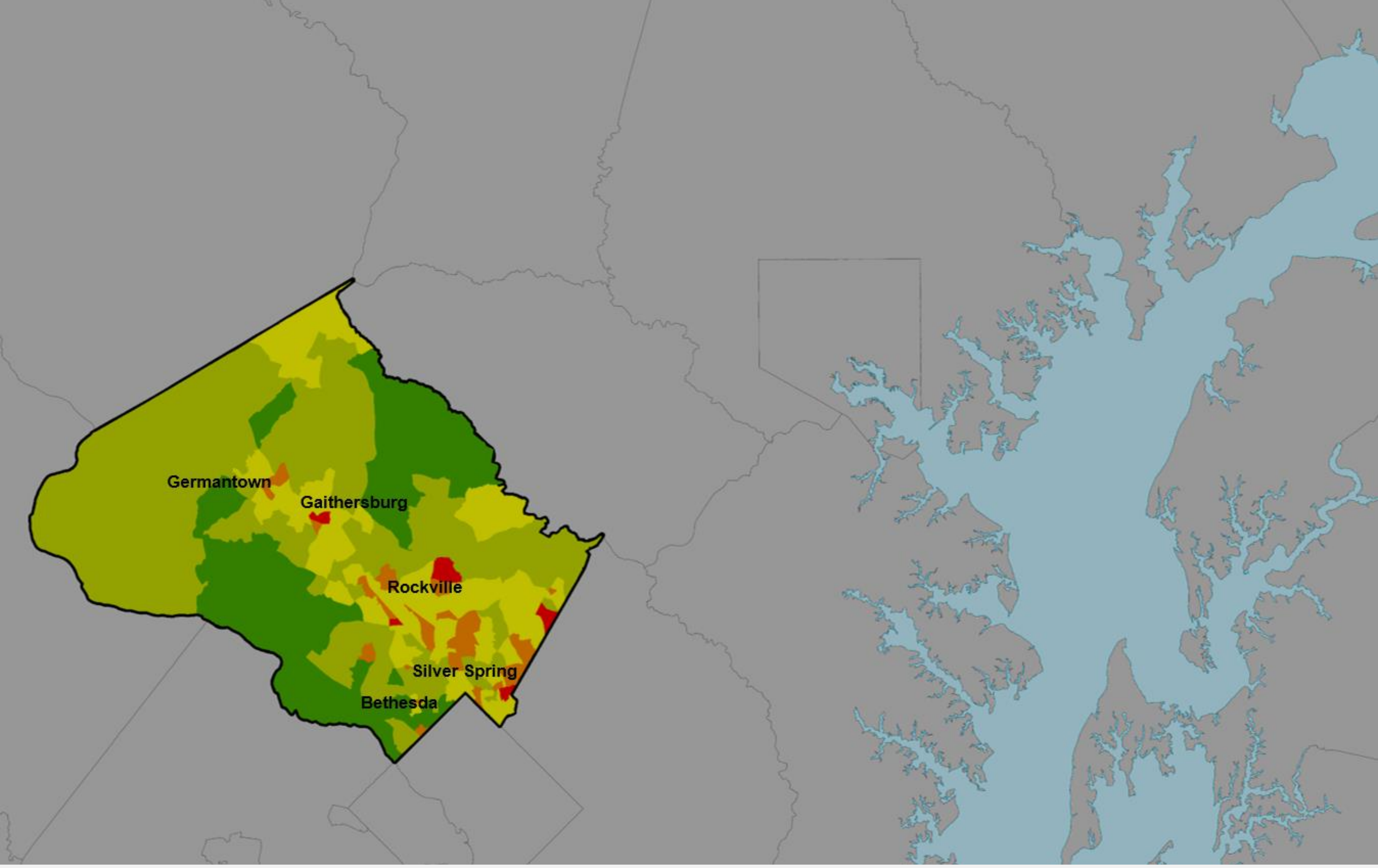
Artist: Ben Cole (Age 5)

Appendix C: Climate Vulnerability Assessment



Montgomery County, Maryland
Climate Vulnerability Assessment

Climate Action Plan ("CAP")

Submitted:
December 10, 2020

AECOM

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Executive Summary

AECOM is developing a Climate Action Plan ("CAP") for Montgomery County, Maryland, to identify a list of high-impact actions that will provide a path to the County's goals of 80% reduction of greenhouse gas (GHG) emissions by 2027 and 100% reduction by 2035.[1]

One component of the CAP is a climate vulnerability assessment analyzing the County's climate baseline and projected spatial climate threats through projection years of 2035, 2050, and 2100 for two different climate scenarios: Representative Carbon Pathway 4.5 (RCP4.5), a moderate GHG increase, and RCP8.5, a larger increase in GHG emissions. Future precipitation, temperature, and drought conditions were considered along with current high wind data. Increases in precipitation and worsening drought conditions are projected, but the most severe climate hazard appears to be temperature, with a large increase in the number of days above 95°F, as shown for the RCP4.5 and RCP8.5 scenarios in Figure 1-1.

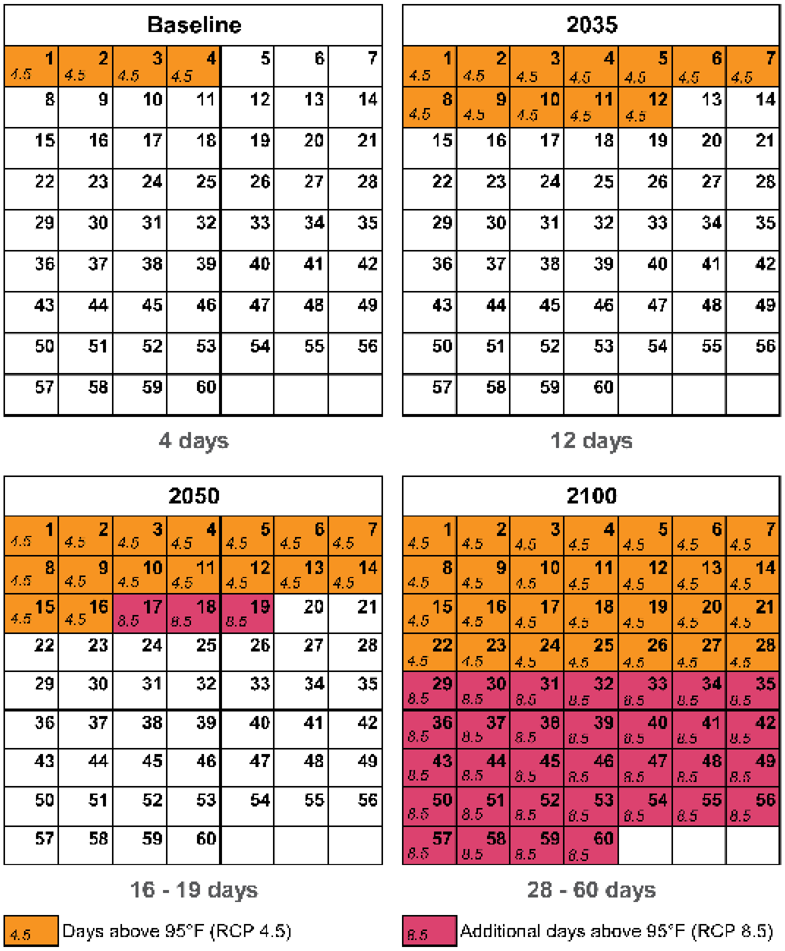

Figure 1-1. Average number of days above 95°F for Montgomery County

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[1] https://www.montgomerycountymd.gov/COUNCIL/Resources/Files/res/2017/20171205_18-974.pdf

The future climate conditions were evaluated in seven asset categories representing key components of the County’s built and human resources: transportation; critical and County resources; utilities; stormwater management systems; the agricultural reserve; parks, wetlands, and trees; and people and homes.

The vulnerability assessment considers the exposure, sensitivity, and adaptive capacity of these asset categories compared to the climate risks. Temperature is expected to have the most impact on assets within the County, with precipitation and drought coming in at a close second and third, respectively. High winds remain a hazard of concern but not to the same degree as the other hazards under consideration. Future wind conditions were not considered quantitatively, which may underrepresent their impact on County assets.

Looking at the exposure, sensitivity, and adaptive capacity of the asset categories found throughout Montgomery County, the highest risk asset categories and hazard combinations are:

- **Transportation:** Precipitation and Temperature
- **Utilities:** Temperature, Drought, and High Winds
- **Stormwater Management:** Precipitation
- **Agriculture:** Temperature and Drought
- **People and Homes:** Precipitation, Temperature, and Drought

Although other hazards pose some risk to the asset categories listed above, those risks are more limited than that of the hazards listed. Additionally, there are lower hazard risks for Critical and County Resources and Parks, Wetlands, and Trees.

