.

## Sector: Public Safety

### *Fire Safety Services*

***Vulnerability Part I: Sensitivity***

Like many city departments, the Fire Department's resources are stretched thin. The Atlanta Fire Department is funded through the General Fund and is therefore subject to economic fluctuations and changes in political will. The tight budget of recent years has required the department to develop creative solutions while still maintaining critical resources and providing a high level of service to Atlantans. One of these solutions involves "brownouts," a strategy which temporarily shuts down operating fire stations. Although they reduce costs, brownouts result in more dispersed fire safety services. Because the responding fire unit may be farther away, response time may suffer. Other strategies include reducing personnel hours and instituting restrictions on overtime pay. While budget constraints represent a current and recurring stress on the Fire Department, there are other inefficiencies that reduce its effectiveness. The department struggles with thousands of false alarms every year, which cost several hundred dollars each time. A current program is underway to reduce false alarms by penalizing repeat offenders (11/12/2009 interview with Chief Baker).

The Fire Department places great emphasis on community education. Fire fighters canvas all neighborhoods and sometimes concentrate on fire-prone neighborhoods. A concerted effort to attend neighborhood meetings is made. The Department also offers educational fire programs to citizens, including Atlanta Citizens Emergency Response Team (ACERT). The ACERT program is funded by Georgia

Emergency Management Agency (GEMA) and FEMA, and provides ten representatives from each community with free training to improve survival knowledge for up to 72 hours (11/12/2009 interview with Chief Baker).

Emergencies and the fire safety personnel that respond to them are often affected by climate conditions, but the department has found ways to mitigate these effects. The Fire Department deals with climate in the following ways:

- There are more fires in the winter when unattended fires are made inside vacant buildings, often by the homeless population.
- During very hot days, backup fire fighters are sent out to fire calls. When there are fewer operating stations, fewer vehicles are available, resulting in fire trucks that are sent out simply to transport fire fighters.
- On hot days, crews are sent out to check on communities as welfare calls.
- During droughts, a backup tanker of water is sometimes needed.
- Floods create the need for full response and specialized personnel, like a technical rescue unit (11/12/2009 interview with Chief Baker).

The current state of the Fire Department, as well as its moderate exposure to climate, results in a sensitivity score of medium.

***Vulnerability Part II: Adaptive Capacity***

The Fire Department displays a high degree of creative resourcefulness to deal with challenges. The time spent on community engagement and education serves to extend the department's reach and increase efficiency in times of need. The relationship with the Atlanta Police Department, AFCEMA, and other safety organizations also supports the department's ability to achieve its mission. Despite

financial barriers (or perhaps because of), the Fire Department has demonstrated a high level of adaptive capacity.

| FIRE SAFETY SERVICES VULNERABILITY ASSESSMENT | | |
|---|---|---|
| SENSITIVITY SCORE | ADAPTIVE CAPACITY SCORE | VULNERABILITY LEVEL |
| Medium | High | 2 Points: Low |

***Risk***

The proportion of citizens that need fire safety help is small, but many cases are life-threatening. Warmer winters may result in fewer winter fires and save the department money during winter months. Greater staffing and equipment needs prompted by adverse climate conditions will likely pose relatively minor additional annual costs. The climate conditions that will have an impact (milder winters, droughts, and heat waves) are very likely to occur. The City's fire safety services are at a medium level of risk.

| FIRE SAFETY SERVICES RISK ASSESSMENT | | |
|---|---|---|
| DEGREE OF IMPACT OF CHANGE ON SYSTEM | PROBABILITY OF IMPACT | ESTIMATED RISK LEVEL |
| Citizens Affected: Few (1)<br>Life-Threatening: Yes (3)<br>Costs: Low (1) | Very Likely (3) | 8 Points: Medium |

***Planning Area Summary***

The planning area of fire safety services demonstrates a low level of vulnerability to climate change due to a medium level of sensitivity and high adaptive capacity. The risk level is medium. In total, the planning area has a total of 10 points, resulting in placement in Tier Eight.

## *Police Services*

***Vulnerability Part I: Sensitivity***

The Atlanta Police Department is the largest department in the City and operates through the General Fund. The size of the department is influenced by political will and budget constraints. The Justice

Assistance Grant and grants through the Office of Community Oriented Policing Services, which are annually renewable federal grants supplement the budget by funding additional police officer positions (1/27/2010 interview with Debra A. Williams).

Climate has direct and indirect effects on crime and the police officers that work to keep the city safe. Heat waves often correspond with spikes in crime. A 2002 study found that for every 1˚F increase in average temperature, murders and assaults increase by about nine per 100,000 people (Anderson 2002). A conservative 1˚F increase would lead to more than seventy additional murders and assaults in Atlanta in 2030 (using a projected 780,000 population). This rate could be higher if temperature rises follow more extreme predictions. The Atlanta police force understands the influence of heat and makes an effort to be more visible during these times as a means of reducing crime (1/27/2010 interview with Debra A. Williams). This strategy exposes officers to high temperatures and often air pollution. Some officers decide to remove protective garments to avoid over-heating (2/4/2010 meeting with Debra A. Williams).

Winters usually correspond with lower crime rates (shoplifting and auto larceny rates may increase slightly) in Atlanta because people stay inside more (1/27/2010 interview with Debra A. Williams). Climate projections suggest longer summer seasons and warmer winter months in the coming decades, so the periods of lower crime associated with winter may dwindle.

Climate change will likely compound the steady demand for safety services from the Atlanta Police Department. Severe storm and flood events decrease the safety of an officer's working environment and can delay response time (1/27/2010 interview with Debra A. Williams). Atlanta Police will likely have to work around these less-than-ideal factors more often in the future. Demands on manpower will increase, thus increasing overtime costs.

The current state of the Police Department and its exposure to climate result in a sensitivity score of medium.

***Vulnerability Part II: Adaptive Capacity***

The Atlanta Police Department has created important collaborative ties with emergency, crime, and safety entities throughout metropolitan Atlanta through Memorandums of Agreement (MOAs). This coordination mechanism helps ensure that resources are available when they are needed most (1/27/2010 interview with Debra A. Williams).

However, the department already operates with a smaller force than many decision makers would like due to budget cuts. Despite these constraints, the force is still able to step up operations in response to higher crime periods (i.e. placing more police on foot patrol in the summer). Mayor Reed has made increasing the size of the force a priority (2/4/2010 meeting with Debra A. Williams). Therefore it would seem that a police force that can adapt to climate change can in part be accomplished through political will. Ensuring an individual officer's resilience to climate is much more difficult. These barriers to overall resilience result in an adaptive capacity score of low.

| POLICE SERVICES VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | Low | **4 Points: High** |

***Risk***

A small proportion of Atlantans are affected directly by crimes; those that are often experience a life-threatening event. Temperature increases, severe storm events, and floods are very likely to occur and impact the department through increased costs to the department due to higher crime rates, demands on officers, etc. Since it is the largest department in the City, these costs could be substantial. The estimated risk level is medium.

| POLICE SERVICES RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Impacted: Few (1)<br>Life Threatening: Yes (3)<br>Costs: Medium (2) | Very Likely (3) | **9 Points: Medium** |

***Planning Area Summary***

The police services planning area demonstrates a high vulnerability to climate change, in part due to its low adaptive capacity. The risk level is medium. These results lead to a total of 13 points and the planning area's position in Tier Five.

## *Disaster Response*

***Vulnerability Part I: Sensitivity***

Atlanta's sensitivity and current response capacity to natural disasters can best be illustrated by two events- a tornado and a flood - that have affected the city in the past three years.

In March of 2008, a tornado touched down in downtown Atlanta. The tornado ravaged an area six miles long and several blocks wide – affecting the Vine City area, downtown, and into the east Atlanta neighborhood of Cabbagetown . The storm left a path of debris, damaged buildings, and power outages in its wake. Fulton Cotton Mill Lofts, a series of occupied historical buildings (seen in Figure 11), was especially hard hit and became the focus of emergency responders (Wessels and

**Figure 11. Tornado damage at Fulton Cotton Mill Lofts (Simpson 2008)**

Woodworth 2008). Municipal emergency responders were aided by neighboring county staff, state personnel, and the Atlanta-Fulton County Emergency Management Agency (AFCEMA), among others to provide emergency response services. The City's efforts were also supported by the private sector and the military. In total, thirty injuries were reported. Afterwards, a thorough analysis of the disaster and following response was conducted. This analysis uncovered important lessons that would improve response to similar disasters in the future.

In September of 2009, a week-long flood required the activation of the Emergency Response Plan. This involved coordination through AFCEMA. The preliminary debriefing revealed the primary weakness during the emergency response was the new leadership in AFCEMA and Atlanta's Fire Department. These officials were less familiar with the Emergency Response Plan and the process, so response times suffered (10/21/2009 interview with Luz Borrero).

AFCEMA's administrative and organizational operations are jointly paid by the City of Atlanta and Fulton County, but emergency costs are typically paid by federal emergency funds. The current system for these transactions requires local areas to advance the money for response and recovery needs and then receive reimbursement by FEMA's Public Assistance (PA) program.

Increased natural disasters (especially in the form of floods and heat waves) will place greater stress on community service organizations and call for a strong working relationship with municipal emergency managers. The increasing population within Atlanta will make this need even more apparent.

Emergency response services are often required when natural disasters occur in areas of high population density. Therefore the emergency response planning area is highly sensitive to climate change and given a high sensitivity score.

