

Climate Resilience in Carlisle and Cumberland County: Infrastructure, Utilities, and Services

By Christian Polk
Dickinson College

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1. INTRODUCTION

Cumberland County, one of the largest counties in the Harrisburg metropolitan area, is home to a bustling transportation hub as well as extensive agricultural development. The intersection of the Pennsylvania Turnpike (I-76) and Interstate 81 (I-81) has increased commercial development drastically, oftentimes replacing agricultural land and permeable surfaces. As climate change continues to worsen the severity and increase the frequency of storm events, as well as increasing the frequency of extreme heat events, sustainable development remains a critical role in building climate resilience. Cumberland County exhibits large potential for building climate resilience through building upon existing renewable energy infrastructure as well as implementing stormwater management practices that aim at reducing runoff into surface waters.

While stormwater and electrical infrastructure are some of the most crucial planning areas in building climate resilience in the county, this section of the assessment will also discuss how public water supplies, structural integrity of buildings, transportation infrastructure, and telecommunications are affected by climate risks and how resilience can be built within each of them. Climate risks as well as non-climate related risks are discussed in coordination with the resulting vulnerabilities across these planning areas. Strengths and weaknesses are also assessed in each of these planning areas and how each can be monitored through a series of resilience indicators and metrics.

Building climate resilience in the county and Carlisle in addition to mitigating fossil fuel emissions can be achieved and developed together to build a sustainable future. The Cumberland County Climate Action Plan as well as the Carlisle Climate Action Plan focus primarily on mitigation efforts to climate change and do not go into detail about resilience strategies. It is an unfortunate reality that climate change has progressed to the point where risks are inevitable, further emphasizing the importance of building resilience in the county. Climate resilience must be included in public discourse and policy making, as mitigation cannot prevent climate hazards that are already present and will worsen in the near future.

2. STORMWATER INFRASTRUCTURE

Increased frequency and severity of flash floods and nuisance flood events is one of the primary hazards associated with climate change in Cumberland County. For decades the bordering Susquehanna River and its two large tributaries, the Conodoguinet and Yellow Breeches, have been responsible for countless flooding events in the county (Cumberland County Hazard Mitigation Plan 2020). One of the primary factors that contributes to the increased severity of flooding events and resulting vulnerabilities in addition to climate change is the decrease of permeable surfaces associated with increased development in residential, commercial, and industrial sectors. Housings and commercial developments, as well as major highways are a few examples of developments that are currently being built on a large scale in the county that exhibit high rates of impervious surface construction. Removing native vegetation and agricultural land present in the valley and replacing them with impervious surfaces drastically reduces stormwater infiltration rates and forces rainfall to run off into nearby surface waters. Aside from increased quantities of stormwater entering streams, the quality also decreases as more runoff can pick up and carry increased concentrations of pollutants from roadways, residential lawns, agricultural fields, and industrial sites.

Erosion and damage to road infrastructure is also a crucial factor to consider when discussing the vulnerabilities of stormwater infrastructure in relation to climate hazards. Increased quantities and decreased quality of stormwater runoff have the potential to create adverse effects on aquatic ecosystems that are presently of serious concern in Cumberland County (A. Moyer 2023). Fortunately, stormwater management systems are required to be put into effect by each municipality in Pennsylvania, but as climate change continues to worsen extreme weather events, these systems will become over-stressed and ineffective (Cumberland County Stormwater Management Plan 2010).

People that reside within the floodplains of the Susquehanna, Conodoguinet, and Yellow Breeches, as well as infrastructure, are more susceptible to damage from river flooding. Flash floods in areas outside of a floodplain can contribute to river floods through the addition of large quantities of water in a short period upstream but are not always intertwined. Areas with poor drainage and/or are heavily characterized by impervious surfaces in these floodplains are at high risk of flood damage. While the most effective resilience strategy to mitigate risks from flooding in river floodplains is to limit or completely eliminate construction within these areas, this may not always be feasible. On a national scale only 7% of the country's total land area is floodplains but between 8-10 million homes are located within them, emphasizing the abundant need to plan for resiliency in these areas of risk (FEMA, 2005).