1.0 Introduction

To assess Montgomery County's climate vulnerability for the Climate Action Plan (CAP), AECOM estimated baseline and projected climate data, and collected relevant asset datasets and grouped them into seven categories: transportation; critical and County resources; utilities; stormwater management; the agricultural reserve; parks, wetlands, and trees; and people and homes. This asset data is presented in Section 2.0.

The objective of this vulnerability study was to assess future climate risks through down-scaling global climate change information. This report estimates projected climate impacts for 2035, 2050, and 2100 for two CO_2 concentration scenarios, as presented in Section 3.0. This data can be used for future studies that focus on assets or proposed actions.

The goal of this climate vulnerability assessment is to understand the County's exposure and sensitivity to current and future natural hazards, including high heat, drought, changing precipitation patterns, high winds, and combinations of these hazards ("other climate hazards"), and to understand the adaptive capacity of assets within the County. Data results are presented in Section 4.0, with conclusions in Section 5.0.

For the next step in the process, the climate vulnerability assessment data will be used to help prioritize the CAP actions. Details on this process are provided in the main CAP document.

2.0 Asset Data

Assets within the context of this vulnerability assessment have been broadly defined to include key structural components of a system such as roadways, hospitals, and stormwater management/conveyance as well as the people within the community, with a particular focus on socially vulnerable groups. Asset data was provided by the Montgomery County Department of Environmental Protection and collected online from other sources listed in Attachment A. The assets were grouped into seven categories: transportation, critical and County resources, utilities, stormwater management systems, the agricultural reserve, parks and wetlands, and people. Due to the broad scope of this assessment, it was not possible to consider all relevant assets within each category. Additionally, many asset categories have interdependencies (for example, stormwater management systems and transportation) that are not considered in this assessment. The following sections outline which assets were considered in each category.

2.1 Transportation

Transportation assets collected for this project include:

- Bikeways
- Ride On Bus Stops
- Street Centerlines (including Emergency Routes and Major Roads)

- Railroads
- MARC Stations
- Metro Stations
- Airports

Montgomery County transportation assets are shown in Figure 2-1.

2.2 Critical and County Resources

Assets in the Critical and County Resources group include a variety of County-owned buildings and places as well as some privately owned facilities. The assets included in this category include:

- Schools (elementary, middle, and high)
- County Recreation Centers
- Libraries
- Health and Human Services (HHS) Nursing Homes
- Hospitals
- Police Stations
- Fire Stations
- Emergency Shelters (Note: these are a sub-set of high schools and recreation centers)
- Multi-Agency Buildings

These layers, in addition to a County-owned property layer, are shown in Figure 2-2.