***Vulnerability Part II: Adaptive Capacity***

According to Luz Borrero, Deputy Chief Operating Officer, the best way to decrease vulnerability is to have a plan before an emergency arises. Once emergency plans are designed by AFCEMA or other emergency agencies, adequate training at all levels (from the mayor to on-the-ground responders) is imperative. Effective preparation is achieved through disaster scenario planning and training (10/21/2009 interview). Unfortunately, financing such efforts has presented a barrier for municipalities that cannot afford the high costs. While FEMA's PA Program encourages planning for emergencies, it does *not* provide funds for emergency mitigation planning efforts (Federal Emergency Management Agency 2007). Funding for these activities is provided by the Pre-Disaster Mitigation (PDM) program, a competitive grant program through FEMA (Federal Emergency Management Agency). Prohibitive costs have meant that only three scenario trainings have been completed in the last six years in Atlanta. These scenarios were financed through federal grants from the Department of Homeland Security and/or the Department of Justice (10/21/2009 interview with Luz Borrero). It is unclear whether any of the three scenarios included emergencies related to climate change impacts.

Three years ago, the City's Homeland Security Council learned about regional climate change impacts from local academic experts. This discussion of regional impacts emphasized the importance of flexible emergency response plans (10/21/2009 interview with Luz Borrero). While the meeting increased awareness of global climate change, it is unclear how much the meeting resulted in increased preparedness for the specific climate changes Atlantans will face.

When disasters do occur, local agencies must initially fund all response and recovery efforts. The capability to advance cash is limited, so the City's ability to fund emergency response would be weakened if emergencies occurred more often. For example, when the RM Clayton Wastewater Treatment Plant sustained over $50 million in damages during the September 2009 flood, the City relied on creative financing mechanisms to fund the repairs quickly (10/21/2009 interview with Luz Borrero).

Had another disaster followed before the City was reimbursed for the initial disaster costs, the ability to fund the necessary response could have been compromised.

Complete reliance on FEMA funding for disaster recovery can leave damages or problems unaddressed. FEMA funds cannot be used towards lost economic productivity, the majority of damages to private property, or other damages that do not pose an imminent threat to human health. Additionally, FEMA requires that any work to restore a facility through repair or restoration be completed to the facility's pre-disaster design, function, and capacity. While the PA program encourages future protective measures by supplying funds for hazard mitigation during the recovery process, these improvements must be identifiable at the time of reconstruction (Federal Emergency Management Agency 2007). The Hazard Mitigation Grant Program (HMGP) provides such assistance for post-disaster improvements (Federal Emergency Management Agency). The requirement effectively prevents improving the *overall* disaster resilience of the facility or shifting the structure's function to a more suitable and resilient use. It may provide a perverse incentive to replace a vulnerable facility with a new facility that may still be vulnerable in the same or other ways.

Due to the strict requirements to receive federal assistance for hazard mitigation planning as well as the nuanced nature of recovery funding briefly described above, the current adaptive capability to *prepare* for the impacts of climate change is low. If the city experiences stronger, more frequent weather events as projections indicate, better planning and emergency financing mechanisms will need to be created.

Performance evaluation after disasters implies a degree of adaptive management. Atlanta's practice of conducting post-disaster analyses is an important mechanism that facilitates resiliency improving measures. However, if back-to-back disasters occur and time and resources are stretched, it is uncertain whether this practice would be maintained.

An additional source of vulnerability during urban natural disasters is the design of emergency warning systems. Because visual, auditory, and cognitive impairments are common among the frail elderly, a redundant warning should be shared through multiple venues (Fernandez, Byard et al. 2002). AFCEMA has recently upgraded its system for public communication to the press and community organizations. According to Luz Borrero, the updated system allows for more disciplined and uniform communication process (10/21/2009 interview).

As a whole, the disaster response effort is largely reactive and does little to prevent disasters from occurring in the first place. With that in mind, the work relies heavily on accessing the funding needed to create a response plan, having funds ready for emergency response and recovery, and successfully leveraging the help of other jurisdictions and the community. While the City demonstrates high capability in the last aspect, the rest are tied to federal and state actions that can hinder achievement of the highest level of protection. With these facts in mind, the adaptive capacity is low.

| DISASTER RESPONSE VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Low | **4 Points: High** |

***Risk***

The number of citizens impacted by a disaster varies. Some events may affect isolated geographic areas, like the tornado that blew through the city in 2008. Other events can shut down the entire city, such as the September 2009 flood. Disasters are life-threatening, and the costs of response and recovery are high. The conditions that can lead to natural disasters - floods, heat waves, and tropical storms- are very likely to occur. The estimated risk for the planning area of disaster response is high.

| DISASTER RESPONSE RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life Threatening: Yes (3)<br>Costs: High (3) | Very Likely (3) | **11 Points: High** |

***Planning Area Summary***

The disaster response planning area exhibits high vulnerability and high risk to climate change. The priority level for adaptation planning is Tier Three.

## Sector: Land Use and Development

### *Urban Planning*

***Vulnerability Part I: Sensitivity***

Among many other factors, successful urban planning requires a keen understanding of geography and climate. Despite this, Atlanta's developers are required to consider only one climate factor as they make zoning decisions and design new developments – flood plain restrictions designated by FEMA.

The Bureau of Planning is in charge of zoning and permitting needs and produces a Comprehensive Development Plan (CDP) every five years, a practice which most cities choose to forgo. Atlanta's CDP looks 15-20 years into the future and considers economic development, transportation, and historic preservation areas. The Bureau has also produced in-depth transportation guidance through the Connect Atlanta Plan. In addition to producing CDPs, the Bureau of Planning administers several of the city's ordinances, provides policy guidance, and plays an advocacy role. The Bureau has not discussed how climate changes will impact its mission (1/19/2009 interview with Charletta Jacks).

While working to remedy its environmental challenges, Atlanta has excelled in certain areas related to land use. The municipality has implemented a brownfield and greyfield redevelopment program, with Atlantic Station as a national poster child of success. Planners have recently developed different zoning options, including "Quality of Life" and mixed use. In addition, transit-oriented development is a key component of the BeltLine Project.

Development patterns can influence the impact of flood events by increasing the surface area of impermeable surfaces. Temperatures can also be intensified by development patterns when surface reflectivity is low, buildings are densely situated, and air flow is inhibited. These dynamics can influence the success of a development. This planning area will be particularly impacted by increasing temperatures and changing flood patterns.

Climate change and policies (that guide transportation and land use) will continue to shift the demand for the location and types of development that occur in Atlanta. Therefore, the sensitivity score for this planning area is medium.

**Figure 12: Opportunities for in-fill development abound in Atlanta**

***Vulnerability Part II: Adaptive Capacity***

Increasing temperatures will likely mean rising utility costs for businesses and residents. Storm impacts and possible air pollution regulations could mean rising transportation costs. More intense and frequent flood events will cause developers to think more carefully about choosing sites. As a result, mixed use-zoning, transit-oriented development, shade trees, and permeable surfaces stand to become

more attractive to residents and businesses. Developers may embrace some of these design options voluntarily, but many others will require mandates and a local political climate that is willing to enforce them. As described in the section above, it appears the city is moving in this direction, albeit in sometimes disjointed efforts. Several of the city's recent projects have been incentivized through federal dollars, which creates a reliance on non-local actors. The Bureau of Planning has yet to realize its unique and important opportunity to consider future climate. While there are many locations in the city that will be sited for infill development in the coming decades, most of the land in the city is already developed. The small pockets available for infill development can be planned with climate resilience in mind, but, it is unknown how effective these piecemeal efforts will be.

Many factors restrict and impact the types of urban planning and development that occur in the city. With several success stories and a social climate that is beginning to support resilient urban planning there seems to be hope that the barriers (zoning restrictions and lack of demand) can be overcome. The adaptive capacity score for urban planning is medium.

| URBAN PLANNING VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | Medium | **3 Points: Medium** |

***Risk***

In future decades, it is safe to assume that urban planning decisions will affect half of Atlantans, as a conservative estimate. The climate changes that stand to impact urban planning are increased occurrence of severe storms and thus flooding, and rising temperatures that will often be oppressive. These changes are likely to occur. The costs of the impacts are unclear and depend on a variety of factors, including economic conditions. Impacts of climate change on urban planning will not be life-threatening, but they will directly affect quality of life. The estimated risk level is medium.

| URBAN PLANNING RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life-threatening: No (1)<br>Costs: Low (1) | Very Likely (3) | **7 Points: Medium** |

***Planning Area Summary***

The planning area of urban planning shows a medium level of vulnerability (due to sensitivity and adaptive capacity scores of medium). Additionally, the estimated risk level is medium. These results lead to a total of 10 points and the planning area's placement in Tier Eight.

## *Affordable Housing*

***Vulnerability Part I: Sensitivity***

Affordable housing plays a key role in ensuring a climate resilient city because the housing stock is directly exposed to climate and so many are especially impacted by under-performing housing. Increasing temperatures will necessitate the need for higher energy use or more efficient housing. Drought periods will make home water conservation increasingly important and flood events will present more frequent challenges to residents.

The City of Atlanta's Bureau of Housing offers a number of assistance programs that "promote coordinated community development and support the production and rehabilitation of safe, sanitary, and affordable housing (Department of Planning and Community Development 2009)." These efforts, like the "HOME" program, support for non-profit Community Housing Development Organizations, and Atlanta's BeltLine Affordable Housing Trust Fund (BAHTF), are often funded by federal agencies like the US Department of Housing and Urban Development (HUD). The dependence on federal grants make the programs subject to yearly variations in funding amounts. According to Jay Perlmutter of the Bureau of

Housing, there are never enough funds to satisfy the need for affordable housing in the city (2/4/2010 meeting with Jay Perlmutter).

On the whole, the programs offer financial assistance, in the form of grants and flexible loans, to build new homes or improve existing homes for the elderly, disabled, and low-income. Local non-profit and civic organizations are affiliated with these programs, some of which are focused on a certain geographic area of the city. The homes constructed and renovated using the Bureau of Housing's assistance are required to meet the City's energy efficiency standards. The Bureau follows guidance from state and federal agencies as well as technical organizations, like ASHRAE (2/3/2010 interview with Evelyn Nu'man).

Climate change impacts may result in a larger vulnerable population of elderly, low-income, and disabled groups. These groups demonstrate a lower ability to withstand and recover from climactic events due to low levels of disposable income, less independent mobility, and sometimes weaker social networks. If a city can support vulnerable populations and help them address these weaknesses, the resiliency of the entire community can increase. Much of this support will come from a climate-resilient affordable housing stock.