Encouraging the purchase of flood insurance for residents and businesses that own property within a floodplain is a strong first step towards building more climate resilient infrastructure in Cumberland County and Carlisle. According to National Flood Insurance Program which falls under the responsibility of the Federal Emergency Management Agency (FEMA), communities that agree to regulate development in floodplains which receive flood insurance through FEMA for properties within the floodplain (2005).

In addition to flood insurance, other federal and state-mandated programs exist that aim at limiting flood and stormwater risks. In accordance with the state-mandated Municipal Separate Storm Sewer System program (MS4), municipalities are required to obtain a National Pollutant Discharge Elimination System permit (NPDES) in order to reduce their overall polluted runoff into surface waters within the county (Municipal Stormwater, DEP). While this program and required permit offer a solid foundation for implementing solutions to limit

environmental harms associated with polluted runoff, the federal and state governments do not provide any funding for the program (A. Moyer 2023). Therefore, municipalities in Cumberland County implemented a stormwater fee which is charged to landowners in which the amount is based on the total impervious surface area on their land. State-regulated programs like MS4 provide support to each of the municipalities within Cumberland County but with the impending hazards brought on by climate change, other solutions may be needed such as green infrastructure initiatives.

Infrastructure built with the goal of reducing stormwater runoff and increasing infiltration into surrounding soils is often referred to as green infrastructure. Different types of green infrastructure are present in Cumberland County such as bioretention facilities adjacent to major intersections and highways, as well as near large parking lots and roads. The goal of these developments is to capture stormwater runoff from these impervious surfaces to either retain and allow for groundwater infiltration, slow down runoff before it enters surface water sources, or both. Green infrastructure is essential in building resilience towards climate change as precipitation and extreme weather events are likely to increase in the coming decades. In Cumberland County 21.9% of land is considered urban, a substantial proportion of the county's total land use (A Profile of Land Use, 2023). Increasing development in the county in commercial and residential sectors will increase this number drastically as warehouses and housing developments continue to be built and lower percentages of forested and crop land use.

The climate risks discussed above in relation to stormwater management in Cumberland County are also present in Carlisle where similar vulnerabilities exist. Nuisance floods are a common sight in the borough when rain events occur and are largely due to poor stormwater infrastructure. One of the most significant weaknesses in the stormwater system in Carlisle is the age of pipes and water mains that intake stormwater runoff. Some of these pipes are over 100 years old and the borough currently aims at replacing 1.5 to 2 miles of piping per year (B. Landis, 2023). Carlisle has over 28 miles of underground pipes that are included in the borough's MS4 program, many of which are not able to handle projected increases in stormwater runoff (MS4 & Stormwater Management, n.d.).

3. WATER

The issues introduced by climate change that affect flooding and stormwater runoff are closely intertwined with public drinking water supplies. As mentioned previously, the increase in impervious surface area associated with development in the county has led to an increased concentration of pollutants in surface water sources. As a result, water treatment plants must expend more energy purifying intake water for public supply. In addition to other constraints on the electrical grid, increased energy demand for water treatment plants will further constrain renewable energy sources and will result in more fossil fuels being used. The primary concern for Cumberland County regarding public water supply is the increased quantity of pollutants that will enter surface waters as a result of increased severity and frequency of storm events. Water treatment plant productivity can be affected by heavy rain events that carry high quantities of pollutants into surface waters, creating water conservation orders and limiting public water supplies (Amwater.com, 2023). Recently on November 24th 2023, a water conservation order was issued for the Mechanicsburg water system by Pennsylvania American Water due to heavy rainfall that struck the area days prior. The order was given out of caution, as heavy rains can carry increased quantities of pollutants into public drinking water supplies, especially in areas of high development and/or impervious surface areas (Amwater.com, 2023). These heavy

rainfall events, which will continue to increase due to climate change, will create additional stress on public drinking water supplies and the infrastructure needed to provide it.