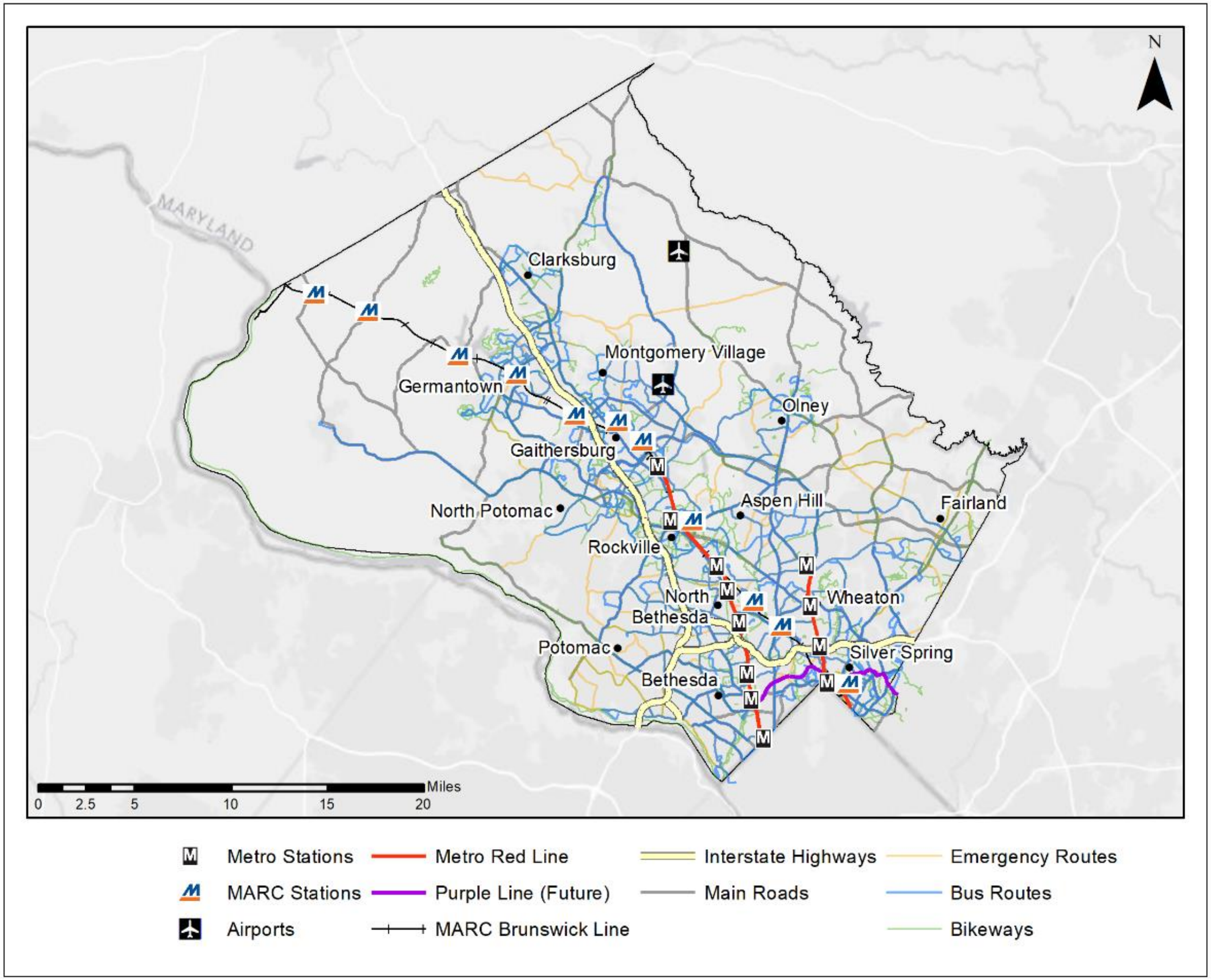

Figure 2-1. Transportation assets in Montgomery County

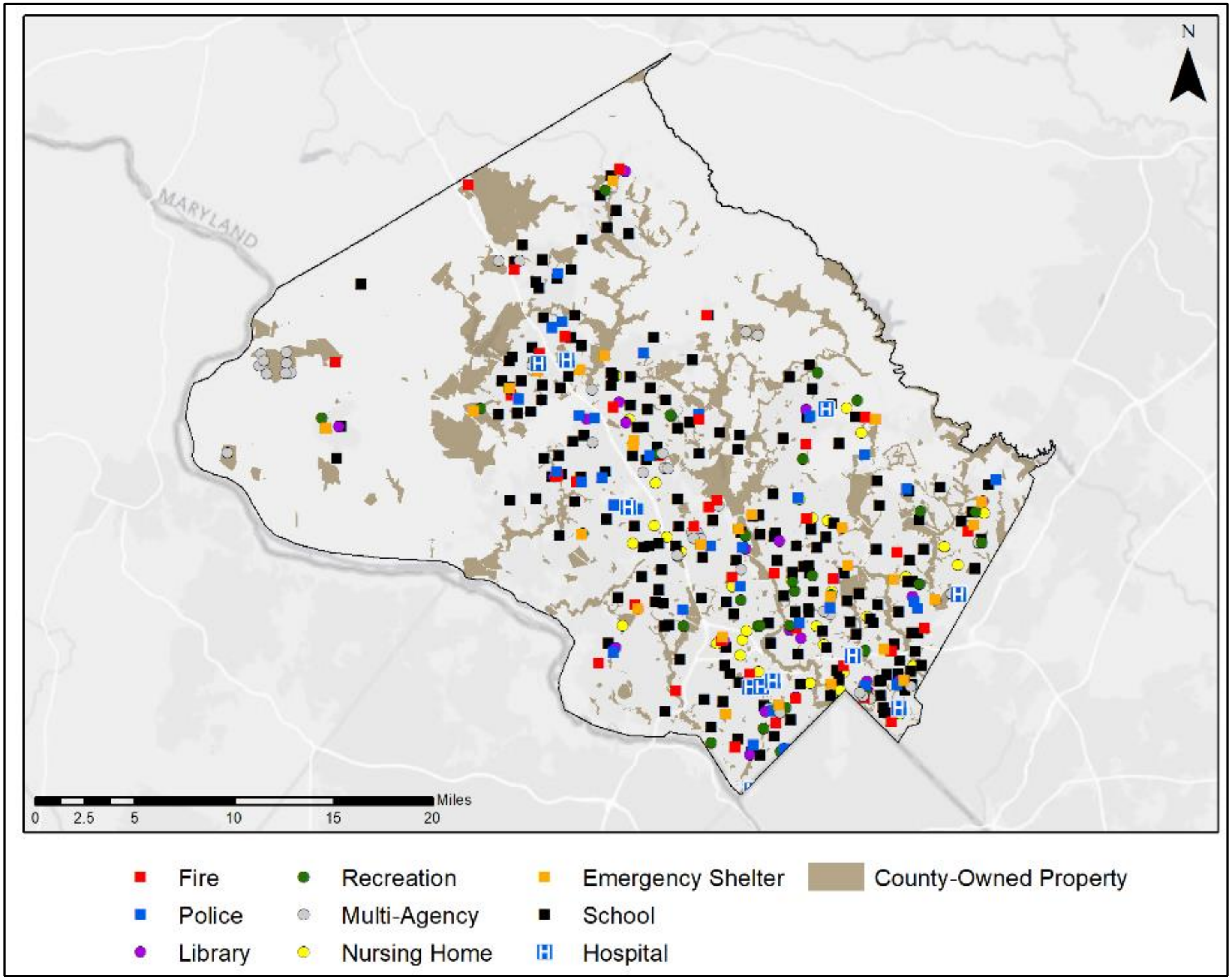

Figure 2-2. Critical and County Resources assets in Montgomery County

2.3 Utilities

For this assessment, utilities include:

- Drinking Water Reservoirs
- Pump Stations
- Electrical Lines
- Substations
- Montgomery County Resource Recovery Facility
- WSSC Potomac Water Filtration Plant
- Shady Grove Trash Transfer Station

Figure 2-3 shows key utility assets for Montgomery County.

2.4 Stormwater Management System

The stormwater management system is an important component in preventing flooding. The following asset types were included in this category:

- Dry/Wet Ponds
- Swales and Bioswales
- Infiltration Trenches
- Underground Detention Basins
- Dry Wells
- Culverts

Figure 2-4 shows stormwater assets throughout the County.

2.5 Agricultural Reserve

In 1980, the Montgomery County Council created what is now called the Agricultural Reserve, which encompasses 93,000 acres along the County's northern, western, and eastern borders. The Agricultural Reserve shows the County's sustained commitment to agriculture and has helped retain more than 500 farms within the County boundary, despite development pressures. This valuable County asset is shown in Figure 2-5.