The amount of affordable housing in Atlanta is currently insufficient, and climate change impacts stand to further increase demand and render many current homes less affordable due to rising utility costs. The sensitivity score for this planning area is high.

***Vulnerability Part II: Adaptive Capacity***

Many of the homes for which the Bureau of Housing provides support were built between 1950 and 1970, when efficiency standards were lower. The Bureau's efforts are subject to city policy, which requires renovations to achieve current building and energy codes. This policy improves the performance of existing buildings, particularly in terms of energy and water efficiency and conservation.

Not all homes can be made resilient through efficiency retrofits. Many Atlanta homes lie in the floodplain, for which little can be done to improve resiliency against flooding. Not surprisingly, it is easier to build a new house to be resilient by designing a strong structure and placing the building in a safe and strategic location. For example, homes situated near transit stations and greenspace will be important factors in making them affordable and resilient.

The Bureau of Housing's activities are largely dependent on insufficient federal funding. This reduces the City's adaptive capacity. Because the capacity to absorb or respond to climate change is low; the adaptive capacity score for this planning area is low.

| AFFORDABLE HOUSING VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| High | Low | **5 Points: High** |

***Risk***

In 2005, an estimated 27% of the city's residents were living in poverty (Department of Planning and Community Development 2007). It is very possible that demand for affordable housing will rise due to population growth and stretched personal budgets in the decades to come. Because the number of low to moderate income households is substantial, the number of Atlantans that will require affordable housing could be nearly half.

Rising temperatures and flood events are the two significant climate changes that will impact homeowners and renters. These conditions, which are very likely to occur, can sometimes create life-threatening situations. Exorbitant residential utility bills for residents as well as the cost of renovating homes after destructive climate events will be high. On the other hand, the cost of building new resilient housing does not have to be prohibitive. Habitat for Humanity homes may serve as useful models for such housing needs. The estimated risk level of the affordable housing planning area is high.

| AFFORDABLE HOUSING RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Half (2)<br>Life-threatening: Uncertain (2)<br>Costs: High (3) | Very Likely (3) | **10 Points: High** |

***Planning Area Summary***

The affordable housing planning area shows a high level of vulnerability to climate change due to a high sensitivity to climate and a low capacity to change. The risk level is high, and the planning area garnered a total of 15 points, enough to place it in Tier Three for prioritization of adaptation efforts.

## Sector: Materials

### *Residential Waste Collection*

***Vulnerability Part I: Sensitivity***

Residential waste management and recycling services have substantial exposure to weather events. Floods and major storms hinder or prevent collection service provided by the Office of Solid Waste Services in the Department of Public Works (Office of Solid Waste Services 2009). Missed waste and recycling collection services can result in a short-term build-up of refuse in the city's streets and in customer homes. High winds or stormwater runoff can cause unwanted transport of materials, contaminating water sources and scattering refuse to places where it will not be collected.

Atlanta is likely to experience warmer winter temperatures and may experience fewer winter storms, which may decrease the number of disruptions to collections services during this season. During the summer, extreme heat waves, storm events, and floods will likely result in more frequent and possibly longer disruptions in collection services. Of particular concern is the effect that changing weather will have on the city's landfills. Although unlikely, flooding or erosion that intercepts a landfill can spread waste and contaminate water supplies.

Due to these current and possible future climate impacts, the residential waste collection planning area is given a sensitivity score of medium.

***Vulnerability Part II: Adaptive Capacity***

There seems to be little concern over the effects of storm and flood events on the City's waste collection services. When weather prevents a scheduled pick-up, these customers have their waste collected at the next available time. Former Commissioner Joe Basista noted a general understanding by customers in these instances (8/12/2009 interview). This flexibility leads to an adaptive capacity score of high.

| RESIDENTIAL WASTE COLLECTION VULNERABILITY ASSESSMENT | | |
|---|---|---|
| **SENSITIVITY SCORE** | **ADAPTIVE CAPACITY SCORE** | **VULNERABILITY LEVEL** |
| Medium | High | **2 Points: Low** |

***Risk***

A staggered pick-up schedule usually means that waste collection disruptions affect small sections of the city. These disruptions are not life-threatening and are relatively low cost for the Department of Public Works to work around. The flood and severe storm conditions that could create these impacts are very likely. Together, these factors result in a low estimated risk level.

| RESIDENTIAL WASTE COLLECTION RISK ASSESSMENT | | |
|---|---|---|
| **DEGREE OF IMPACT OF CHANGE ON SYSTEM** | **PROBABILITY OF IMPACT** | **ESTIMATED RISK LEVEL** |
| Citizens Affected: Few (1)<br>Life-threatening: No (1)<br>Cost: Low (1) | Very Likely (3) | **6 Points: Low** |

***Planning Area Summary***

The residential waste collection planning area shows a low level of vulnerability and risk to climate change. It has a total of 8 points, making it the lowest priority of all planning areas for adaptation planning.

## Summary

Table 13 provides a summary of vulnerability, risk, and total scores for each planning area. This table also provides assessment averages by sector.

**Table 13. Assessment scores by planning area and sector**

| Sector | Planning Area | Vulnerability Score | Risk Score | Combined Score | Sector Average Combined Score |
|---|---|---|---|---|---|
| Energy | Energy Assurance | 5 | 11 | 16 | 15 |
| | Electricity Production | 5 | 10 | 15 | |
| | Electricity Demand | 4 | 10 | 14 | |
| Water Resources | Water Quality | 5 | 11 | 16 | 14.5 |
| | Water Supply | 3 | 10 | 13 | |
| Health | Air Quality | 5 | 12 | 17 | 14 |
| | Heat Relief | 4 | 10 | 14 | |
| | Outbreak Prevention | 3 | 8 | 11 | |
| Public Safety | Disaster Response | 4 | 11 | 15 | 12. 7 |
| | Police Services | 4 | 9 | 13 | |
| | Fire Safety | 2 | 8 | 10 | |
| Ecology | Urban Forest Management | 4 | 10 | 14 | 12. 7 |
| | Pest and Invasive Management | 5 | 8 | 13 | |
| | Greenspace | 3 | 8 | 11 | |
| Transportation | Air Transport | 4 | 11 | 15 | 12.5 |
| | Road and Bridge Maintenance | 4 | 10 | 14 | |
| | Public Transit | 3 | 9 | 12 | |
| | Paratransit Service | 2 | 7 | 9 | |
| Land Use and Development | Affordable Housing | 5 | 10 | 15 | 12.5 |
| | Urban Planning | 3 | 7 | 10 | |
| Building Infrastructure | Stormwater Management | 4 | 10 | 14 | 12 |
| | Building and Energy Code | 4 | 8 | 12 | |
| | Building Maintenance | 3 | 7 | 10 | |
| Materials | Residential Waste Collection | 2 | 6 | 8 | 8 |

### Vulnerability Assessment Summary

Vulnerable systems are those that are highly exposed to climate conditions, face current and future (non-climate) stresses, and have little ability to absorb or adapt to changing climate conditions. Atlanta's

most vulnerable systems are directly impacted by climate and often characterized as large-scale problems that must be addressed (at least in part) at a level higher than city government. These have a vulnerability score of 5 (out of 5) on Table 13 and include air quality, energy assurance and production, and water quality. However, improvement of a number of other highly vulnerable planning areas can be accomplished through existing city government structures. With scores of 4 and 5 on Table 13, affordable housing, urban forest management, heat relief, stormwater management, pest and invasive species management, police services, building and energy codes, and most road maintenance areas are under the sole purview of the City.

Nine planning areas are less vulnerable to climate change (each scoring 3 points, as shown on Table 13). These include water supply, public transit, greenspace, outbreak prevention, building maintenance, and urban planning. While Atlanta's management of water supply has been a hotly debated subject, the City has shown a high level of adaptive capacity when faced with drought conditions.

Fire safety, paratransit service and residential waste collection have a low vulnerability to climate change. Each of these planning areas exhibits a great deal of flexibility.

If vulnerability is considered by sector, and planning area scores are averaged, the results are as follows:

- The energy sector shows the highest vulnerability to climate change, with an average vulnerability score of 4.6 points (out of 5).
- Several sectors had an average vulnerability score of 4 points. These include water resources, health, ecology, and land use and development.
- The average vulnerability score for the building infrastructure sector was 3.6.
- The public safety sector averaged 3.3 points in the vulnerability assessments, closely followed by the transportation sector, which averaged 3.25 points.

- The last sector – materials – included only one planning area, with a vulnerability score of 2.

## Risk Assessment Summary

The most at-risk planning areas impact many citizens, pose threats to human life, and are associated with high costs of recovery once impacts are felt. The probability of climate impacts also affects the magnitude of risk.

Most planning areas in this study will be affected by multiple changes that are very likely to occur, although the assessment scoring system only incorporated one score – the highest possible for that planning area. Further planning efforts may consider using an additive method that would differentiate between a planning area that will be impacted by increasing temperatures only, and one that might be impacted by high temperatures, floods, and droughts. With such a broad array of planning areas assessed in this study, in-depth cost calculations were not possible. Future adaptation planning efforts might focus on developing these numbers.

According to the results of this analysis, the planning areas of air quality, energy assurance, water quality, disaster response and air transport have the highest risk to climate change (with scores of 11 or 12 out of 12 on Table 13). Electricity production and demand, affordable housing, road and bridge maintenance, urban forest management, stormwater management, heat relief, and water supply are also at great risk to climate changes. Impacts in these areas are felt by many people, and the costs of recovery are very high. Of the 24 planning areas, building maintenance, urban planning, paratransit service, and waste collection show the lowest risk to climate change impacts.

If risk is considered by sector, and the planning area risk scores are averaged, the rankings are as follows:

- Water resources – consisting of the planning areas of supply and quality – are the most at-risk to climate change, with an average risk score of 10.5.

