Claudia Bonaccorsi

Baird Honors Practicum

Prof. Neil Leary

7 December 2021

Chapter 6: Water

An Assessment of Vulnerabilities and Adaptation Options

Overview

The severity of climate-risks demands mitigation of greenhouse gases and strategic adaptation action to protect the county's assets and vulnerable populations. This section of the vulnerability assessment is concerned with understanding who and what in Cumberland County is at an elevated risk of being impacted negatively by water quality and water supply issues tied to climate change. The vulnerability assessment can measure and quantify risk to inform effective adaptation strategies and protect those most vulnerable.

Cumberland County, Pennsylvania, is characterized by mountains and low-lying land, with most of the county situated in the valley (Skelly and Loy, 2010, p. 11-1). The main watersheds in Cumberland County are Cedar Run, Conodoguinet Creek, Hogestown Run, LeTort Spring Run, Middle Spring Creek, Mountain Creek, Yellow Breeches Creek, Susquehanna River, Conewago Creek, and Conococheague Creek Watershed (Skelly and Loy, 2010, p. 4). The waterbodies and waterways make up 0.18% of Cumberland County (Skelly and Loy, 2010, p. 3) while 2% of the county is wetlands, and 5% of the county is in floodplains (Cumberland County Comprehensive Plan, 2017, p. 2). Due to the ground and soil characteristics, there is generally a moderate infiltration rate and water transmission rate, however, floodplains in the county exhibit a slow infiltration rate (Skelly and Loy, 2010, p. 11-3).

In a study conducted by Skelly and Loy Inc on behalf of Cumberland County, the survey reports demonstrated that protecting and improving water quality is *very important* to residents (Skelly and Loy, 2010, p. 11-11). The waterways in Cumberland County, especially those that have been designated as High Quality and of Exceptional Value, are great resources and require continued protection from water quality issues. Unfortunately, there are many streams that are impaired because the pollutant level exceeds non-impaired levels. Cumberland is the county with the fastest growing population in Pennsylvania which leads to an increase in development (Cumberland County Planning Department, 2020, p. 9). Development and an increasing population contribute to impaired streams because they lead to an increase in impervious surfaces which creates stormwater runoff during rain events. (Skelly and Loy, 2010, p. 111). Water security decreases as less clean and freshwater is made available to drink, apply to

agricultural fields, and fuel healthy ecosystems (USGCRP. 2018). Water activities and recreation in the county rely on water availability and quality as well.

Water systems across the county provide a clean and safe water supply. There are 63 community water systems in the County that serve 85% of the population and the remaining 15% of the population relies on on-lot wells (Cumberland County Planning Department, 2017, p. 15). There are approximately 11,982 wells in use in the county that rely on clean and available water (Cumberland County Planning Department, 2020, p.47).

To provide context on water supply systems in Cumberland County, I will discuss two water treatment plants. The Borough of Carlisle Water Treatment Plant provides clean water for the Borough of Carlisle and three other townships by taking approximately 3.04 million gallons per day (MGD) of raw water from the Conodoguinet creek and treating it at the plant before distributing it (Borough of Carlisle Water Treatment Plant, 2020, p. 1). Although demand for water from the plant is only 3 MGD, the treatment plant is permitted to take 7 MGD and capable of taking 9 MGD; water supply is not a foreseeable issue even with population rise (Borough of Carlisle Water Treatment Plant, 2020, p. 1).