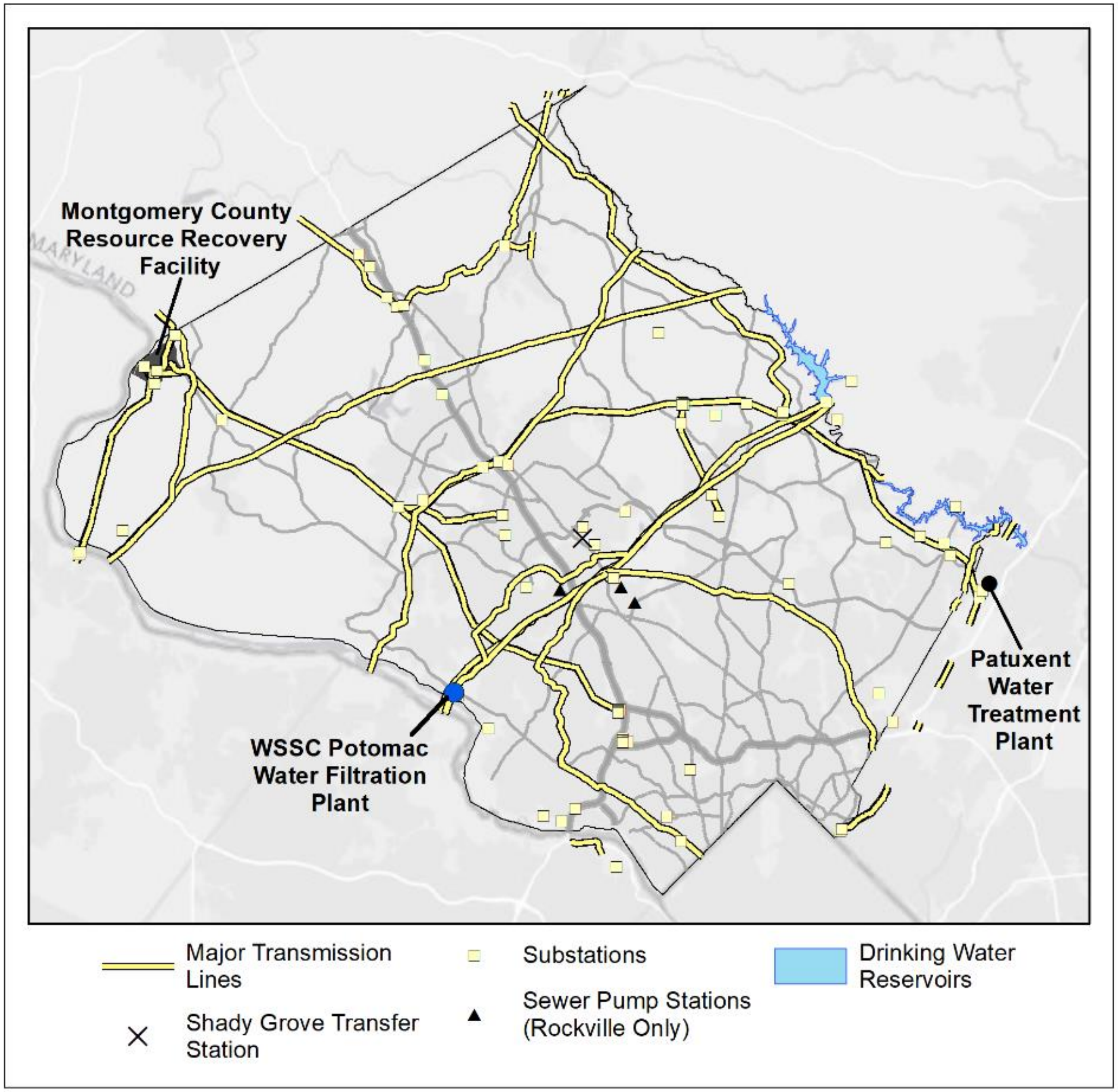

Figure 2-3. Utility assets in Montgomery County

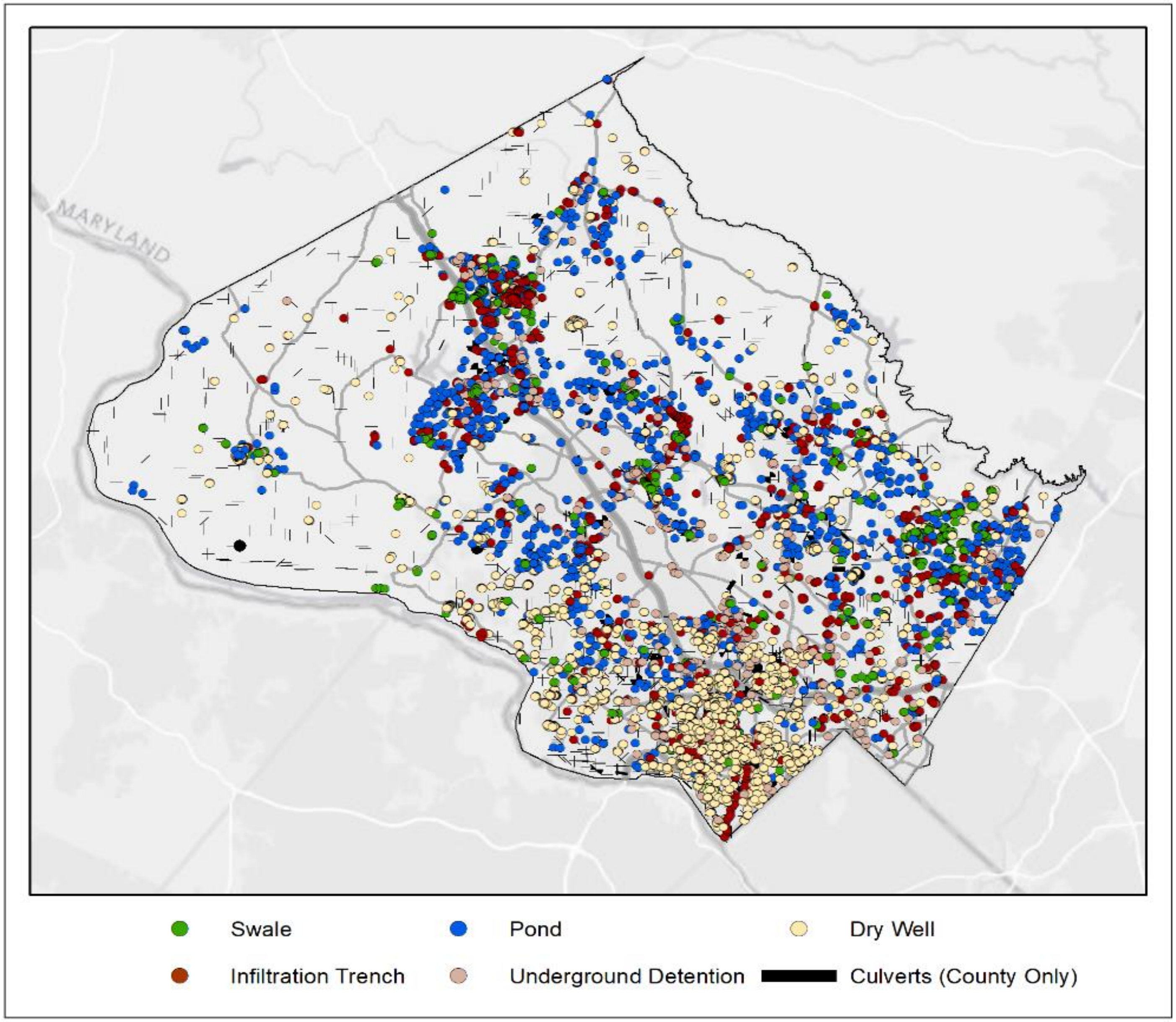

Figure 2-4. Key stormwater assets in Montgomery County

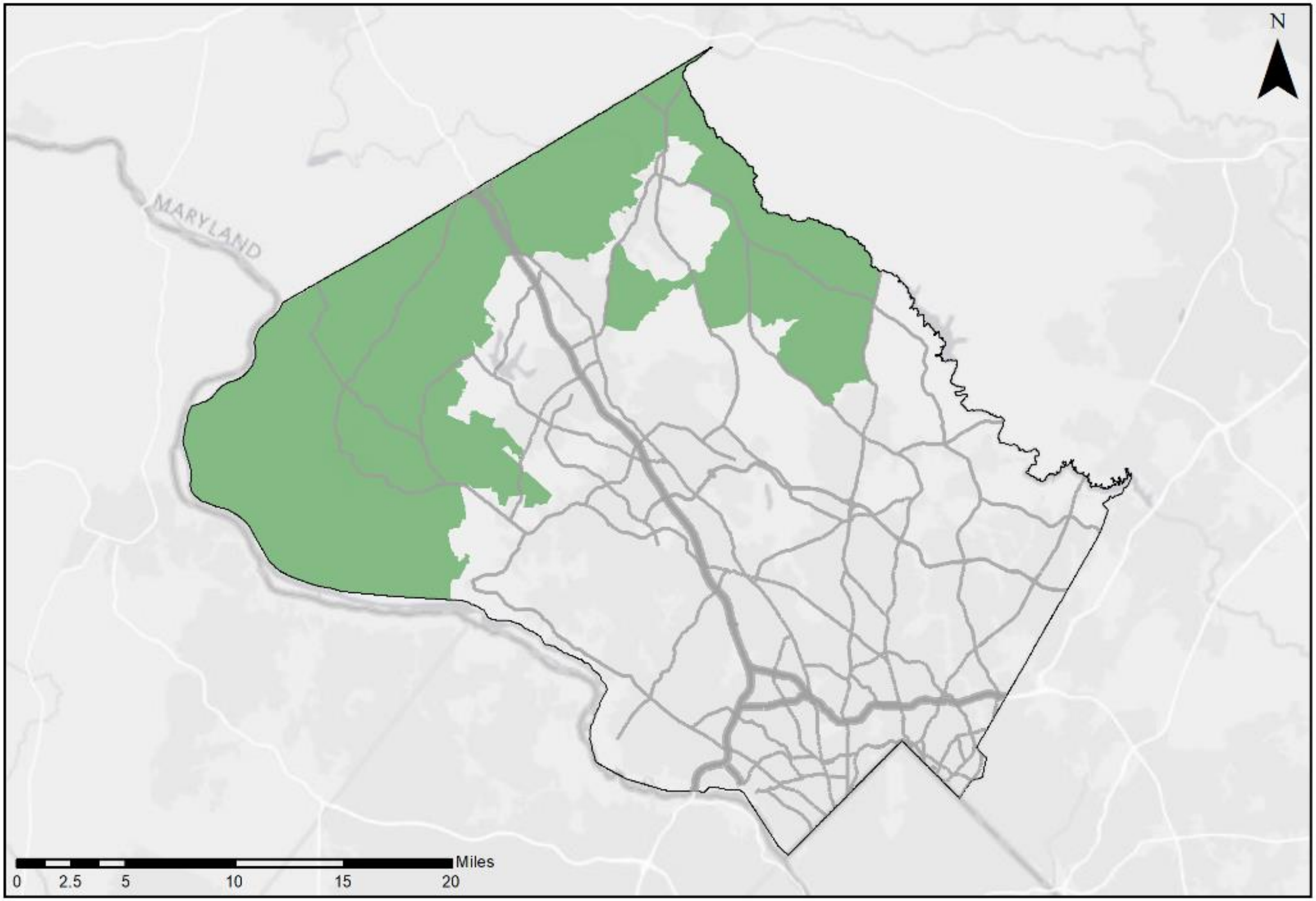

Figure 2-5. Montgomery County Agricultural Reserve (in green)

2.6 Parks, Wetlands, and Trees

Parks, wetlands, trees, and other open spaces are an important asset category in Montgomery County. This asset category provides habitat for many species of Montgomery County's flora and fauna as well as recreational areas for the community. Figure 2-6 shows the park and wetland areas within Montgomery County.

2.7 People and Homes

Traditional vulnerability assessments include mostly structural assets such as those listed above. This analysis also includes *homes* as an asset category; the *people* who live in the County are considered part of this asset category. This category focuses on health and wellness of all County residents, but especially vulnerable communities as well as the homes and properties where they live. The U.S. Census Bureau estimated the County population at 1,050,688 as of July 2019.[2]

The Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI) (form 2016) was used to assess socially vulnerable areas within the County. CDC defines social vulnerability as "the potential negative effects on communities caused by [natural or human-caused] external stresses on human health."[3] The CDC SVI uses 15 U.S. Census variables, including poverty and crowded housing, to identify communities that may need additional support when preparing for hazards or recovering from a disaster. The 15 social factors are grouped into four themes: (1) socioeconomic status, (2) household composition, (3) race/ethnicity/language, and (4) housing/transportation. The four themes are then combined into a final SVI ranking with values ranging from 0 to 1, with 1 being the most vulnerable and 0 being the least. The most vulnerable communities are shown in dark red in Figure 2-7.

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2 https://www.census.gov/quickfacts/montgomerycountymaryland
3 https://www.atsdr.cdc.gov/placeandhealth/svi/index.html