- The energy sector is the second most at-risk sector, with an average risk score of 10.3.
- Health ranks third, with an average risk score of 10 points.
- Public safety had an average of 9.3 risk points, closely followed by the transportation sector, which averaged 9.25 risk points.
- The sectors of ecology, land use and development, and building infrastructure demonstrated relatively low risk, with average risk scores of 8.6, 8.5, and 8.3, respectively.
- The least at-risk sector was materials, with a single planning area that had a risk score of 6 points.

### Sector Summary

The sectors that contained the highest average scores were consistent with the planning area results, as indicated by the sector average score column in Table 13. The sectors with the highest scores were energy, water and health (with scores ranging from 14 – 15 points). These three sectors each contain one of the three highest scoring planning areas. Public safety, ecology, transportation, and land use and development contained planning areas that averaged 12.7 -12.5 points). The sector of building infrastructure followed closely, with an average planning area score of 12 points, as shown in Table 13. Lastly, the materials sector had the lowest average score by default. This sector contained just one planning area - residential waste collection – which had a combined score of 8 points.

### Planning Area Summary

Table 14 summarizes the vulnerability and risk scores of the 24 planning areas assessed. The planning areas of air quality, water quality, and energy assurance are highly vulnerable and demonstrate a high risk level to climate change. These planning areas generated totals of 16 or 17 points and have the darkest shading in Table 14. Disaster response, air transport, electricity production, and affordable

housing each had a combined score of 15 points. Just behind these planning areas are those of stormwater management, urban forest management, road and bridge maintenance, electricity demand, and heat relief, with 14 total points. Pest and invasive species management, police services, and water supply came next with totals of 13 points. The planning areas of building and energy code, public transit, greenspace, and outbreak prevention each had a combined score of 11 or 12 points. The fire safety, building maintenance, urban planning, paratransit service, and residential waste collection areas demonstrated low vulnerability and risk to climate change (with combined totals of 8-10 points) Table 14 indicates their scores with the lightest shading.

**Table 14: Assessment scoring matrix for 24 planning areas**

| | | VULNERABILITY SCORE | | | |
|---|---|---|---|---|---|
| | | **5** | **4** | **3** | **2** |
| **RISK SCORE** | **12** | 17<br>**Air Quality** | 16 | 15 | 14 |
| | **11** | 16<br>**Energy Assurance**<br>**Water Quality** | 15<br>**Disaster Response**<br>**Air Transport** | 14 | 13 |
| | **10** | 15<br>**Electricity Production**<br>**Affordable Housing** | 14<br>**Road and Bridge Maintenance**<br>**Urban Forest Management**<br>**Stormwater Management**<br>**Electricity Demand**<br>**Heat Relief** | 13<br>**Water Supply** | 12 |
| | **9** | 14 | 13<br>**Police Services** | 12<br>**Public Transit** | 11 |
| | **8** | 13<br>**Pest and Invasive Species Management** | 12<br>**Building and Energy Code** | 11<br>**Greenspace**<br>**Outbreak Prevention** | 10<br>**Fire Safety** |
| | **7** | 12 | 11 | 10<br>**Building Maintenance**<br>**Urban Planning** | 9<br>**Paratransit Service** |
| | **6** | 11 | 10 | 9 | 8<br>**Residential Waste Collection** |

# Discussion

## Climate Change Impacts on Vulnerable Populations

Understanding climate change impacts is critical for many City policies and actions, particularly with regard to knowing how climate change might differentially impact various groups of citizens. According to the IPCC, the poor, infirm, elderly, and other dependent populations feel disproportionate impacts of extreme events. The effects of these events can be amplified by inadequate provision and execution of public sector services (Field, Mortsch et al. 2007). The City will be expected to have the capacity to provide adequate human services to these vulnerable groups.

For example, Atlanta's elderly population is expected to increase in the coming decades. According to the ARC, 20% of metropolitan Atlanta residents will be over the age of sixty in 2030 (Atlanta Regional Commission 2006; Atlanta Regional Commission 2009). The majority of this population owns their home, does not plan to move, and is currently dependent on the automobile (Atlanta Regional Commission 2006). Climate will affect this group in many ways, including decreased health and mobility. Increased ambient temperatures are correlated with increased ground level ozone levels (Liao, Tagaris et al. 2009), both conditions that promote health problems in the elderly. As in other sectors and planning areas, the frail elderly population is especially vulnerable during disasters. These citizens rely on a number of community services that are susceptible to disruption (Fernandez, Byard et al. 2002). Therefore, this population will be more resilient if the organizations upon which they rely are also resilient. Resilient organizations are those that understand and address their own vulnerabilities, ensure service continuity, prepare for times of upscaled operations, and have strong disaster recovery plans.

Municipal emergency managers can ensure a high resiliency of the elderly population through collaboration with existing community organizations (Fernandez, Byard et al. 2002). Atlanta's first responders have an awareness of the location of elderly populations and make consistent efforts to build relationships with neighborhoods. This awareness and continued effort suggests that first

responders have developed working relationships with organizations like Meals on Wheels, home nursing programs, paratransit providers, and other organizations that have already identified the elderly population before an emergency arises.

## Indirect Impacts of Climate Change on Atlanta

Climate change will require general municipal operational adjustments, but there are increased projections of severe to catastrophic regional weather events that will inevitably impact the city and thus require more drastic responses. Examples of such events are not hard to find. Electricity demands that increase during heat waves have been known to end in disastrous power outages across entire regions. Recent hurricanes that have damaged oil and gas pipelines have demonstrated the far-reaching energy disruptions that may become more common with increased hurricane activity (Field, Mortsch et al. 2007). Deep droughts require strict government oversight and can have lasting impacts on the local economy.

As the impacts of climate change are felt in the US and around the world, “climate refugees” may migrate away from impacted areas towards more resilient places. Atlanta is the largest city in the Southeast, and is especially attractive to African Americans looking for opportunities in the region. These characteristics may draw climate refugees - especially those migrating from coastal areas dealing with sea level rise. In fact, Atlanta has already seen in-migration occur from a natural/human disaster once. In 2005, Hurricane Katrina caused an influx of 100,000 people into the City of Atlanta, triggering a sudden need for the City to provide affordable housing, employment, and medical care to these refugees (2006). How the City prepares for more events like these is undoubtedly important.

In addition to the possibility of catastrophic storm events, farms may see reduced productivity in the long term. Crop failures and shortages result in rising food prices, which would have debilitating impacts on the city - particularly on individuals and families on strict budgets. Such impacts would have

a generally negative effect on the local economy. Informing local farmers of changing climate and suggesting suitable crops could help reduce this impact on Atlantans.

### Degrees of Adaptation Strategy

The adaptation strategies and tactics adopted to address the vulnerable, at-risk systems will vary. Cost benefit analyses and decision exercises should be carried out to find the best tactics to increase resiliency for each system. In some cases, an aggressive strategy may be best, with early, active adaptation measures employed. In other instances, a more cautious passive strategy may be more appropriate. The passive strategy would involve waiting until specific climate impacts have been identified and are imminent before action is taken. The end goal of all adaptation strategies should be to mitigate the amount of negative impacts and recovery efforts required.

Although some climate change projections are less certain than others, cultivating awareness and preparing for them where needed will be a prudent move for the City. The factors that increase a community's vulnerability to climate changes include lower economic status of citizens, inefficient human services, and a lack of preparedness. In many cases, the best adaptation practices also improve the City's ability to achieve its usual objectives of improving these conditions.

## Recommendations

### Prioritization of Planning Areas

Prioritizing the planning areas for adaptation planning will help ensure efforts are directed where they are needed most. A simple method of prioritization involves using a point-based tier system. Planning areas that are highly vulnerable and demonstrate the highest risk fall into Tier One. Tier One should be given the greatest priority in the design of a comprehensive adaptation strategy. The planning area that

is least vulnerable and at-risk falls into Tier Ten, and should be given the lowest priority. Table 14 lists the planning areas by their position in the tier system.

The planning areas of air quality, water quality, and energy assurance fall into Tiers One and Two, which indicate their high priority level for the City's adaptation efforts. Disaster response, air transport, energy production, and affordable housing are Tier Three planning areas that also demonstrate significant vulnerability and risk to impacts. It is recommended that these planning areas are given priority.

A number of planning areas demonstrate moderate vulnerability and risk. Tier Four planning areas include: stormwater management, urban forest management, road and bridge maintenance, energy demand, and heat relief. Tier Five is comprised of pest and invasive species management, police services, and water supply. Building and energy code, public transit, greenspace, and outbreak prevention planning areas fall in Tiers Six and Seven because they show lesser but notable vulnerability and risk. Lastly, there are several planning areas that exhibit low levels of vulnerability and risk. Tiers Eight, Nine, and Ten include fire safety, building maintenance, urban planning, paratransit service, and residential waste collection.

This method of prioritization fails to capture several important considerations. City of Atlanta staff felt that perceived risks and non-market costs should be taken into account during prioritization. In addition, staffers felt priority should be given to adaptation measures that provide co-benefits, solve more than one challenge, and use existing governmental structures and funding streams. For example, increasing the priority level of greenspace and urban forest management and implementing adaptation measures for those planning areas would provide co-benefits and improve the climate resiliency of higher priority planning areas, including air quality, energy assurance, water quality, stormwater management, and heat relief services. This type of strategic, cross-sectoral thinking would serve adaptation planners well.

Others with access to more comprehensive data on each planning area should be able to easily adapt the methods from this study to evaluate changes in priority that might emerge from consideration of additional data or differing interpretations of circumstances facing planning areas (and thus different scores). In particular, the subjective nature of the scoring system creates opportunities for different groups or individuals to develop slightly different priorities if scores are changed or evaluated differently. For example, the tier system could encompass planning areas with a range of scores, rather than one score per tier. Tier One could include those planning areas that scored 16-17 points instead of just 17 points, Tier Two could include planning areas that scored 14-15 points, and so on.