Other climate risks that create strain on public water supplies include the increasing number of extreme heat events and days over 90° F as well as greater average temperatures which have risen by 1.8°F in Cumberland County in the past century (Cumberland County Hazard Mitigation Plan, 2020).

One of Cumberland County's largest economic sectors is agriculture located primarily in the central and western parts of the county. Issues surrounding excessive nutrient runoff from agricultural fields has long been an issue in the county as it relates to public drinking supplies. Of the pollutants that come from agricultural runoff, nitrates are of significant concern especially to infants. Nitrates in drinking water above 10 mg/L may seriously affect an infant's ability to carry oxygen in its blood (Carlisle Drinking Water Quality Report 2022). While sampling work in 2022 has found nitrate levels to be below the limit set by the EPA (10 mg/L), concentrations may increase due to increase erosion as a result of more frequent storm events. Most of Cumberland County's nutrient pollution comes from agricultural land (63%), with the remaining coming from developed/urban areas (17%) and wastewater (10%) (Cumberland County Clean Water Technical Toolbox, 2020). Management practices for nutrient and manure exist within the county and operate under the Nutrient Management Act that aims at limiting pollutants like nitrates and phosphorous from entering surface water and groundwater supplies (Nutrient management program, n.d.).

Aside from surface waters, groundwater contamination remains a critically important issue regarding public drinking water supply and how septic systems in rural areas, are being impacted by more extreme and frequent weather events. During flooding events, septic systems can become infiltrated by floodwaters and overflow, leaching contaminants into surface water and groundwater supplies. Those in rural areas also heavily rely on well water, which can become contaminated from septic system leaks (EPA, n.d.). Flooding in rural areas can have adverse effects on aquatic ecosystems as well as residents by limiting access to drinking water from wells after severe flooding events, and increasing concentrations of pollutants from agricultural and septic system runoff into surface waters.

Continuing to fund and implement management practices for the previously mentioned pollutants will build resilience amongst public drinking water infrastructure. Lower concentrations of pollutants in surface and groundwater supplies is a primary indicator of resilience in this planning area, and should be a focus of Cumberland County and Carlisle to reduce.

4. ENERGY

Climate change has and will continue to put constraints on the electrical grid through the increased demand for cooling/AC services. In the summer months, high energy demand for these services can result in power outages due to overloading (Green Up the Footprint 2022). Currently Cumberland County is focused on mitigating the effects of climate change through decreasing fossil fuel usage and increasing renewable energy sources. Renewables in the county currently do not provide enough energy to meet demands which can result in an increased reliance on fossil fuels. Other climate stressors including more frequent and intense storm events also pose high risks to energy infrastructure, as prolonged outages can seriously threaten the welfare of people and businesses all over the county. Building climate resilience in energy infrastructure in addition to mitigating climate change through reductions in fossil fuel usage, should be developed in tandem in Cumberland County and Carlisle.

Energy infrastructure will become more at risk of damage in the near future from severe storm events as climate risks worsen in severity and increase in frequency. Minor outages occur several times a year, while major outages that span over multiple days occur usually every few years, which is likely to increase due to the previously mentioned climate risks (Cumberland County Hazard Mitigation Plan 2020). Outages are usually part of a series of cascading effects from a severe storm or other weather-related events. These utilities interruptions have the potential to considerably impact people and businesses all over the county, especially when outages occur during heat-waves or other climate-related events that create cascading effects across multiple planning areas. In 2021, the Pennsylvania Public Utility Commission (PUC) recorded the highest number of reportable outage events (ROEs) at 63 in total among electrical distribution companies (EDCs) since measurement began 29 years ago in 1992 (Public Utility Commission, 2021). While the data provided in this report does not focus specifically on Cumberland County or Carlisle, it is very useful in indicating that outages are becoming more frequent throughout the state due to more frequent extreme weather events.