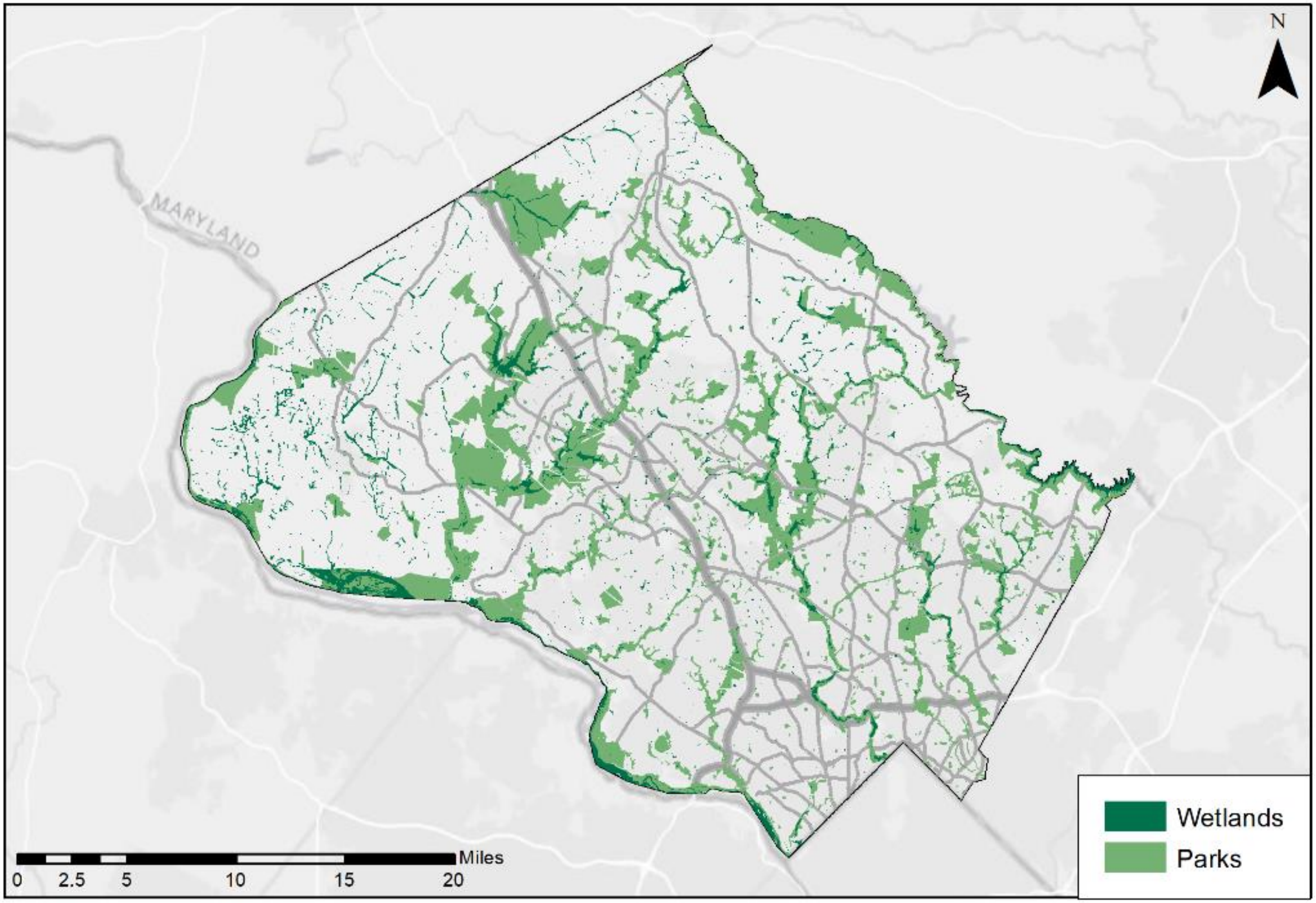

Figure 2-6. Parks and wetland assets in Montgomery County

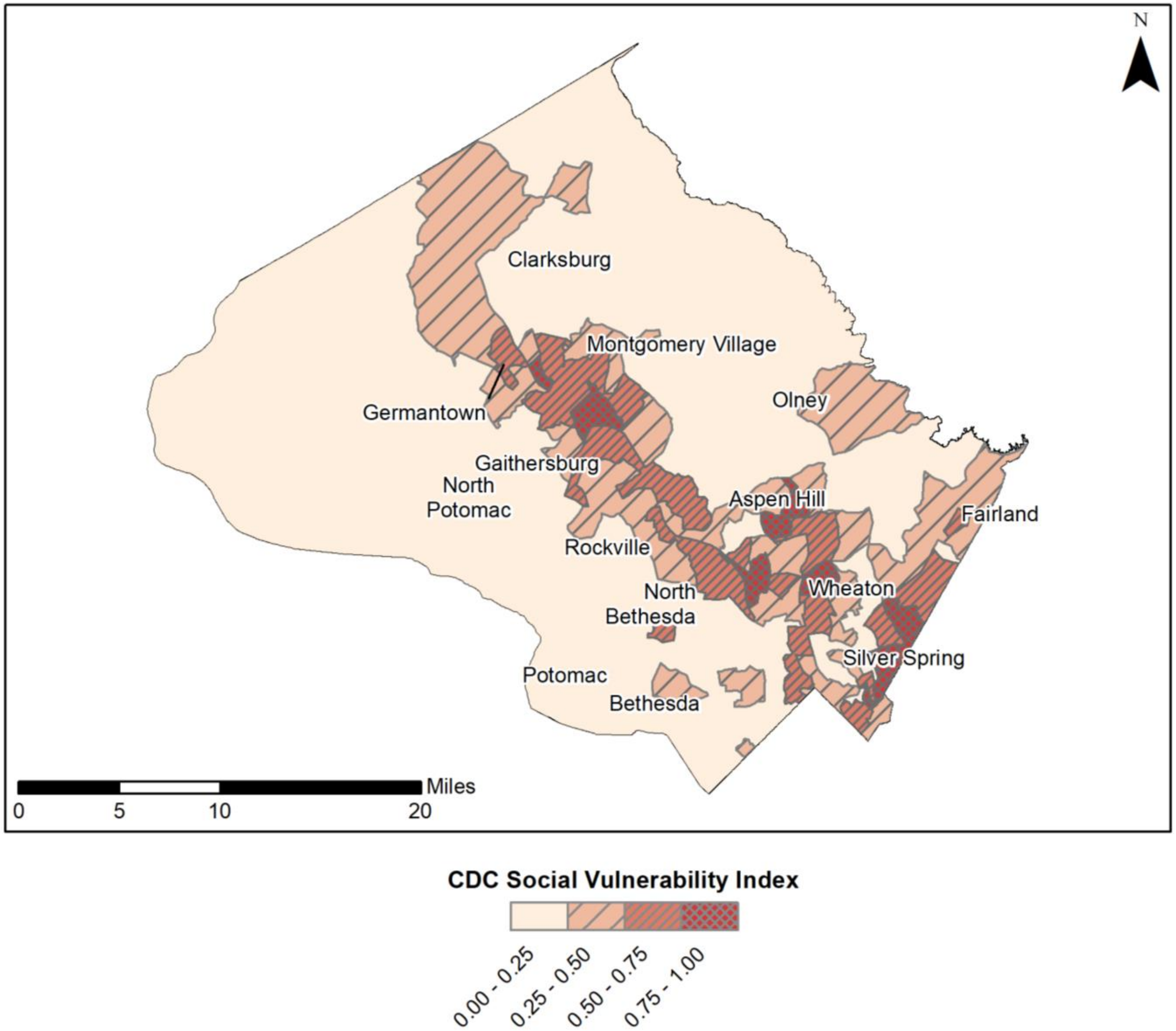

Figure 2-7. Social vulnerability in Montgomery County

3.0 Future Conditions Climate Assessment

The vulnerability assessment seeks to understand the impact of exposure of assets to natural hazards. For this study, the project team performed a statistical analysis of temperature and precipitation downscaled from general circulation model (GCM) output for two representative concentration pathways (RCP4.5 and RCP8.5) and four time horizons as shown in Table 3-1.

Table 3-1. Time Horizons for Future Conditions Climate Assessment

Time Horizon	Period of Analysis
Baseline (Historical)	1950-2005
2035	2005-2035
2050	2020-2050
2100	2070-2100

RCP8.5 is the “worst case” scenario included in the most recent Intergovernmental Panel on Climate Change (IPCC) set of scenarios, representing unabated emissions without any advances in technology or implementation of any climate action measures, while RCP4.5 represents a more optimistic “stabilization” scenario where atmospheric greenhouse gas concentrations increase until mid-century (~2050), after which concentrations remain stable until 2100.

The following sections discuss the methods used in the future conditions climate assessment as well as the results.

3.1 Methodology

The future conditions statistical analyses performed for this study were driven by gridded observed data and statistically downscaled GCM outputs developed by the Bureau of Reclamation. The dataset provides a high spatial resolution (6-kilometer x 6-kilometer) of daily downscaled precipitation data from 32 GCMs through the localized constructed analogs (LOCA) statistical downscaling method.[4]

AECOM conducted post-processing of the LOCA dataset to calculate future temperature, precipitation, and drought statistics using the Forecasting Local Extremes (FLEx) tool, a method developed by AECOM to retrieve and analyze statistics for a large number of downscaled GCMs and grid cells. After calculating the statistics for each grid cell, the future condition results were then mapped using a geographic information system (GIS) model framework to display statistics over the entire study area for further evaluation.

In the future conditions assessment, all 32 GCMs were equally weighted as an ensemble and analyzed to capture the full range of model variability, based on guidance from the IPCC that an ensemble average of several GCMs is expected to outperform the results of individual ensemble

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[4] *Pierce, D. W., Cayan, D. R., & Thrasher, B. L. (2014). Statistical Downscaling Using Localized Constructed Analogs (LOCA). Journal of Hydrometeorology, 2558-2585.*

members and provide an improved “best estimate” forecast.[5] Statistics were calculated for each grid cell separately and then spatially averaged (i.e., area-weighted) for the County using the jurisdictional boundary.

3.2 Temperature

The results from the temperature analysis are shown in Figure 3-1, Figure 3-2, Figure 3-3, and Figure 3-4. Average annual temperatures are projected to increase significantly, with the greatest changes in summer and autumn. Extreme heat is also projected to increase significantly, with the average annual number of days above 95°F and 105°F increasing by 56 and 9 days, respectively, by 2100 in RCP8.5. Additionally, the number of nights above 75°F is projected to increase from close to zero currently to 12 nights per year in RCP4.5 and 40 in RCP8.5 for 2100.