**Table 15. Prioritization of planning areas by tiers**

| Tier | Planning Area(s) | Points |
|---|---|---|
| **One** | Air Quality | 17 |
| **Two** | Energy Assurance, Water Quality | 16 |
| **Three** | Electricity Production, Affordable Housing, Disaster Response, Air Transport | 15 |
| **Four** | Road and Bridge Maintenance, Urban Forest Management, Stormwater Management, Electricity Demand, Heat Relief | 14 |
| **Five** | Pest and Invasive Species Management, Police Services, Water Supply | 13 |
| **Six** | Building and Energy Code, Public Transit | 12 |
| **Seven** | Greenspace, Outbreak Prevention | 11 |
| **Eight** | Building Maintenance, Urban Planning, Fire Safety | 10 |
| **Nine** | Paratransit Service | 9 |
| **Ten** | Residential Waste Collection | 8 |

The vulnerability and risk of planning areas are likely to change over time, regardless of whether adaptation measures are implemented. Technological advances, economic circumstances, and fluctuating demands for various services are several dynamic factors that influence a planning area's resiliency. Furthermore, City action to improve resiliency through adaptation planning should result in a

changes in vulnerability and risk. This reality will make consistent reassessments necessary as time passes.

## Next Steps

It is recommended that the City establish a climate task force consisting of city leaders, climate experts, and stakeholders to continue the work of adaptation planning. As shown in Table 16, Phase 1 of the adaptation planning process has been completed through this report, although it is recommended that the findings of this study be verified and refined by such a climate task force. Once planning areas are prioritized, the task force should define high-level adaptation objectives. This might take the form of focusing on a certain set of climate changes, sectors, planning areas or populations.

**Table 16. Recommended phases of adaptation planning**

| Planning Phase | Item | Completion |
|---|---|---|
| Phase 1 | Conduct a Vulnerability Assessment for all sectors and planning areas | ✓ |
| | Conduct a Risk Assessment for all sectors and planning areas | ✓ |
| | Prioritize planning areas | ✓ |
| Phase 2 | Determine adaptation objectives | |
| | Determine city, state, and federal policies and programs that are barriers or facilitators to achieving resiliency | |
| | Develop an inventory of tactics that will achieve adaptation objectives | |
| | Employ a decision-making framework to choose tactics | |
| | Propose and develop adaptation tactics | |
| Phase 3 | Implementation | |
| Phase 4 | Monitoring and Evaluation | |
| | Vulnerability and Risk Re-assessments | |

Atlanta has been actively working to mitigate GHG emissions in the past several years and has made considerable progress toward this aim. However, recent literature shows that some mitigation actions actually work against adaptation measures (Hamin and Gurran 2009). It is for this reason that city

leaders and stakeholders should work to adopt adaptation practices that will complement current and future mitigation actions. In doing so, the City will work towards a stabilized future that will not require a continuously changing set of adaptation measures.

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### *Personal Interviews*

1. Heather Alhadeff, Assistant Director, Transportation Planning, City of Atlanta Bureau of Planning, 8/13/2009.
2. Charletta Jacks, Assistant Director, City of Atlanta Bureau of Planning, 1/19/2010.
3. Janelle Lyons, Aviation Engineer Associate, Planning and Development, Hartsfield Jackson Atlanta International Airport, 2/4/2010.
4. Jay Perlmutter, Management Analyst, City of Atlanta Bureau of Housing, 2/4/2010.
5. Rebecca Carter, ICLEI, 7/14/2009.
6. Kelvin Cochran, Chief, City of Atlanta Fire Department, 8/13/2009.
7. Joel Baker, Chief, City of Atlanta Fire Department, 11/12/2009.
8. Huley Dodson, Assistant Chief, City of Atlanta Fire Department, 2/4/2010.
9. Donny Reese, AFCEMA, 2/4/2010.
10. Elaine Olivares, Research Division, Atlanta Regional Commission, 7/29/2009.
11. Ryan Barrett, Research Division, Atlanta Regional Commission, 7/29/2009.
12. Michael Chang, School of Earth and Atmospheric Sciences, Georgia Technical University, 8/3/2009.
13. William Chameides, Dean, Nicholas School of the Environment, Duke University, 7/28/2009.
14. Ainsley Caldwell, Arboricultural Manager, City of Atlanta Arborist Division, 11/24/2009.
15. Josh Foster, Center for Clean Air Policy, 8/13/2009.
16. Ken Gillett, Director, City of Atlanta Office of Parks, 12/22/2009.
17. Luz Borrero, Deputy Chief Operating Officer, City of Atlanta, 10/21/2009.
18. Susan Rutherford, Department of Watershed Management, 8/31/2009.
19. Robert Reed, Southface, Sustainable Cities Institute, 1/29/2010.

20. Tamara Jones, Director of Program Development and Government Relations, Southface, 2/4/2010.
21. Melinda Langston, Director of Water Conservation, City of Atlanta Department of Watershed Management, 8/6/2009.
22. Kenna Laslavic, Urban Planner, City of Atlanta Bureau of Watershed Protection, 2/4/2010.
23. Valerie Thomas, Associate Professor, School of Industrial and Systems Engineering, Georgia Technical University, 7/24/2009.
24. Brian Hughes, Supervisory Hydrologist, United States Geological Survey, 2/11/2010.
25. Brian Stone, Associate Professor, City and Regional Planning Program, Georgia Technical University, 9/4/2009.
26. Dr. George Luber, Associate Director for Global Climate Change, National Center for Environmental Health, CDC, 8/7/2009.
27. Paul Shramm, National Center for Environmental Health CDC, 2/4/2010.
28. Shirley Franklin, (Former) Mayor, City of Atlanta, 8/13/2009.
29. Jean Pullen, City of Atlanta Energy Manager, 1/18/2010.
30. Marilyn Brown, Professor, School of Public Policy, Georgia Technical University, 7/24/2009.
31. Markell Heilbron, Georgia Power, 12/9/2009.
32. Steve Ewald, External Issues Principal, Georgia Power, 12/9/2009.
33. Paul Grether, MARTA, 2/12/2010.
34. Mike Alexander, Chief, Research Division, Atlanta Regional Commission, 7/29/2009.
35. Debra A. Williams, Corporate Service Section Commander, City of Atlanta Police Department, 1/26/2010.
36. Michelle Wynn, Public Works Manager, Office of Transportation, City of Atlanta Department of Public Works, 2/4/2010.