The 383 m^2 of the Conodoguinet watershed supplies water to the Conodoguinet Creek and subsequently the Borough of Carlisle Water Treatment Plant. There are water quality issues in the watershed mainly caused by pollutants from agriculture, construction sites, and urban stormwater runoff that are mobilized by rainfall (See Fig. 1) (Borough of Carlisle Water Treatment Plant, 2020, p. 1). In the Conodoguinet watershed, 62% of the land is agricultural, 33% is forested, 5% is developed, and the remaining is approximately 1% water (Borough of Carlisle Water Treatment Plant, 2020, p. 4). Stormwater is diverted often into waterways across the county that provide drinking water, but the treatment plants can clean the water for human consumption (Borough of Carlisle Water Treatment Plant, 2020, p. 1). However, the water remains impaired and impure for all other groups. In the annual water report conducted by the Borough of Carlisle Water Treatment Plant, there is included an assessment of the raw water quality of the Conodoguinet watershed. Fig. 1 lists the sources of contaminants that impact the Conodoguinet creek.

Table 1. – Contaminant Priority Listing for the Conodoguinet Creek Watershed

Source of Contaminants	Protection Priority
Agriculture - crops	A
Agriculture - livestock	A
Urban Runoff	A
Industrial Discharges	B
Transportation Corridors	C
Sewage Treatment Facilities	C
Residential / Golf Courses	C
On-Lot Septic	D
Petroleum Storage Tanks, Gas/Service Stations	D
Landfills	E

Figure 1: Borough of Carlisle Water Treatment Plant. 2020, p. 4

The Mechanicsburg water treatment plant takes 10.9 MGD from the Conoduguinet and the Yellow Breeches – the Yellow Breeches watershed is 218 m^2 (Pennsylvania American Water, 2020, p. 5). The water supply of this treatment plant is vulnerable to urban stormwater runoff, transportation corridors, and agriculture similarly to the Borough of Carlisle Water Treatment Plant (Pennsylvania American Water, 2020, p. 5). Both the Carlisle and the Mechanicsburg treatment plants complied with drinking water requirements.

Climate Vulnerabilities

The following information on climate change projections in Cumberland County is sourced from Chapter 2 unless otherwise indicated. To read more in depth on climate change in Cumberland County, refer to Chapter 2 on Changing Climate Hazards.

The climate is expected to become increasingly wet and warm across Pennsylvania due to climate change (PA DEP, 2021, p. ix). With temperatures rising across the globe, there has been more evaporation from water bodies leading to increases in precipitation and intensity of precipitation events. In Pennsylvania, more common and extreme heat events are occurring presently and will continue to rise. There is a potential increase in total average rainfall, and the rain events are projected to be higher in intensity but occur less frequently (PA DEP, 2021, p ix). As is seen across the globe, it is not possible yet to create accurate projections of changes in extreme weather at a particular location, but hydrologic variability and wider ranges of plausible climate conditions are a reality (USGCRP, 2018).

In Cumberland County, rising average temperatures and extreme heat are virtually certain to rise while extreme cold events are virtually certain to decrease. Because of rising temperatures, all U.S regions are experiencing warming water temperatures which will impact and further impair water quality and ecosystem health (USGCRP, 2018).

Changing average precipitation and extreme precipitation events will potentially increase but the confidence in these projections is low compared to heat and rising temperatures.

Although projections are uncertain, the current exposure in Cumberland County to extreme precipitation is very high; rain events are generally intense and frequent which can cause damaging floods. This climate-hazard impacts water quality in the county by contributing to pollution of water resources (PA DEP, 2021, p. 32). Water treatment plants may experience a rise in costs of treating increasingly contaminated raw water quality as well (USGCRP, 2018).

The climate projections of drought, severe storms, and compound events are uncertain in Cumberland County. The impacts of droughts vary greatly depending on the time of year, location, severity, and duration of the drought event and usually impact agriculture most heavily but can cause various effects as well. Hydraulic drought events reduce stream flows, groundwater levels, and lake and reservoir water storage and can also increase the salt content and water temperature of water resources (Cumberland County Planning Department, 2020, p. 37).