There are several types of energy infrastructure in Cumberland County and Carlisle that are vulnerable to climate risks now and in the future. For example, power lines are at considerable risk, as some power companies, as of 2014, are not required to preventatively trim trees and only take action once the lines have been damaged. (Ron Hamilton, Cumberland County Hazard Mitigation Plan 2023). Currently, Pennsylvania Power and Light (PPL) as well as UGI Utilities Incorporated are the main electrical providers for Cumberland County (Utility programs, n.d.) Both power companies reported in 2021 that the primary cause of outages were trees/vegetation damaging transmission lines, likely due to weather-related events (Public Utility Commission, 2021). While both power companies have vegetation management plans in place, damage to transmission lines from vegetation is inevitable and at times not preventable during extreme weather events.

In addition to vegetation management, these power companies that service Cumberland County have several other management plans in place to limit the number of outages per year. Of these plans includes replacing infrastructure that is susceptible to failure (porcelain insulators, cut outs) as well as underground cable and wood pole replacements (Public Utility Commission, 2021). Both companies as of 2021 have continued to invest in the implementation of Fault Isolation and System Restoration technologies that aim at isolating faulted line sections and restoring undamaged areas to limit the impact of outages on customers (Public Utility Commission, 2021). These management plans are helping to build more resilient energy infrastructure that will require continued attention as climate stressors worsen and add additional stress to these infrastructure systems. Additionally, these management plans and their desired results can be useful indicators in determining whether energy infrastructure is becoming more climate resilient or not.

Another type of energy infrastructure that is of concern in Cumberland County is natural gas pipelines. Severe flooding and storm events have the potential to create adverse effects on pipelines that may lead to leaks and/or explosions (NPR, 2019). Landslides that may form because of heavy rain are a cascading effect of severe weather events that pose high risk to pipelines and pipeline construction. Pennsylvania's Pipeline and Hazardous Materials Safety Administration (PHMSA) currently sends advisory statements to pipeline construction companies about the dangers of building in flood-prone areas or areas that are susceptible to earth-movement/landslides, while the Pennsylvania Public Utility Commission is responsible for regulation and safety (NPR, 2019). The Mariner East II and Mariner East 2X pipelines are the largest natural gas pipelines that run through Cumberland County as they stretch across the state of Pennsylvania (Marrioni, 2018).

This critical type of energy infrastructure can become more resilient through following precautionary measures to not build in the previously mentioned hazardous areas. Completely eliminating construction from these hazardous areas may not be feasible, emphasizing the need for a higher degree of maintenance and analysis of surrounding soils before and after construction of pipelines. This resilience strategy is very important in

Cumberland County as most of the surrounding geology is characterized as karst geological formations prone to sink holes/landslides.

5. TRANSPORTATION

As Cumberland County's trucking and warehouse industries continue to expand, roads and highways remain some of the most crucial infrastructure within the county. As previously mentioned, one of the most significant impacts that have been and will continue to be brought on by climate change are increased frequencies and severities of storm events. These extreme weather events can significantly impact and damage roadways, highways, and bridges, which have serious consequences for civilian and commercial traffic. According to the Pennsylvania Department of Transportation's (PennDOT) Extreme Weather Vulnerability study, roadway infrastructure weather-related damages usually occur from tropical storm events as well as other extreme weather events, in addition to improper drainage systems (2017).

Severe flash and river floods have become more frequent in the county in the past ten years because of climate change along with significant increases in impervious surfaces driven in part by commercial warehouse and residential development (Cumberland County Hazard Mitigation Plan 2020). Other climate stressors that are and will continue to impact transportation infrastructure include the increased frequency and severity of heat events. Extreme heat can degrade the durability of roadway construction materials resulting in high maintenance costs and shorter life cycles (PennDOT, 2017). With each of these climate stressors, the rapidly growing logistics industries can significantly impact transportation infrastructure.