37. Evelyn Nu'man, Director, City of Atlanta Bureau of Housing, 2/3/2010.

38. Joe Basista,(Former) Commissioner, City of Atlanta Department of Public Works, 8/12/2009

## Appendix A: Vulnerability Assessment Part I: Sensitivity Analysis Summary Table

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Public Health | Heat Relief | Low capacity to avoid needing heat relief services; UHI effect increases the intensity ad frequency of very hot days; Atlanta's heat-related mortality trend does seem to be downward due to more air conditioning; growing elderly population will require more attention on these days | Temperature | Oppressive hot air masses are common in Atlanta | average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; heat island effect may amplify this increase | Rising temperatures will lead to a higher demand for heat relief services; rising energy bills | Negative | High |
| | Air Quality | Long history of non-compliance with ozone standards; young and elderly populations are disproportionately affected by bad air quality; growing regional population that will likely increase the number of vehicles | Temperature, season length, humidity, wind activity | Increased ambient temperatures are correlated with increased ground level ozone | average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; heat island effect may amplify this increase | Increased levels of ozone and therefore days that exceed NAAQS regulations; longer seasons will lengthen allergy seasons | Negative | High |
| | Outbreak Prevention | Common outbreaks in Southeastern cities include: mold infestations, pathogenic outbreaks, and Lyme disease; citizens are often responsible for protecting themselves from these outbreaks; government increase awareness when Lyme disease or pathogenic outbreaks occur | Humidity, precipitation events, floods, season length | Humidity, precipitation events and floods can lead to mold infestations; precipitation events and floods contribute to risk of waterborne disease outbreaks; longer summer seasons extend the growing season for mold and ticks | With an average of 120 days over 90F by 2080, summer season will be much longer; More frequent severe storm events and associated floods; more frequent and longer lasting droughts | Mold infestations will likely become more of a problem; Lyme disease and pathogenic outbreaks may be more likely | Negative | High |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Water Resources | Water Supply | Atlanta has enough water to supply current demand and is planning efficiency and conservation projects to ensure that the growing population will also have enough; a recent court ruling has put surrounding areas reliant on Lake Lanier in jeopardy of water shortages; drought conditions are well handled by the Department of Watershed Management | Temperature, drought | High temperatures increase demand for water, and also speed surface water evaporation; drought conditions lead to ever-decreasing amounts of available water | average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; More frequent severe storm events and associated floods more frequent and longer lasting droughts | Conservation practices and efficiency projects will become more important as droughts are more frequent; floods may fill reservoirs to higher levels | Negative | High |
| | Water Quality | Water quality of Atlanta's streams was low until the city signed a consent decree and followed through on water infrastructure improvements; several water quality monitoring projects are underway; increasing land development will place further stress on water quality | Temperature, precipitation events, floods, drought | Surface water quality is degraded during droughts; storms alter the hydrology of streams and add pollutants through runoff; high temperatures can also decrease quality | average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; More frequent severe storm events and associated floods more frequent and longer lasting droughts | Current water quality problems will be exacerbated | Negative | High |
| Energy | Electricity Production | Georgia Power (governed by the Georgia Public Service Commission) is the main power generator and distributor in the region, and because of high population growth, will have to increase generation capacity over the coming decades- the future energy mix will be dominated by coal, nuclear, and natural gas, with minor contributions from renewable sources. | Temperature | Demand for cooling energy is high in the summer and demand for heating energy is high in the winter; high temperatures can reduce the efficiency of production in thermal power plants | average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080 - heat island effect may amplify this increase; reduction in extreme cold temperatures | Demand for cooling energy will be higher in the summer, and will last longer throughout the year; demand for heating energy will lessen in the winter; thermal power plants will operate at lower efficiency due to high summer temperatures | Negative | High |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Energy | Electricity Demand | Demand has decreased during the recent economic recession, but is projected to resume its increasing trend around 2012; high energy bills can place a heavy burden on Atlantans; the city's population is projected to grow significantly, thereby increasing demand; few extensive energy efficiency programs in the area | Temperature | Demand for cooling energy rises 5-20% for every 1.8 of warming; winter demand for heating would decrease 3-15% | average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080 - heat island effect may amplify this increase; reduction in extreme cold temperatures | Increase in summer electricity use will not offset decrease in winter use; utility customers will be faced with increasing energy bills which may have a negative impact on the economy | Negative | High |
| | Energy Assurance | Georgia Power deals with a number of outages due to power line problems and unexpected high demand that leads to production by peak generators, or even brown-outs; the increasing population will make energy assurance even more important | Temperature, severe storms, droughts, length of growing season | Power lines are damaged by high winds, fallen trees, lightening strikes, etc.; thermal power plants must be halted if water temperatures exceed a threshold temperature | average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080 - heat island effect may amplify this increase; more frequent severe storm events; longer lasting droughts | Increased power outages and strain on cooling machinery; longer growing seasons that allow more plant growth near transmission lines; more back-up generators used for critical resources | Negative | High |
| Building Infrastructure | Stormwater Management | In the future, the city will have less permeable surface area due to land-use development; the Department of Watershed Management is in the midst of very costly water pipeline systems | Precipitation events, floods, drought | Heavy rains fall on the city's impermeable surfaces and flow directly into stormwater pipes and streams, overflowing pipelines and creating flood conditions; drought allows build-up of pollutants, which are carried en masse to water bodies during flashfloods | More frequent severe storm events and associated floods; longer lasting droughts | Stormwater challenges will be exacerbated, longer droughts will allow for a greater build-up of pollutants | Negative | Medium |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Building Infrastructure | Building Maintenance | Atlanta is well known for its historic buildings and prime real-estate; buildings are well-built, but are subject to substantial weather-related damage that can take years to fix | Temperature, severe storms | Buildings are subject to damage by severe storms, high temperatures can place great demands on building operating systems (like HVAC) | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent severe storm events and associated floods more frequent and longer lasting droughts | More intense storms may cause outer building damage and long periods of high temperatures are likely to decrease the lifetime of building operating systems | Slightly negative | Low |
| | Building and Energy Code | Atlanta has adopted state and national regulations for its building and energy codes, these have proven highly difficult to amend locally; buildings are large contributors to GHG emissions - a fact that technical associations plan to address in future years; the city currently struggles to enforce these codes | Temperature, floods | A building's ability to withstand high temperatures and flood conditions can determine its success; codes are designed to operate within the historical context of these climate conditions | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent severe storm events and associated floods | Building and energy codes will likely continue to change in coming years as a response to changing climate conditions; proper enforcement will become more important | Neutral | Medium |
| Ecology | Greenspace | The City manages thousands of acres of greenspace, although this amount is below other comparable US cities; funding streams are not strong, and often lead to under-management; there are recurring efforts to safeguard and improve the greenspace in Atlanta | Temperature, season length, severe storms, floods, drought | High temperatures can lead to greater use of greenspace; severe storms and flooding can damage the landscape as well as parks equipment; season length determines the amount of time that seasonal workers are employed | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent severe storm events and associated floods; longer lasting droughts | Species composition will likely shift and biodiversity may decrease; storm damage will draw on the Park's budget; longer summer seasons will lead to lengthier employment for seasonal staff, habits of citizen use will change | Negative | Medium |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Ecology | Urban Forest Management | Atlanta is known as the "city of trees", but the number of trees in the city seems to be quickly deteriorating; there is no baseline measure of the urban canopy; the Arborist Division is charged with maintaining the urban canopy, which it does on a very small budget; the Tree Trust Fund helps pay for the Arborist Division but is mainly used to fund tree plantings on public lands; Atlanta has a "no net loss" policy for trees and is currently looking for ways to strengthen this policy. | Temperature, air pollution, severe storms, floods, droughts | Heat can cause trees to transpire more and lose water and even drop their leaves; heat-induced ozone also decreases a tree's health; droughts and floods decrease tree resilience and stability in the ground | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent severe storm events and associated floods; longer lasting droughts | Some studies indicate that tree growth is improved by higher amounts of carbon dioxide, but this benefit is short-lived due to limiting nutrients; the proposed changes will likely decrease the resilience and ability of the urban forest to withstand climate stressors | Negative | High |
| | Pest and Invasive Species Management | Pest and invasive species management strategy is reactive and ineffective at the large scale | Temperature, precipitation | The Atlanta climate is condusive to invasive plants like Kudzu; long summer season and warm winters can create more optimal conditions for pest species | Average 4.5 – 9 ˚F warmer than today's averages; more frequent severe storm events and associated floods; longer lasting droughts | The changes will reduce the resilience of native species to impacts of pests and invasives; the longer growing seasons may benefit these species | Negative | High |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Transportation | Road and Bridge Maintenance | Atlanta's roads are congested and in constant need of repair; the Public Works operating budget does not cover annual road maintenance needs | Temperature, severe storms, floods | Flood events cause delays; road bases, rail beds, and bridge supports can be eroded and experience subsidence due to flood events; pavement integrity is compromised due to periods of high heat; construction projects are subject to severe storms, floods, and high temperatures | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent severe storm events and associated floods | Climate change will create more road and bridge problems, accelerate degradation, and hinder maintenance projects; warmer winter temperatures may result in a reduction of winter road damage, although this is unclear | Negative | Medium |
| | Public Transit | The city's public transit systems struggle with funding streams, yet a growing population provides more opportunities to increase ridership; MARTA is the main public transit provider - operating a rail and bus system; the BeltLine Project will increase the number of rail lines over the next decades | Temperature, icy conditions, severe storms, floods | Intense storm events and floods can lead to disruptions and route changes; heatwaves increase the instance of breakdowns and discomfort of riders; icy conditions also impede bus routes and rail lines | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; reduction in extreme cold events; more frequent severe storm events and associated floods | More breakdowns and re-routing are very possible; riders are likely to be exposed to uncomfortable situations; fewer ice-related disruptions possible | Negative | Medium |
| | Paratransit Service | MARTA is required to offer paratransit service; this is an expensive program, but a small portion of the total public transit system; MARTA's service uses 175 lift-equipped vehicles | Temperature, icy conditions, severe storms, floods | Icy conditions and severe storms can impact routes, extreme heat can place stress on vehicles and lead to shorter lifespans | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; reduction in extreme cold events; more frequent severe storm events and associated floods | There may be fewer climate-related disruptions in service during the winter; severe weather and disasters may cause fewer requests from service population | Negative | Low |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Transportation | Air Transport | The Atlanta Hartsfield-Jackson Airport saw 38 million passengers in 2007 and is one of the largest airports in the nation; delays are common and costly to airlines and passengers | Temperature, severe storms, icy conditions, climate conditions in other locations | Air travel is highly exposed to climate - local and destination conditions determine the smoothness of flights; hot air masses reduce lift; icy conditions are common causes of delay | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; reduction in extreme cold events; more frequent severe storm events | Hotter air masses reduce aircraft lift, which could result in payload restrictions, flight cancellations, and possibly the need to extend runway lengths; in addition, flights connecting to more vulnerable coastal airports would be more susceptible to weather-related delays; the inability to complete international cargo transfers could result in high fees to the airport ; warmer winters would reduce the need for de-icing and other run-way clearing machinery | Negative | Medium |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Safety | Fire Safety | Atlanta's Fire Department has dealt with recent budget cuts and common inefficiencies (like false alarms) with a high level of creative problem solving; the Department places a good deal of emphasis on community education to empower Atlantans | Temperature, drought, floods | Low temperatures often correspond to an increase in the number of indoor fires; in hot weather, the Department sends more backup during fire calls, and also increases the number of proactive "welfare calls"; fires during periods of drought often require a backup tanker of water; full response and specialized personnel are needed during flood events | Average 4.5 – 9 ˚F warmer than today's averages; reduction in extreme cold events; more frequent severe storm events and associated floods; longer lasting droughts | The Fire Department will need to continue to employ creative problem solving to counteract the negative impacts | Negative | Medium |
| | Police Services | The Police Department is the largest department in the city, and its year-to-year size is subject to political will and budget constraints; the department's budget is supplemented by several federal annual competitive grants | Temperature, severe storms, floods | Heat waves often correspond to spikes in crime; PD responds by sending out more officers on foot - which exposes those officers to high temperatures and air pollution; crime rates usually drop in winter periods; severe storms and floods decrease the safety of the work environment and also increase response times | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; More frequent severe storm events and associated floods | Violent crimes increase as temperatures rise - for Atlanta this could mean 70 additional murders and assaults per year by 2030; officers will be more exposed to high temperatures and will try to adapt; long summer seasons and warmer winters may result in dwindling periods of low crime associated with winter months; storms and floods will continue to pose hazards and impediments to officers | Negative | Medium |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Safety | Disaster Response | Weather-related disasters are not uncommon in Atlanta and are addressed through the collaborative work by emergency responders in the city, county, and surrounding jurisdictions; after each disaster these groups assess the strengths and weaknesses of the response to refine the plan for future emergencies; the costs of emergency response must first be paid by localities who may then be reimbursed by FEMA; planning is sometimes supplemented by disaster scenario planning and training, which is a very costly process | Temperature, severe storms, floods | Tornados, heat waves, severe storms, and floods can all present citizens with life-threatening situations; emergency responders and decision-makers must be ready on a moment's notice to navigate unique situations quickly and safely | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent severe storm events and associated floods | Increased storm events, floods and heat waves will create more opportunities for disaster situations to develop; if these events are more frequent, resources will be stretched and may reduce the ability of responders to solve problems quickly and safely | Negative | High |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Land Use and Development | Urban Planning | Developers are required to adhere to the city's flood plain restrictions; the Bureau of Planning produces a Comprehensive Development Plan every 5 years, which looks 15-20 ahead and considers economic development, transportation, and historic preservation areas; there are several examples of progressive planning in the city, including brownfield/greyfield redevelopment programs, zoning changes, and transit-oriented development projects; population is expected to increase drastically over the next decades, which will increase the demand for housing and places to work | Temperature, floods | Flood events have caused the city to adopt a floodplain ordinance which prohibits new development in the FEMA floodplain; high-rise buildings that are close together and expanses of heat-absorbing surfaces create UHI effect; developments that exacerbate negative climate conditions stand to be less successful | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent floods | The current effects of climate on urban planning will be exacerbated in that flooding will be worse and more frequent, and temperatures will result in hotter heat islands; the city will likely see an increase in demand for transit-oriented development, greenspace or street trees, and mixed use development | Negative | Medium |