Sensitivity

Water quality is sensitive to the climate-risk of flooding which causes increases in water pollution across the county (PA DEP, 2021, p. 32). For example, when agricultural lands experience heavy rain events, pollution in the form of sediments or nutrients loads are mobilized and can run off the fields and into local waterways, contributing to water pollution and water quality issues (PA DEP, 2021, p. 54). Rainfall and runoff events are the major drivers of nonpoint pollution which will make water quality worse and increase nutrient load pollution (ENRI, 2020, p. 48). Not only does this affect aquatic ecosystems and cause harmful algal blooms that kill fish and wildlife, but it can lead to poor raw drinking water quality and water-borne diseases (Cumberland County, 2021, p. 7).

There are many flooding related sensitives in the County. Flooding is the most costly and frequent hazard in Pennsylvania which has resulted from increased precipitation due to climate change (Cumberland County Planning Department, 2020, p. 30). The permeable ground in Cumberland County is shrinking as the county's population grows (Skelly and Loy, 2010, p. 1). Urban areas, impermeable ground, and poor stormwater infrastructure can lead to increased flooding and stormwater runoff which can be particularly harmful due to the pollutants that stormwater can carry to Cumberland County's drinking water supplies and aquatic ecosystems (Cumberland County Planning Department, 2020, p. 58). In the Borough of Carlisle, for example, polluted stormwater runoff is collected and transported through a municipal separate storm sewer system (MS4) and then discharged untreated into the LeTort Run which eventually drains to the Chesapeake Bay (Carlisle Borough).

Snow and ice melt contribute to runoff and have similar impacts on water quality. With potential rises in winter storms due to average increases in precipitation, there may be an increase in de-icing chemicals and salt applied to transportation corridors. These pollutants often

end up in local waterways and decrease water quality (Cumberland County Planning Department, 2020, p. 129).

Adaptive Capacity

The Clean Water Cumberland Countywide Action Plan, released in 2021, is a guide to reaching water quality goals in Cumberland County which will lead to improvements in the community as well as in the Chesapeake Bay (Clean Water Cumberland, 2021, p. 1). A key finding of the action plan was that there are already many organizations and individuals who are supporting water quality goals and taking action in Cumberland County (Clean Water Cumberland, 2021, p. 3). The existence of the action plan is itself an indication of adaptive capacity. Many collaborators contributed to the design of the Countywide Action Plan who are already supporting adaptive strategies such as the Alliance for Aquatic Resource Monitoring, the Chesapeake Bay Foundation, Penn State Extension, the Pennsylvania Farm Bureau, the USDA, the Alliance for the Chesapeake Bay, and more. Not only are there many organizations involved with adaptive strategies to improve the quality of water resources and water supply, but in a survey across Cumberland County, 76% of the participants said they were motivated to take climate action to improve water quality, with only improved air quality higher at 78% (Cumberland County, 2021, p. 7). Cumberland County clearly has many individuals and organizations engaged with and aware of issues in the water sector.

There are ongoing projects in Cumberland County that indicate adaptive capability in the water sector. The following Watershed groups support water quality issue adaptations in Cumberland County: Conodoguinet Watershed Association, Yellow Breeches Watershed Association, Big Spring Watershed Association, LeTort Regional Authority, Middle Spring Watershed Association, and Friends of Opossum Lake Conservancy. While organizations such as the watershed groups work to restore, protect, and monitor watersheds across the county, other projects are ongoing to repair, improve, and protect the quality of local watersheds. There is the Burd Run Stream Restoration Project, a rain barrel program, and four BMP projects taking place on agricultural land in Cumberland County (Cumberland County Watershed Program). These programs represent six grants, totaling $675,000 that the county received to improve watersheds.