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[5] *IPCC. (2007). The Multi-Model Ensemble Approach. Retrieved June 2018, from IPCC Fourth Assessment Report: Climate Change 2007. Available: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch10s10-5-4-1.html*

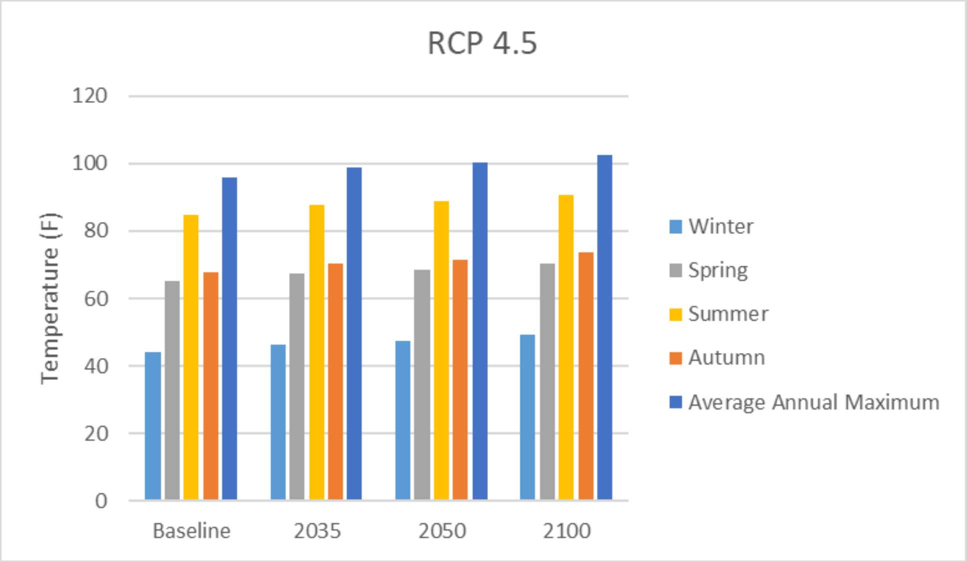

Figure 3-1. Future annual maximum and seasonal maximum temperature (RCP4.5)

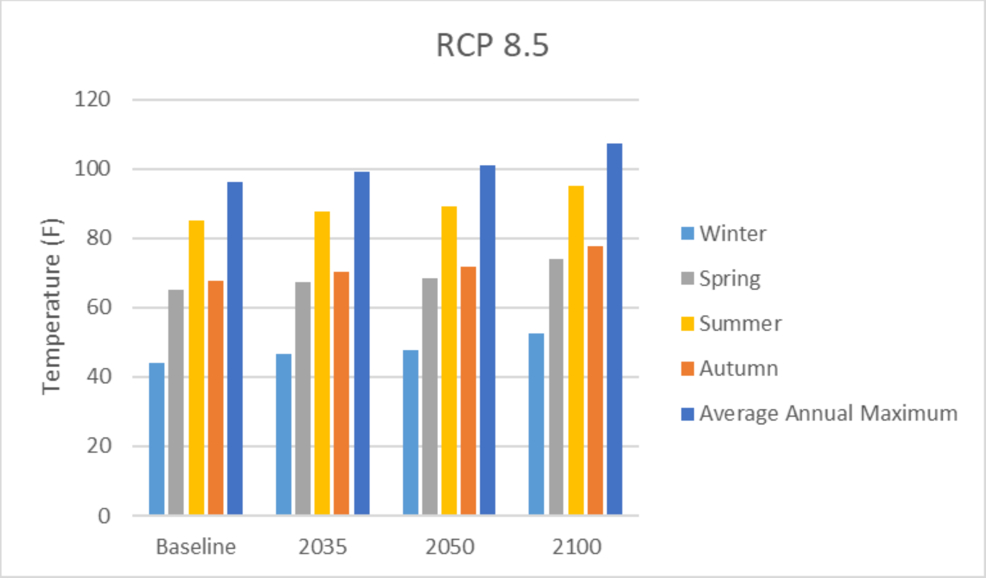

Figure 3-2. Future annual maximum and seasonal maximum temperature (RCP8.5)

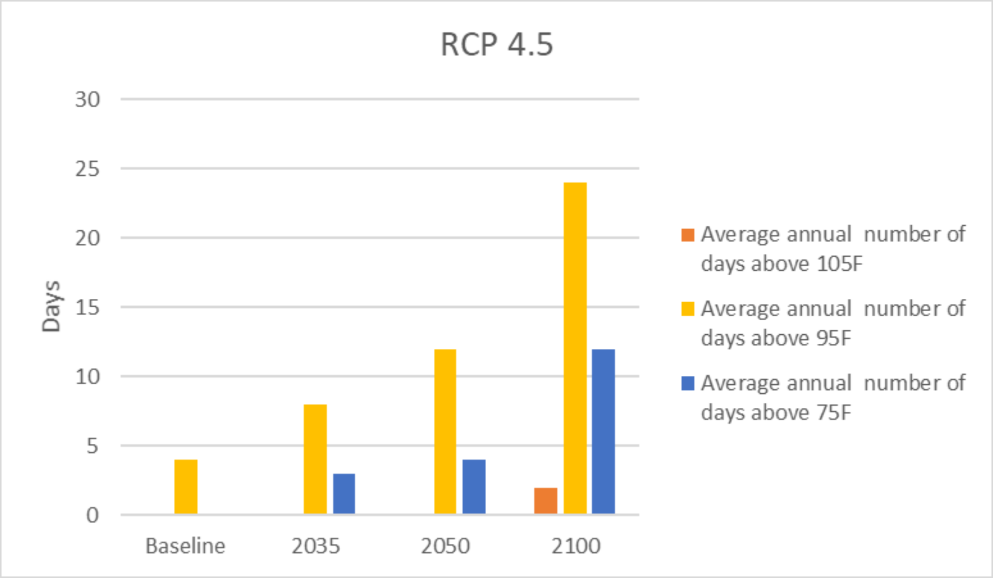

Figure 3-3. Future average annual number of high heat days (RCP4.5)

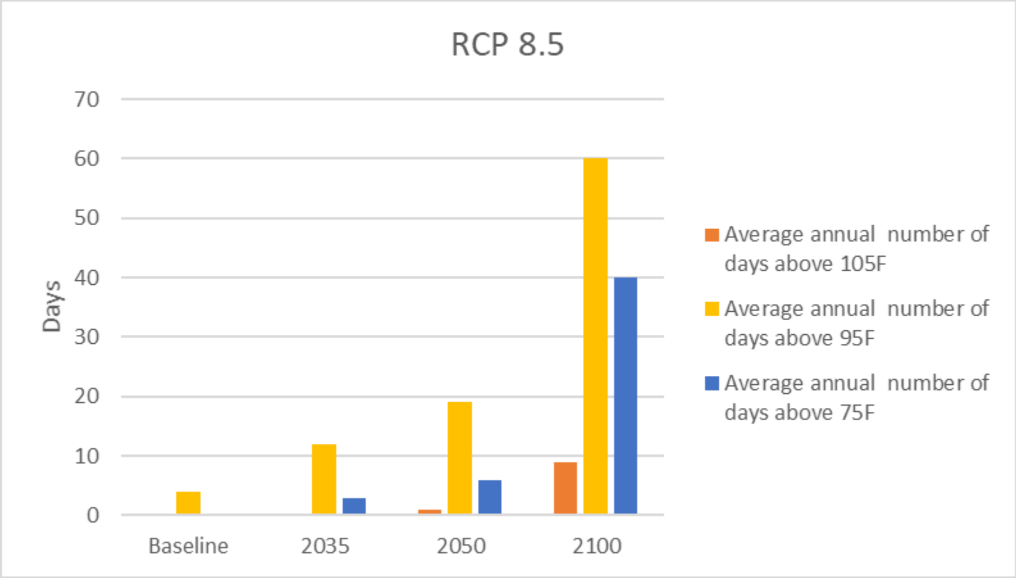

Figure 3-4. Future average annual number of extreme heat days (RCP8.5)

3.3 Drought

Future changes to drought were evaluated by calculating the monthly Palmer Drought Severity Index (PDSI) and then calculating the average annual number of months of mild, moderate, severe, and extreme drought. These types of drought are defined by the National Oceanic and Atmospheric Administration (NOAA) using the following PDSI values:

- PDSI 1 to -2 = Mild Drought
- PDSI -2 to -3 = Moderate Drought
- PDSI -3 to -4 = Severe Drought
- PDSI -4 or less = Extreme Drought

The results of the drought analysis are shown in Figure 3-5 and Figure 3-6. Mild drought conditions are projected to decrease or stay the same in both RCP4.5 and RCP8.5, while the annual risk of moderate, severe, and extreme drought is projected to increase significantly by the year 2100. Mild droughts decrease in frequency as harsher droughts occur more frequently instead.