| SECTOR | PLANNING AREA | CURRENT AND FUTURE CAPACITY AND STRESS LEVEL OF SYSTEM | KNOWN CLIMATE CONDITIONS RELEVANT TO THIS SYSTEM | HOW CLIMATE CURRENTLY AFFECTS THIS SYSTEM (SYSTEM EXPOSURE) | EXPECTED CLIMATE CHANGE | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | PROJECTED DIRECTION OF CHANGE IN STRESSES TO SYSTEMS (BAU) | SENSITIVITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|---|---|---|
| Land Use and Development | Affordable Housing | The Bureau of Housing offers federally funded assistance programs that promote community development and the creation and rehabilitation of affordable housing, although the full demand is never met; as population increases the demand for affordable housing will increase; the majority of the Bureau's work is with existing homes, which are inefficient, and sometimes in the floodplain; the Bureau adheres to city building and energy codes in an effort to ensure that operating costs are manageable | Temperature, floods | To be affordable, a house's operating costs must also be affordable - extreme temperatures make energy efficiency imperative, and resilience to flood events and storm damage is a necessity | Average 4.5 – 9 ˚F warmer than today's averages and average of 120 days over 90˚ by 2080; more frequent floods | Flood plains stand to change with increased development and more intense storms; extreme heat and longer summer seasons will place stress on home owners and renters that struggle to pay energy bills | Negative | High |
| Materials | Residential Waste Collection | The Office of Solid Waste appears to work well to collect the city's waste and recycling | Temperature, severe storms, floods | Extreme temperatures, storms, and floods can lead to temporary disruptions of service, although customers are generally understanding of this; high winds and stormwater runoff can cause unwanted transport of materials; flooding or erosion of landfills is a concern | Heat waves, more frequent severe storm events and associated floods | Collection disruptions may occur more frequently and create a greater risk of compromised landfills | Slightly negative | Medium |

## Appendix B: Vulnerability Assessment Part II: Adaptive Capacity Analysis Table

| SECTOR | PLANNING AREA | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | ABILITY OF SYSTEM TO ABSORB EXPECTED CHANGES | BARRIERS AND FACILITATORS TO IMPROVING RESILIENCY | ADAPTIVE CAPACITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|
| Health | Heat Relief | Rising temperatures will lead to a higher demand for heat relief services; rising energy bills | High temperatures lead to increased reliance on air conditioning, but growing energy bills may limit their use; trees could be planted and surfaces could be made more reflective; heat emergency warning systems, fan distribution programs, and cooling centers are common responses | The pervasiveness of air conditioning is definitely a benefit, however, a limiting factor to many of these responses is often cost; planting trees and increasing greenspace would decrease UHI, but the city departments that oversee these functions are also strapped for funding; vulnerable populations are especially hard to reach and unable to adapt | Medium |
| | Air Quality | Increased levels of ozone and therefore days that exceed NAAQS regulations; longer seasons will lengthen allergy seasons | The city and surrounding region has tried many programs to overcome bad air quality, but these have been largely unsuccessful as the city still is not in compliance; little is done to reduce the impact of airborne allergens like pollen | Past weather patterns informs pollution control policies, but future climate will be different - rendering this strategy ineffective; policies also focus on transportation and public transit may reduce traffic; land use controls might be effective, but the federal government cannot regulate land-use-leaving this up to localities; prohibitive medical costs and lack of public medical guidance is a barrier to resilience against respiratory allergies | Low |
| | Outbreak Prevention | Mold infestations will likely become more of a problem; Lyme disease and pathogenic outbreaks may be more likely | Minimal ability to absorb impacts without negative effects | Adaptation and outbreak prevention is possible through increased public education campaigns and revised building and site standards | Medium |
| Water Resources | Water Supply | Conservation practices and efficiency projects will become more important as droughts are more frequent; floods may fill reservoirs to higher levels | Atlanta has a highly managed water supply system and continues to improve the efficiency and conservation of water; population growth may make this more difficult | A future reservoir will increase water storage; the legal rights of Lake Lanier may complicate this control, but this would more likely impact areas surrounding the City | High |

| SECTOR | PLANNING AREA | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | ABILITY OF SYSTEM TO ABSORB EXPECTED CHANGES | BARRIERS AND FACILITATORS TO IMPROVING RESILIENCY | ADAPTIVE CAPACITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|
| Water Resources | Water Quality | Current water quality problems will be exacerbated | Ability to absorb decreased water quality will likely be reduced due to population growth and continued land use development | Water quality monitoring and improvements are often prohibitively costly and occur only with a legal mandate; the chemical and physical processes that control water quality are complex and not fully understood or accounted for by national regulations | Low |
| Energy | Electricity Production | Demand for cooling energy will be higher in the summer, and will last longer throughout the year; demand for heating energy will lessen in the winter; thermal power plants will operate at lower efficiency due to high summer temperatures | Georgia Power is already looking to expand generation capacity nto supply a growing regional population and uses weather forecasts to anticipate short-term changes in demand; renewable energy may play a growing role in production | Increasing generation capacity is a very costly and time consuming process; renewable energy production also faces national and local regulatory barriers, as well as cost challenges. | Low |
| | Electricity Demand | Increase in summer electricity use will not offset decrease in winter use; utility customers will be faced with increasing energy bills which may have a negative impact on the economy | Customers may simply opt to pay more for electricity bills or invest in energy efficiency retrofits, but this will not be an option for all; current weatherization and financial aid programs may prove essential | Main barriers are electricity or retrofit cost and limited capability and dissemination of demand-side technology | Medium |
| | Energy Assurance | Increased power outages and strain on cooling machinery; longer growing seasons that allow more plant growth near transmission lines; more back-up generators used for critical resources | Ability to absorb impacts will depend on how much Georgia Power increases its base load generation capacity, renewable energy, and transmission and demand technology dissemination | Building generation capacity and more resilient transmission infrastructure is expensive and time consuming; renewable energy production, technology capability and dissemination is limited due to costs and regulatory barriers | Low |

| SECTOR | PLANNING AREA | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | ABILITY OF SYSTEM TO ABSORB EXPECTED CHANGES | BARRIERS AND FACILITATORS TO IMPROVING RESILIENCY | ADAPTIVE CAPACITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|
| Building Infrastructure | Stormwater Management | Stormwater challenges will be exacerbated, longer droughts will allow for a greater build-up of pollutants | Flood plain ordinance will continue to protect many residents, but it is flawed, which means that many others will be not be appropriately protected; continued loss of permeable surface will further reduce the capacity to absorb flood impacts | Flood plain ordinance is based on FEMA maps, which are backward-looking and may not be accurate representations of flood patterns; high project costs and lack of a funding stream reduce probability that stormwater infrastructure will be improved | Low |
| | Building Maintenance | More intense storms may cause outer building damage and long periods of high temperatures are likely to decrease the lifetime of building operating systems | Fairly high, although exterior and interior building maintenance needs may arise more quickly than usual | High cost and tendency to wait until systems are in dire need of repair can reduce building resiliency to climate impacts | Low |
| | Building and Energy Code | Building and energy codes will likely continue to change in coming years as a response to changing climate conditions; proper enforcement will become more important | Low absorptive capacity due to lack of enforcement of current codes | Local code reform faces many obstacles, so that most changes are most likely to occur as a result of state or national changes | Low |
| Ecology | Greenspace | Species composition will likely shift and biodiversity may decrease; storm damage will draw on the Park's budget; longer summer seasons will lead to lengthier employment for seasonal staff, habits of citizen use will change | Atlanta's greenspace management is overseen and monitored by numerous task forces; if climate changes occur slowly, greenspace ecosystems and municipal operations may be able to absorb changes | Lack of funding to maintain current space properly; dwindling opportunities for increased greenspace acreage; lack of monetary value of benefits provided by greenspace | Medium |
| | Urban Forest Management | Some studies indicate that tree growth is improved by higher amounts of carbon dioxide, but this benefit is short-lived due to limiting nutrients; the proposed changes will likely decrease the resilience and ability of the urban forest to withstand climate stressors | A number of municipal and civil actors will provide some insurance that Atlanta's urban forest is maintained, although there is a lack of data to measure this | Lack of funding to ensure that Tree Ordinance is implemented completely; Ordinance is short-sighted and may be too narrow to accomplish its objectives; lack of monetary value of benefits provided by urban trees | Medium |