The Capability Assessment Survey from the 2020 Cumberland County Hazard Mitigation Plan indicates that there are many “existing authorities, policies, programs, and resources that reduce hazard impacts or that could be used to implement hazard mitigation activities.” (Hoffman, 2020, p. 1). Out of the capabilities, there are a few that relate to the water sector:

- Stormwater Management Plan & Ordinance, 2010
- Natural Resource Protection Plan, 2013, which includes protection of creeks and watersheds
- The floodplain ordinance that the county has adopted

Andy Yencha, who works at Penn State Extension and is knowledgeable on the local water sector, responded to an adaptation capacity questionnaire designed for this vulnerability assessment and noted that it is of high importance to increase financial resources, knowledge and expertise, physical infrastructure, and networks to share and utilize resources. For current measures being taken to limit climate-related risks on water quantity, quality, and water infrastructure, Yencha commented that "My sense is some municipalities in Cumberland County are starting to budget in more extensive stormwater infrastructure, but more should be doing this," and he also mentioned that "efforts by local government and non-profit groups to increase riparian buffers should help reduce flooding risks in the long term."

Equity Concerns

An Environmental Justice Area is defined as a "census block group where 20% or more of individuals live in poverty, and/or 30% or more is a minority" (PA DEP, 2021, p. 28). Environmental justice areas are more likely to experience extreme floods such as 100-year floods and 500-year floods (PA DEP, 2021, p. 28). Elderly people and people with low socioeconomic status tend to be living in floodplains which is hazardous (PA DEP, 2021, p. 61). These communities with populations living in poverty or populations of minority peoples have increased sensitivity to potential future flooding hazards and possible increases in average precipitation.

As climate change progresses, it has been observed that some populations are at higher risk to climate hazards such as environmental justice communities (PA DEP, 2021, p. xii). Communities of people, agricultural lands, or infrastructure located near or inside of a floodplain are more vulnerable to flooding risks (PA DEP, 2021, p. 32). These communities are not experiencing water equity and they will continue to be impacted by climate hazards unless they are protected or able to adapt. Water Equity, as defined by the US Water Alliance, is a when people have access to safe and clean water, are not at a heightened risk to drought and flooding hazards and are able to play a role in wastewater decisions (US Water Alliance, 9). When brownfield sites or industrial sites experience flooding events there is an elevated risk of hazardous materials being distributed in the surrounding area (Pennsylvania, 54). This demonstrates how historical development practices have systematically placed low-income peoples in flood-prone areas (US Water Alliance, 15).

Adaptation Strategies

Urban areas often experience vulnerabilities to water issues which are being exacerbated by climate change. The US Water Alliance outlines five inequalities that often are experienced in urban areas which could be analyzed within the context of urban areas in Cumberland County: "1) Historical development practices placed low-income people and communities of color in flood-prone areas, 2) Infrastructure in economically distressed communities is often in worse

condition, 3) Poverty intersects with flood vulnerability, 4) Social and environmental factors also leave some populations more vulnerable, and 5) Climate change is leading to migration that exacerbates existing flooding inequities". In the urban context, stormwater solutions to decrease flooding risks require creative installation due to pre-existing infrastructure. These creative solutions are known as green infrastructure and can consist of green roofs, rain gardens, pervious pavement, and more (ENRI, 2020, p. 65).

The US Climate Resilience Toolkit outlines five steps to studying climate hazards, deciding what situations to avoid, and developing solutions that will lead to effective and positive outcomes. The advised strategy could be applied to water sector issues in Cumberland County to explore water related climate hazards, access vulnerability and risk to these hazards, investigate options, prioritize a plan, and take action. In relation to specifically urban based water issues, the authors of *Water Rising: Equitable Approaches to Urban Flooding* argue that the priority should be to use data "to identify risks, assets, and community vulnerability" (US Water Alliance, 2020, p. 17). To address flooding risks, it is recommended that flood-prevention projects such as stream restoration, floodplain reconnection, reforestation initiatives, and stormwater infiltration systems are supported in Cumberland County *(Skelly and Loy, 2010, p. 111).* Communities across the US, including Cumberland County, have begun to study and understand vulnerability through vulnerability assessments such as this one. We can inform adaptation in an equitable way by combining the technical data available on climate hazards such as the increased risks of flooding and combine that information with social data such as demographics that would indicate vulnerability (US Water Alliance, 2020, p. 20).