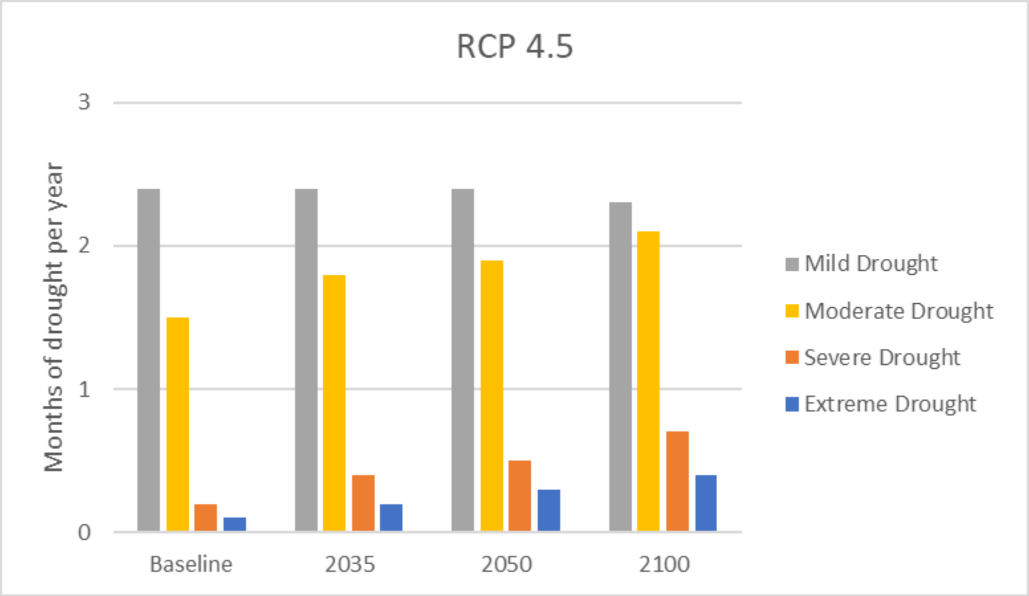

Figure 3-5. Future average annual number of months of drought using PDSI (RCP4.5)

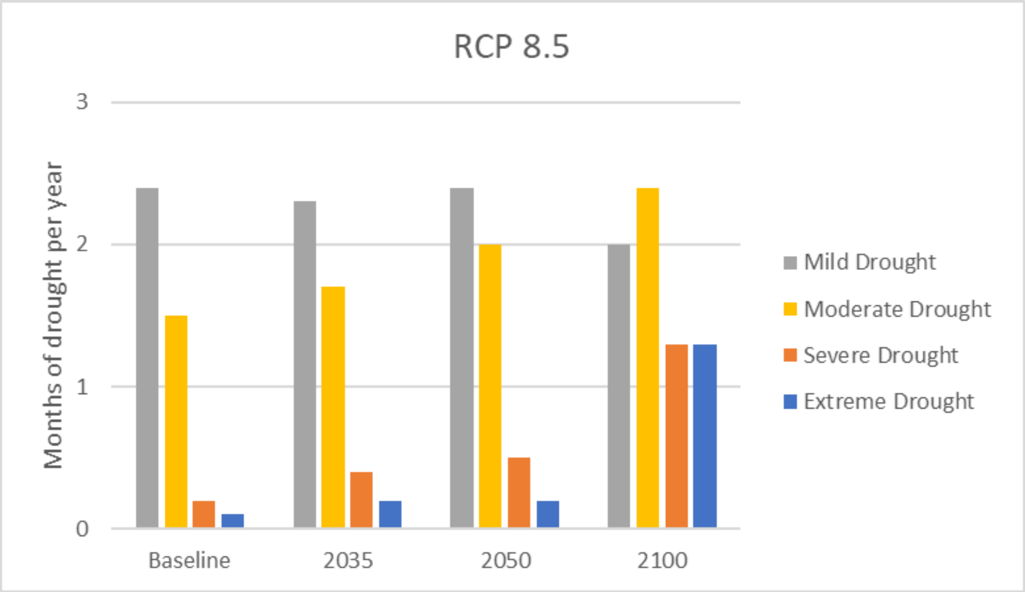

Figure 3-6. Future average annual number of months of drought using PDSI (RCP8.5)

3.4 Precipitation

The results from the precipitation analysis are shown in Figure 3-7, Figure 3-8, Figure 3-9, Figure 3-10, and Figure 3-11. Average annual total precipitation is projected to increase by approximately 6% in RCP4.5 and 9% in RCP8.5 by the end of the century. Figure 3-11 shows an increase of 5% and 7% for RCP4.5 and RCP8.5, respectively, in the percentage of total rainfall due to days with 95th percentile precipitation depth or greater, suggesting a shift to higher-intensity events in the future despite a small increase in overall annual rainfall.

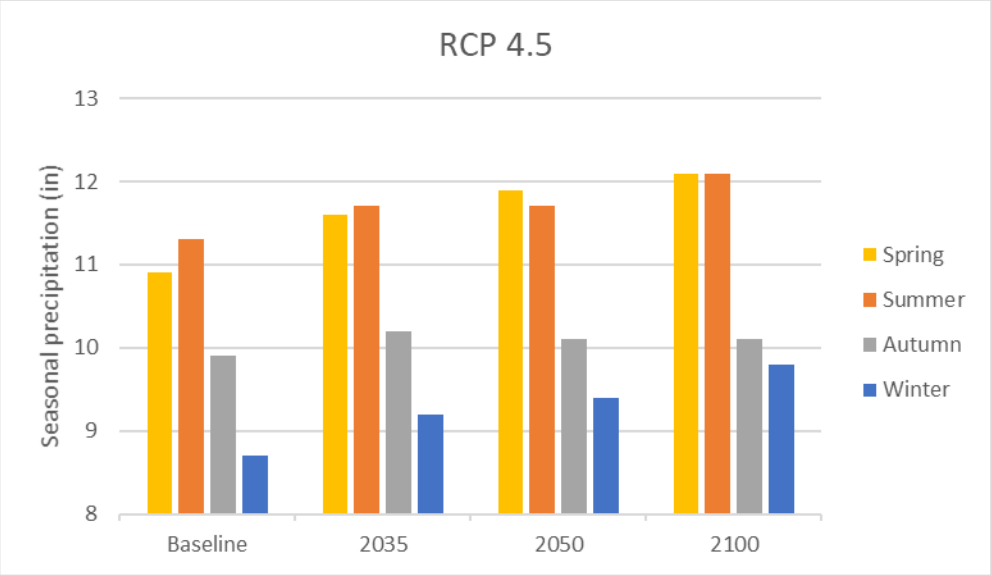

Figure 3-7. Future seasonal precipitation (RCP4.5)

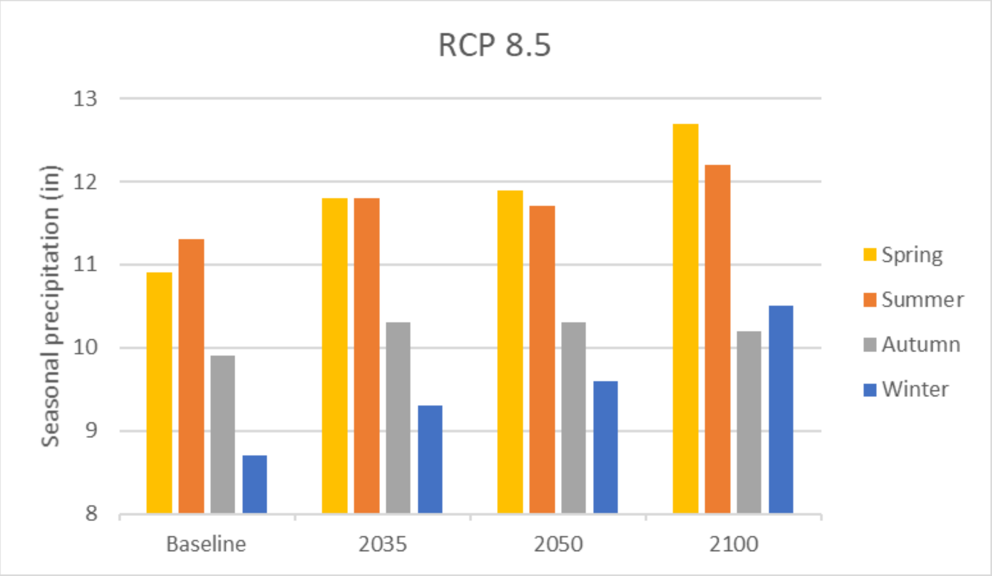

Figure 3-8. Future seasonal precipitation (RCP8.5)