Overall, Pennsylvania's infrastructure, particularly bridges, are at high risk to climate stressors in part due to the forecasted increases in stormwater volumes and number of heat events, but also due to the structural integrity of a large fraction of the total bridges in the state. According to 2022 Report Card for Pennsylvania's Infrastructure, bridges received a grade of D+ (poor: at risk; 13.8% of total bridges) and roads received a grade of C- (mediocre: requires attention; roughly 7.7% of total mileage classified as 'poor roughness'). A lack of structural integrity creates additional stress to roads and bridges on top of the climate stressors. In Cumberland County specifically, some bridges are at risk due to the age of their structures and their inability to withstand projected stormwater runoff volumes (C. Decker, 2023). Bridges that are already in poor condition may become critically damaged from extreme weather events, posing risks to people throughout the county. The combination of these climate and non-climate related stressors has drastically increased risk of damage and failure to transportation infrastructure, measured primarily through the total dollar value required to fix and manage such damage. In 2020 and 2021, \$120 million dollars were used for emergency repairs to bridges and roads, four times over the budgeted amount (PennDOT 2017).

A primary indicator of more climate resilient transportation infrastructure is the total dollar amount spent on emergency repairs to roads, highways, and bridges, on an annual basis. As previously mentioned in 2021 and 2022, PennDOT spent four-times over their budgeted amount of emergency repairs, which emphasizes the abundant need to replace failing infrastructure and properly maintain it with the present climate stressors. As transportation infrastructure has and will continue to take the brunt of impacts from climate change, it is vital that climate resilient planning is used through a variety of methods to ensure long-term stability for these types of infrastructure.

First and foremost, reducing incentives to developers to build in areas of land prone to climate risks, which in the case of Cumberland County and Carlisle are primarily floodplains, is a necessary first step to building

climate resilience. Policymakers in this planning area have a large potential to create significantly more resilient transportation infrastructure through implementing policies that minimize construction in these high-risk areas (McKinsey Global Institute, 2020). Increased funding will also drastically increase resilience, although it can be limited at the borough and county level. For Carlisle specifically, it may be difficult to implement large scale resilience initiatives for transportation infrastructure without outside funding from the state and/or federal government. While there are many state routes that run through Carlisle and are serviced by PennDOT, the remainder fall under the responsibility of Carlisle to maintain and implement resilient measures (B. Landis, 2023).

6. BUILDINGS

Similar to transportation infrastructure, older buildings within Cumberland County and Carlisle are at higher risk to climate stressors as their structural integrity may be insufficient to handle projected stormwater volume increases and heat wave events. As previously mentioned, infrastructure that is constructed in floodplains is at high risk of damage from river flooding, especially buildings and residential structures. Carlisle in particular has very old infrastructure that is continually being replaced, but still poses risks to residents and businesses as these buildings may become severely damaged from flood events.

Aside from flood risks, extreme heat events are another climate stressor that will continue to significantly impact buildings not designed to withstand extreme heat over prolonged periods. Improperly insulated buildings may lead to drastic increases in demand for AC/cooling services during these extreme heat events, adding additional stress to the electrical grid.

To build resilience amongst residential, commercial, and industrial buildings, a crucial first step is to analyze flood risks and whether or not buildings are located within flood plains. While building in floodplains is not optimal, it is inevitable in some situations in which management practices must step in to mitigate flood risks to buildings in the event they happen. Waterproofing buildings, especially those prone to flood and water damage, is a must when constructing in floodplains and other flood-prone areas (A. Iraldi, 2023). A primary indicator of building resilience in buildings is reduction in the total dollar amount of repairs required due to weather events.

7. EMERGENCY SHELTERS

As with many of the planning areas mentioned previously, emergency shelters are managed directly and are solely responsible for by municipal governments. In relation to climate hazards currently affecting Cumberland County, cooling shelters and extreme storm shelters are needed throughout the county to protect those most vulnerable to these hazards. Emergency shelters are coordinated with the Cumberland County Emergency Operations Center and the Cumberland County Department of Public Safety who work closely with the American Red Cross to identify potential sites for shelter (M. Parsons, 2023). Those without access to air conditioning in the summer months are some of the most vulnerable people in the county as average temperatures continue to rise as well as the increases in the frequency of extreme heat events. Similarly, those without ample housing may be vulnerable to extreme storm events that require temporary housing in a

shelter. During power outages, emergency shelters are particularly important for vulnerable elderly populations as well as medical facilities and senior homes.