Recommended Adaptation Pathways in Cumberland County

1: Linking Climate Change Adaptation to Load Reduction Goals to the Chesapeake Bay

To enable more effective adaptation and management of climate-risks on water quantity, quality, and water infrastructure, Andy Yencha commented in the adaptability questionnaire that "there may be more opportunities to link climate change adaptation to the water quality protection efforts happening with the County's Chesapeake Bay action. Climate change is projected to impact the drivers of water quality issues throughout the Bay watershed which includes Cumberland County, therefore, climate change is going to increase the need for treatment of stormwater runoff (Cumberland County, 2021, 48). Pennsylvania is required as a state to reduce pollution loads by 2025 because of the Chesapeake Bay Total Maximum Daily Load (TMDL) requirements and restoring natural buffers and vegetation is a part of the plan to meet the TDML (ENRI, 2020, p. 47). Local efforts to improve resilience to climate change can simultaneously improve water quality which is further explained in the third recommended adaptation pathway.

2: Incorporating Climate Variability into the Countywide Action Plan

The Clean Water Cumberland Countywide Action Plan is a plan for improving water quality in Cumberland County. Climate change, however, poses a risk to water quality, yet is not a main consideration in the plan. In the *Pennsylvania Climate Impact Assessment Update of 2020*, it was supported that climate change is going to have numerous effects on water resources and management plans across Pennsylvania (ENRI, 2020, 83). In Clean Water Cumberland, the first priority action outlined by the plan is to influence land use decisions that are made in the Cumberland County comprehensive plans and establish a consistent and effective approach to reaching clean water goals which would be reflected in future versions of the comprehensive plan (Clean Water Cumberland, 2021, p. 1).

The second priority action is to achieve pollutant reductions of namely nitrogen, phosphorous, and sediments. There has been progress in reducing pollutant loads through improving wastewater treatment processes in the county (Clean Water Cumberland, 2021, p. 2). Agricultural lands present a great opportunity for achieving clean water goals. Part of priority #2 is helping farmers take steps to reduce pollutant loads and provide and locate funding for these changes such as installing natural buffers along farmland streams and borders (Clean Water Cumberland, 2021, p. 2). The adaptive capacity of vulnerable people and capital to flood and precipitation hazards can be improved through nature-based solutions such as restoring natural vegetated buffers on agricultural land (ENRI, 202, p. 64). Andy Yencha, in his response to the adaptation capacity questionnaire, also recommended increasing natural riparian buffers as is being done by local governments and non-profit groups. Installing more water quality driven best management practices in Cumberland County will help improve water quality and help the state meet the TDML requirements (ENRI, 2020, p. 47). Natural buffers that filter pollutant loads can be used to adapt to the non-point pollution from urban areas in the county as well as agricultural lands which are the two major contributors to poor water quality (Fig. 1).

The third priority of the Countywide Action plan is "Monitoring, Verifying, Researching, Educating, and Training" and "Building Participation, Measuring Results, and Refining the Plan" (Clean Water Cumberland, 2021, p. 2). The priorities would build watershed resilience and help the County meet clean water goals, yet potentially could be a greater asset to water resources if climate-risks were addressed and incorporated into the strategy. Further research and planning for varying climate projections will be critical for achieving water quality goals in a cost effective and efficient manner (ENRI, 2020, 58). Planning for a wide range in climate variability is a great challenge for water planning and management but will decrease climate-risks (USGCRP, 2018).