| SECTOR | PLANNING AREA | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | ABILITY OF SYSTEM TO ABSORB EXPECTED CHANGES | BARRIERS AND FACILITATORS TO IMPROVING RESILIENCY | ADAPTIVE CAPACITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|
| Ecology | Pest and Invasive Species Management | The changes will reduce the resilience of native species to impacts of pests and invasives; the longer growing seasons may benefit these species | Low absorptive capacity due to a reactive management approach | Lack of funding and knowledge to create and implement the most efficient and effective pest and invasive species control programs | Low |
| Transportation | Road and Bridge Maintenance | Climate change will create more road and bridge problems, accelerate degradation, and hinder maintenance projects; warmer winter temperatures may result in a reduction of winter road damage, although this is unclear | Road and bridge materials are made to withstand the elements, although they will become weathered and weakened faster | Lack of funding to maintain current roads and bridge infrastructure; lack of understanding of designs might need to be modified to allow for future climate conditions | Low |
| | Public Transit | More breakdowns and re-routing are very possible; riders are likely to be exposed to uncomfortable situations; fewer ice-related disruptions possible | Moderate absorptive capacity - rail system can withstand and operate during most harsh weather conditions, and bus routes are flexible; however, both will be subject to faster weathering | Planning time horizons are not in line with the lifetime of transit infrastructure; climate change is not considered in transportation planning documents; lack of funding to maintain or upscale services or maintenance | Medium |
| | Paratransit Service | There may be fewer climate-related disruptions in service during the winter; severe weather and disasters may cause fewer requests from service population | Similar to bus service - flexible routes will allow the service to work around impacts; vehicles and equipment will likely weather faster | High cost of program (and MARTA's lack of funding) may make future expansion difficult, but the program is mandatory so that ensures that it will be maintained | Medium |

| SECTOR | PLANNING AREA | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | ABILITY OF SYSTEM TO ABSORB EXPECTED CHANGES | BARRIERS AND FACILITATORS TO IMPROVING RESILIENCY | ADAPTIVE CAPACITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|
| Transportation | Air Transport Services | Hotter air masses reduce aircraft lift, which could result in payload restrictions, flight cancellations, and possibly the need to extend runway lengths; Conversely, warmer winters would reduce the need for de-icing and other run-way clearing machinery; in addition, flights connecting to more vulnerable coastal airports would be more susceptible to weather-related delays; the inability to complete international cargo transfers could result in high fees to the airport | Minimal ability to absorb impacts without negative effects | Interdependence on other airports will increase the vulnerability and reduce opportunities for one airport to adapt and avoid all negative impacts; safety standards provide an additional constraint in adaptive planning | Low |
| Safety | Fire Safety Services | The Fire Department will need to continue to employ creative problem solving to counteract the negative impacts | Moderate - currently absorbing climate impacts well | Creative problem solving skills and community education practices will facilitate adaptation; cost constraints will continue to limit resiliency | High |
| | Police Services | Studies show that murders and assaults increase as temperatures rise - for Atlanta this could mean 70 additional murders and assaults per year by 2030; officers will be more exposed to high temperatures and will try to adapt; long summer seasons and warmer winters may result in dwindling periods of low crime that are often associated with winter months; increased frequency and intensity of storms and floods will continue to pose hazards and impediments to officers | Moderate - the force is able to step up operations when needed, but for a cost; crime rates will increase and the force will need to be scaled up to maintain the service level | Budget constraints continue to limit the capacity of Atlanta's police force; fluctuating political will also affects the force size | Low |

| SECTOR | PLANNING AREA | PROJECTED IMPACT OF CLIMATE CHANGES TO SYSTEM (BAU) | ABILITY OF SYSTEM TO ABSORB EXPECTED CHANGES | BARRIERS AND FACILITATORS TO IMPROVING RESILIENCY | ADAPTIVE CAPACITY LEVEL (HIGH, MEDIUM, LOW) |
|---|---|---|---|---|---|
| Safety | Disaster Response | Increased storm events, floods and heat waves will create more opportunities for disaster situations to develop; if these events are more frequent, resources will be stretched and may reduce the ability of responders to solve problems quickly and safely | Low ability to absorb impacts - damage is usually very costly | Lack of funding for planning and training exercises and lack of understanding of potential climate change impacts are barriers; high coordination between governments and post-disaster assessments will continue to facilitate adaptation | Low |
| Land Use and Development | Urban Planning | The current effects of climate on urban planning will be exacerbated in that flooding will be worse and more frequent, and temperatures will result in hotter heat islands; the city will likely see an increase in demand for transit-oriented development, greenspace or street trees, and mixed use development | Low ability to absorb impacts - will likely be influenced by market forces and public demand | Inertia among many developers will necessitate government regulations, which are at times difficult to craft and pass; an additional barrier is a lack of understanding and consideration of the impact of climate dynamics on development success | Medium |
| | Affordable Housing | Flood plains stand to change with increased development and more intense storms; extreme heat and longer summer seasons will place stress on home owners and renters that struggle to pay energy bills | Low to moderate - efficiency can be improved but site qualities (proximity to transportation or flood plains) are much less changeable | Lack of funding and reliance on federal grants are barriers; another barrier is that most homes are already built and will not reach the efficiency levels of newly constructed homes; a facilitator is the city's requirements that all renovations meet current building and energy codes (but these could be stronger); growing utility bills may make even moderate income housing less affordable | Low |
| Materials | Waste Collection | Collection disruptions may occur more frequently and create a greater risk of compromised landfills | High - the planning area already works around common disruptions caused by weather | Customers that accept flexible services facilitate the resiliency of this planning area | High |

## Appendix C: Vulnerability Assessment Summary Table

| SECTOR | PLANNING AREA | SENSITIVITY SCORE | ADAPTIVE CAPACITY SCORE | VULNERABILITY LEVEL |
|---|---|---|---|---|
| Public Health | Heat Relief | High | Medium | High (4) |
| | Air Quality | High | Low | High (5) |
| | Outbreak Prevention | High | High | Medium (3) |
| Water Resources | Water Supply | High | High | Medium (3) |
| | Water Quality | High | Low | High (5) |
| Energy | Energy Production | High | Low | High (5) |
| | Electricity Demand | High | Medium | High (4) |
| | Energy Assurance | High | Low | High (5) |
| Building Infrastructure | Stormwater Management | Medium | Low | High (4) |
| | Building Maintenance | Low | Low | Medium (3) |
| | Building and Energy Code | Medium | Low | High (4) |
| Ecology | Greenspace | Medium | Medium | Medium (3) |
| | Urban Forest Management | High | Medium | High (4) |
| | Pest and Invasive Species Management | High | Low | High (5) |
| Transportation | Road and Bridge Maintenance | Medium | Low | High (4) |
| | Public Transit | Medium | Medium | Medium (3) |
| | Paratransit Service | Low | Medium | Low (2) |
| | Air Transport | Medium | Low | High (4) |
| Safety | Fire Safety | Medium | High | Low (2) |
| | Police Services | Medium | Low | High (4) |
| | Disaster Response | High | Low | High (4) |
| Land Use and Development | Urban Planning | Medium | Medium | Medium (3) |
| | Affordable Housing | High | Low | High (5) |
| Materials | Waste Collection | Medium | High | Low (2) |

| | SENSITIVITY = HIGH | SENSITIVITY = MEDIUM | SENSITIVITY = LOW |
|---|---|---|---|
| ADAPTIVE CAPACITY = LOW | 5 Points | 4Points | 3 Points |
| ADAPTIVE CAPACITY = MEDIUM | 4Points | 3 Points | 2 Points |
| ADAPTIVE CAPACITY = HIGH | 3 Points | 2 Points | 1 point |

## Appendix D: Risk Assessment Summary Table

| SECTOR | PLANNING AREA | CITIZENS AFFECTED | LIFE-THREATENING | COSTS | PROBABILITY OF IMPACT | ESTIMATED RISK LEVEL |
|---|---|---|---|---|---|---|
| Public Health | Heat Relief | Half (2) | Yes (3) | Medium (2) | Very Likely (3) | High (10) |
| | Air Quality | All (3) | Yes (3) | High (3) | Very Likely (3) | High (12) |
| | Outbreak Prevention | Few (1) | Uncertain (2) | Medium (2) | Very Likely (3) | Medium (8) |
| Water Resources | Water Supply | All (3) | No (1) | High (3) | Very Likely (3) | High (10) |
| | Water Quality | All (3) | Uncertain (2) | High (3) | Very Likely (3) | High (11) |
| Energy | Electricity Production | All (3) | No (1) | High (3) | Very Likely (3) | High (10) |
| | Electricity Demand | All (3) | No (1) | High (3) | Very Likely (3) | High (10) |
| | Energy Assurance | Half (2) | Yes (3) | High (3) | Very Likely (3) | High (11) |
| Building Infrastructure | Stormwater Management | Half (2) | Uncertain (2) | High (3) | Very Likely (3) | High (10) |
| | Building Maintenance | Few (1) | No (1) | Medium (2) | Very Likely (3) | Medium (7) |
| | Building and Energy Code | All (3) | No (1) | Medium (2) | Likely (2) | Medium (8) |
| Ecology | Greenspace | Half (2) | No (1) | Medium (2) | Very Likely (3) | Medium (8) |
| | Urban Forest Management | All (3) | Uncertain (2) | Medium (2) | Very Likely (3) | High (10) |
| | Pest and Invasive Species Management | Half (2) | Uncertain (2) | Medium (2) | Likely (2) | Medium (8) |
| Transportation | Road and Bridge Maintenance | All (3) | Uncertain (2) | Medium (2) | Very Likely (3) | High (10) |
| | Public Transit | Half (2) | No (1) | High (3) | Very Likely (3) | Medium (9) |
| | Paratransit Service | Few (1) | Uncertain (2) | Low (1) | Very Likely (3) | Medium (7) |
| | Air Transport Services | All (3) | Uncertain (2) | High (3) | Very Likely (3) | High (11) |
| Safety | Fire Safety Services | Few (1) | Yes (3) | Low (1) | Very Likely (3) | Medium (8) |
| | Police Services | Few (1) | Yes (3) | Medium (2) | Very Likely (3) | Medium (9) |
| | Disaster Response | Half (2) | Yes (3) | High (3) | Very Likely (3) | High (11) |
| Land Use and Development | Urban Planning | Half (2) | No (1) | Low (1) | Very Likely (3) | Medium (7) |
| | Affordable Housing | Half (2) | Uncertain (2) | High (3) | Very Likely (3) | High (10) |
| Materials | Residential Waste Collection | Few (1) | No (1) | Low (1) | Very Likely (3) | Low (6) |