One of the main weaknesses currently facing this planning area is the lack of regulation and/or policy in the designation and maintenance of emergency shelters. As with the nature of Pennsylvania being a commonwealth, municipalities often face the brunt of responsibility for many of the planning areas previously discussed. Some municipalities throughout Cumberland County have identified emergency shelters within their respective borders, but not all municipalities have a designated shelter ready in case of emergency (Cumberland County Hazard Mitigation Plan, 2020).

Policy and action at the state level to introduce mandates for emergency shelters will drastically increase climate resilience in this planning area. While the Cumberland County Department of Public Safety works with the American Red Cross to establish emergency shelters in the event they are needed. State or even federal mandates/policies would effectively ensure that shelters are available across the county to all people.

8. COMMUNICATIONS

Telecommunications infrastructure that allows for emergency calls, phone calls, and radio communications is and will become more at risk of climate hazards, particularly severe storm events. Similar to risks to energy infrastructure, telecommunications transmission lines and towers are susceptible to vegetation damage (i.e. trees falling) as well as damage from high wind speeds. As mentioned in many of the previous planning areas, risks to telecommunications infrastructure usually result from a series of cascading effects, usually beginning with a severe weather event. Severe storms have become a primary climate stressor for Cumberland County, affecting multiple planning areas and creating cascading effects that have and will continue to impact telecommunications systems.

A primary vulnerability associated with telecommunications infrastructure is in the event of transmission interference or physical infrastructure damage, emergency warning systems may not be able to reach their intended audiences (McKinsey Global Institute, 2020) Communication outage events have the potential to delay emergency and disaster response, which in worst-case scenarios may result in fatalities. While scenario such as this are very rare in Cumberland County and Carlisle, it is worth noting and planning for potential communications infrastructure failures and interruptions, and how municipalities within the county will respond during these situations.

Several resilience strategies can be implemented in the telecommunications planning area to better prepare for severe storm events and resulting cascading effects. First and foremost, reducing incentives to build communications infrastructure in areas of high risk to damage (i.e. densely vegetated areas with little maintenance; high wind speeds without proper structural support)(McKinsey Global Institute, 2020). This planning area relates closely to energy infrastructure regarding preventative measures to avoid outages and communication interference. In today's world, telecommunications have the advantage of transmitting calls through mobile devices that do not require constant power input. However, if infrastructure systems that allow for mobile transmissions fail, serious problems could arise in scenarios with cascading effects and where warning systems are attempting to reach populations.

9. CONCLUSIONS

This section of the climate resilience assessment aims at assessing climate risks to infrastructure systems across Cumberland County and Carlisle, and strategies for mitigating those risks and building resilience towards them. Infrastructure in the county is a crucial part of every resident's and business's daily life and essential needs, in which risks to these various planning areas must be addressed and discussed as climate stressors will continually affect them.

Throughout this section of the assessment, it is apparent that severe storm events and extreme heat events are the primary climate hazards associated with Cumberland County and Carlisle that have capacities to create cascading effects amongst multiple planning areas. Of particular concern are stormwater management systems and structures that reside within floodplains. With the drastic increase in development and subsequent increase in impervious surface area in Cumberland County, flood risks are becoming more apparent, especially in areas with poor drainage systems. Cascading effects that form as a result of severe storm events, including electrical outages, telecommunications interruptions, and contamination of public drinking water supply as a result of stormwater runoff, are all of immediate concern in Cumberland County and Carlisle as well.

Building climate resilience in tandem with mitigating climate change should be a priority for Cumberland County and Carlisle moving into the future. While mitigation is necessary, resilience must also be considered to deal with the effects of climate change that are already present and will worsen in the near future.

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