<u>3: Managing land use to reduce GHG emissions and increase resilience: Goal #4 of Cumberland County Climate Action Plan</u>

Adaption to climate risks should be pursued alongside mitigation of climate change and the reduction of greenhouse gas emissions in Cumberland County. It is vital that the County continues to pursue the mitigation of GHGs as outlines in the 2021 Climate Action Plan. There are four priority goals: #1 Reduce transportation related greenhouse gas emissions, #2 Reduce

solid waste disposal greenhouse gas emissions, #3 Reduce GHG emissions related with energy production and usage and #4 Reduce GHG emissions and increase resilience to climate change (Cumberland County Planning Department, 2021, pp. 30-34). Water quality and water supply are going to be heavily influenced by goal #4 to reduce GHG emissions and increase resilience to climate change.

As was supported in the two water quality reports by the Borough of Carlisle Water Treatment Plant and the Mechanicsburg Water Treatment Plant, urban runoff, agriculture practices, and transportation corridors are the primary sources of impaired water quality and water supply sources. As the climate action plan strategizes, developing appropriate land use policies and ordinances will address climate change impacts (See Fig. 2). This strategy is potentially a powerful solution because it can address the need for climate change mitigation in the county, increase resiliency to climate change, and provide an adaption pathway for water quality and supply vulnerabilities in the county.

A few action items of this strategy which I would like to highlight are "green infrastructure, parking reductions, and floodplain management regulations" (See Fig. 2). Under the strategy to preserve parks, trails, greenways, and open space, it is recommended to pursue development in already developed areas with existing infrastructure to preserve prime farmland and sensitive natural features. This connects to comments from Andy Yencha on the importance of managing further development of permeable land and the goal of preserving conservation character areas written about in Cumberland County's 2017 Comprehensive Plan.

	Strategy	Actions		
		Government	***Businesses***	***Residents***
Land Use	Developing land use policies and ordinances that address energy production, efficiency, and climate change impacts	• Develop and adopt land use ordinances that decrease GHG emissions or mitigate climate change impacts. Example model ordinances include green infrastructure, parking reduction, floodplain management regulations, street design, complete streets, EV charging infrastructure, and autonomous vehicle street design. • Provide incentives for green building and design such as LEED or comparable green certification. • Continue implementation of the Cumberland Plans grant program to support municipal efforts to update ordinances. • Develop policies and update model ordinances to guide where alternative energy facilities are best suited and how to compatibly develop those facilities with existing communities.	Provide input to local elected officials on how regulations can assist in achieving sustainability goals while still being business friendly.	Participate in local government planning sustainability planning processes.
Land Use	Preserving parks, trails, greenways, and open space	• Update the Land Partnerships Plan to coordinate county, municipal, and nonprofit preserved land investments. • Continue implementation of the Land Partnerships program that provides funding for parks, trails, and natural resource projects in cooperation with municipal governments, nonprofits, and the private sector. • Work to direct development towards areas with existing infrastructure and away from prime farmland, sensitive natural features and resources.	• Integrate open space or green infrastructure into the design of private sector buildings and campuses. • Support conservation organizations with financial donations and volunteer efforts.	• Use close to home outdoor recreation and open space resources. • Support conservation organizations with financial donations and volunteer efforts.
Land Use	Implementing natural native landscaping standards.	• Leverage state funding that can be used by governments, businesses, and residents to convert landscaping from turfgrass to native species that require less water and maintenance. • Educate public about native plants, include listings from ordinances on municipal websites, and adopt native plant ordinances in local land development ordinances. • Leverage funding from tree planting programs administered by the state and nonprofit organizations. • Use native species when planting trees on government owned property. • Create forest management plans for larger tracts of government owned property. • Implement rain gardens, pervious pavement, and other environmentally friendly stormwater management practices on publicly owned properties.	• Evaluate turf grass conversion opportunities on privately owned properties that have the co-benefit of financial savings. • Plant trees on corporate campuses, where applicable. • Implement rain gardens, pervious pavement, and other environmentally friendly stormwater management practices on privately owned properties.	• Convert landscaping from turfgrass to native plantings. • Plant native tree species. • Volunteer in tree planting initiatives with nonprofit organizations. • Implement rain gardens, pervious pavement, and other environmentally friendly stormwater management practices on privately owned properties. • Consult with the Penn State Agricultural Extension to discuss landscape plans and select appropriate species. • Test soils prior to application of fertilizers or other lawn chemicals • Increased use of battery powered lawn equipment to reduce emissions.
Land Use	Supporting sustainable agricultural practices	• Provide funding for agriculture best management practices that reduce pesticide usage, protect water quality, and sequester GHG. • Preserve 30,000 acres of prime farmland by 2030 through the Cumberland County Agriculture Conservation Easement Program. • Provide incentive programs for renewable energy generation on agricultural operations. • Guide investment in research and development and proof of concept for innovative agricultural practices.	• Provide voluntary donations to the Cumberland County Agriculture Conservation Easement Program. • Where appropriate use or source locally grown agricultural products. • Leverage federal, county, and state funding to construct best management practices on farms. • Participate in carbon sequestration and other incentive programs to support agricultural sustainability. • Reduce use of pesticides and synthetic fertilizers by utilizing sustainable cultural methods. • Explore renewable energy generation on agricultural operations utilizing digester technology for example. • Examine co-location and compatible agricultural practices with solar generation such as agrovoltaics. • Explore opportunities for silvopasture practices and agroforestry to encourage compatible uses of trees and agriculture where appropriate. • Pool resources and work with other farmers to implement annual practices that require customized equipment or training so that these practices can be done more cost-effectively and at larger scales.	• Provide voluntary donations to the Cumberland County Agriculture Conservation Easement Program. • Solicit businesses that use locally sourced agricultural products. • Solicit businesses that use sustainably produced agricultural products. • Participate in an agricultural co-operative.

Figure 2: Cumberland County Planning Department, 2021, p. 33

Supporting sustainable agricultural practices is the final component of the climate action strategy to managing land use to both reduce GHG emissions and increase resiliency to climate change (Fig. 2). The first government action that this category warrants is funding for agriculture best management practices. Agriculture BMPs can protect water quality from climate-risks by reducing the quantity of pesticides applied to agricultural lands while leading to the sequestration of more carbon as well (Fig. 2). These best management practices are critical because effective management of water quality necessitates the management of inputs and outputs of nutrients which are reduced in agricultural BMPs (ENRI, 2020, p. 56).

Conclusions

I will conclude this water section of the climate change vulnerability assessment by summarizing the key takeaways and recommended adaptations. One key takeaway includes that a major problem with the management and planning of water resources is the wide range of possible climate projection futures, which is both a technical challenge and a challenge of

incorporating a wide range of climate projections into County plans. A second key takeaway is that climate change is projected to impact the drivers of water quality issues, making climate change an important aspect of clean water goals. A third takeaway is that Cumberland County exhibits high levels of adaptive capacity due to the plethora of individuals and groups who are working toward water quality goals in both a professional and volunteer capacity.

After assessing adaptation strategies to decreasing climate risks in the water sector from local plans and experts, I proposed the following recommendations: (1) link climate change adaptation to load reduction goals to the Chesapeake Bay, (2) incorporate climate variability into the Countywide Action Plan, and (3) manage land use to reduce GHG emissions and increase resilience as the goal #4 of Cumberland County Climate Action Plan outlines.

References

Carlisle Borough. Stormwater Management https://www.carlislepa.org/residents/stormwater_management/index.php

Chesapeake Bay Program. 2018. Chesapeake Bay Program Quick Reference Guide for Best Management Practices (BMPs): Nonpoint Source BMPs to Reduce Nitrogen, Phosphorus and Sediment Loads to the Chesapeake Bay and its Local Waters. CBP DOC ID. https://www.chesapeakebay.net/documents/BMP-Guide_Full.pdf

Cumberland County Planning Department. (2020). *Cumberland County Hazard Mitigation Plan Update 2020*. https://www.ccpa.net/4902/Hazard-Mitigation-Plan

Cumberland County. (2021). *Cumberland County Climate Change Action Plan 2021: Green Up the Footprint. https://www.ccpa.net/DocumentCenter/View/39031/Climate-Action-Plan-Final-Draft-for-Public-Review-82721?bidId=*

Cumberland County Planning Department. 2017. Cumberland County Comprehensive Plan 2017. https://www.ccpa.net/DocumentCenter/View/39864/2017-Cumberland-County-Comprehensive-Plan-FINAL-ADOPTED?bidId=

Cumberland County. (2013). *Natural Resource Protection.* Land Partnerships Plan a Countywide Strategy. https://www.ccpa.net/DocumentCenter/View/16940/Ch6?bidId=

Clean Water Cumberland. (2021). Countywide Action Plan. https://www.ccpa.net/4897/Clean-Water-Cumberland---Countywide-Acti

Borough of Carlisle Water Treatment Plant. 2020. *2020 ANNUAL WATER QUALITY REPORT:*

THE BOROUGH OF CARLISLE AND APPLICABLE PORTIONS OF SOUTH MIDDLETON, NORTH MIDDLETON AND MIDDLESEX TOWNSHIPS.

ENRI. (2020). Pennsylvania Climate Impact Assessment Update. https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/ClimateChange/2020ClimateChangeImpactsAssessmentUpdate.pdf

Georgetown Climate Center. *Equitable Planning: Green Infrastructure Toolkit.* Retrieved from https://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/equitable-planning.html

Hoffman, S. (2020). *Capability Assessment Survey.* Cumberland County 2020 Hazard Mitigation Update. https://www.ccpa.net/DocumentCenter/View/34070/4---2019-Capability-Assessment-Survey

Metchis, K. (2021). *Pittsburgh Unifies its Approach to Updating Stormwater Management.* Us Climate Resilience Toolkit. Retrieved from https://toolkit.climate.gov/case-studies/pittsburgh-unifies-its-approach-updating-stormwater-management

PA DEP. (2021). *Pennsylvania Climate Impacts Assessment 2021*. Submitted by ICF to the Pennsylvania Department of Environmental Protection. https://www.dep.pa.gov/Citizens/climate/Pages/impacts.aspx

PA DEP. 2020. *Pennsylvania Public Water System Compliance Report for 2020.* https://files.dep.state.pa.us/Water/BSDW/DrinkingWaterManagement/PublicDrinkingWater/PA_DEP_2020_Annual_Compliance_Report_Final.pdf

PA DEP. *Healthy Waters, Healthy Communities: Reducing Runoff Pollution In Pennsylvania's Share of the Chesapeake Bay Watershed.* https://gis.dep.pa.gov/chesapeakebaywatershed/index.html

Pennsylvania American Water. 2020. *2020 Annual Water Report.* https://www.amwater.com/ccr/greaterpgh_2020.pdf

Skelly and Loy. (2010). *Cumberland County Stormwater Management Plan*. Skelly and Loy Inc. *https://www.ccpa.net/DocumentCenter/View/7707/Final-Plan-September-2010?bidId=*

Stormwater PA. *Cumberland County: Clean your water. http://stormwaterpa.org/cumberland-county.html*

USGCRP. (2018). United States: *Fourth National Climate Assessment. Chapter 3: Water*. https://nca2018.globalchange.gov/chapter/3/

U.S. Federal Government. (2021). U.S. Climate Resilience Toolkit Climate Explorer. [Online] https://crt-climate-explorer.nemac.org/ Accessed 10/20/2021.

U.S. Water Alliance. (2020). *Water Rising: Equitable Approaches to Urban Planning.* Us Water Alliance.www.uswateralliance.org/sites/uswateralliance.org/files/publications/Final_USWA_Water%20Rising_0.pdf

Watershed Program. *What is a watershed?* Cumberland County Pennsylvania. https://www.ccpa.net/4628/Watershed