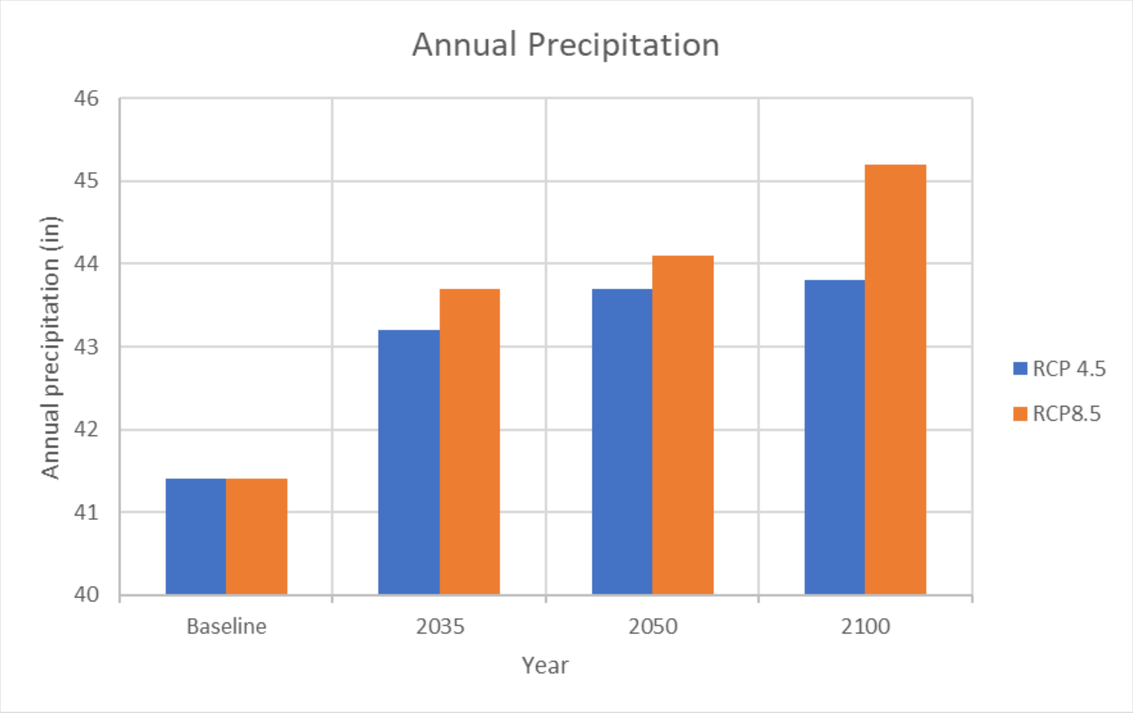

Figure 3-9. Future total annual precipitation

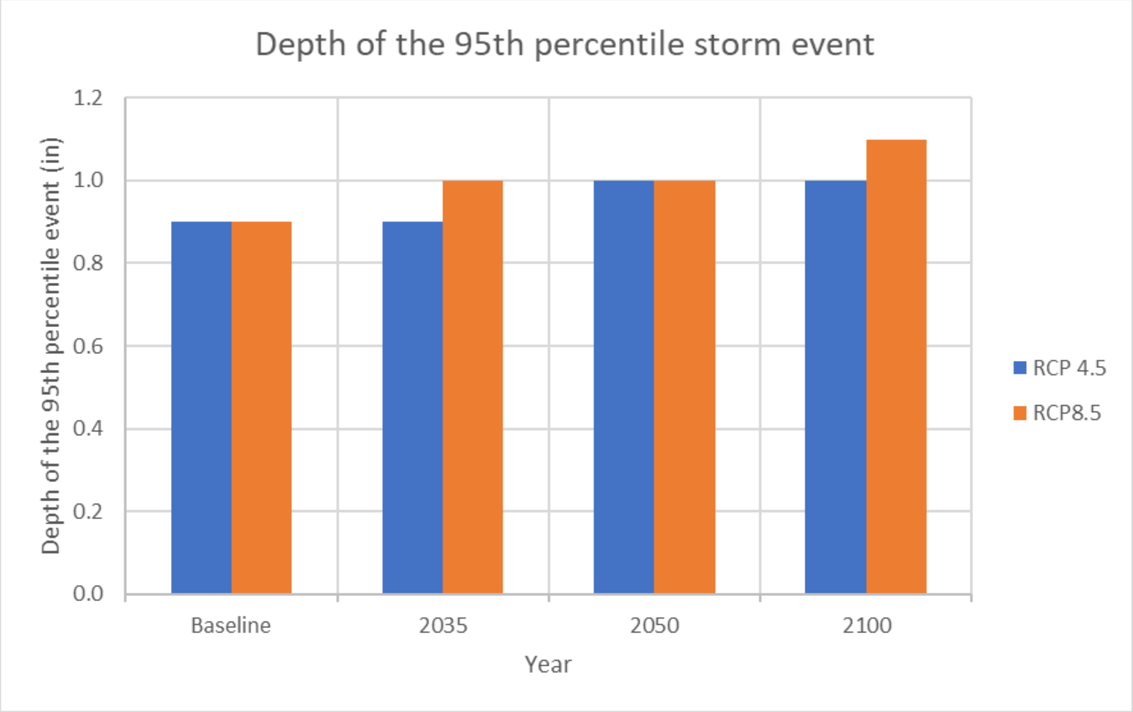

Figure 3-10. Future depth of the 95th-percentile storm event

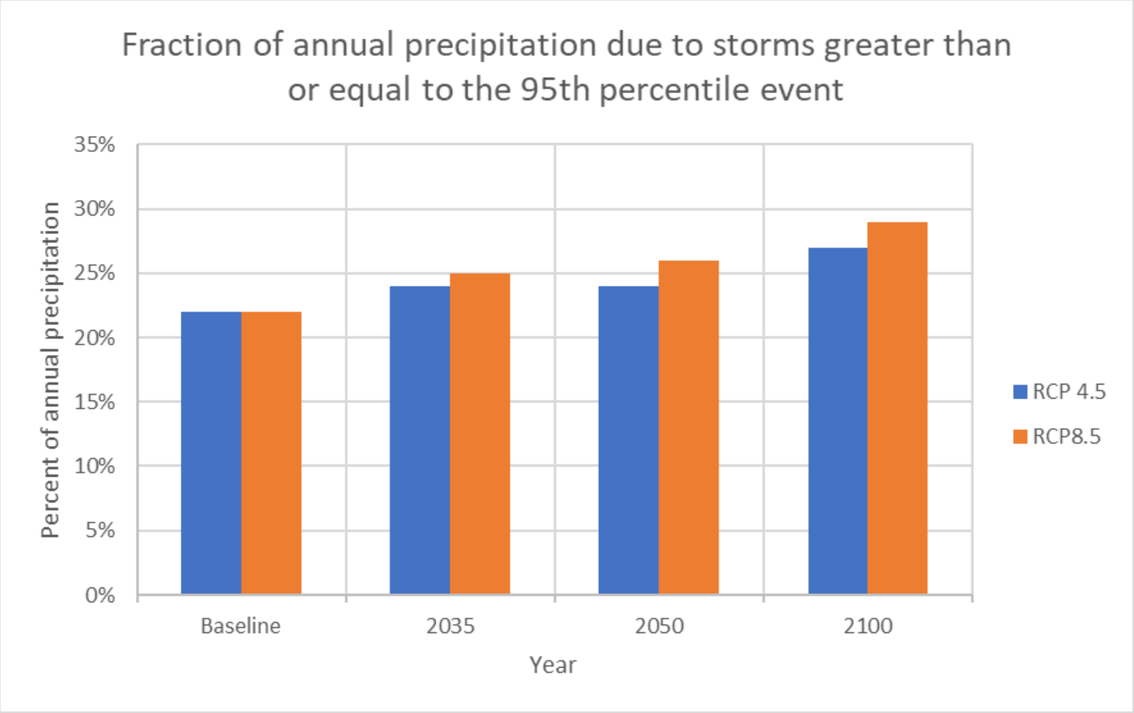

Figure 3-11. Fraction of annual precipitation due to storms greater than or equal to the 95th-percentile storm event

Return period events were estimated using larger windows for each future time horizon as shown in Table 3-2. The larger windows were selected in order to provide a larger sample size, which generally serves to improve the fit of the frequency analysis.

Table 3-2. Time Horizons for Future Conditions Frequency Analysis

Time Horizon	Period of Analysis
Baseline (Historical)	1950-2005
2035	1985-2035
2050	2000-2050
2100	2050-2100

Figure 3-12 and Figure 3-13 show the projected changes to return period storm depths for Montgomery County. Storm return period refers to average recurrence interval associated with a particular storm intensity and duration. For example, the 10-year, 24-hour storm has an average recurrence interval of 10 years and an annual probability of occurrence equal to 10% (1/10). The higher frequency events (1-year and 2-year storms) show very small increases in both scenarios and all time horizons, suggesting that the most common precipitation events will likely remain the same or increase slightly in total depth of rainfall. The less frequent events (10-year and 100-year storms) show somewhat greater increases, particularly in RCP8.5. As shown in Figure 3-12, the 100-year storm is projected to increase by 0.4 inches by 2050 and increase by 0.3 inches by 2100. This apparent decrease in intensity can be explained first, by considering the greater uncertainty associated with predicting low-frequency storm events and second, by understanding that RCP4.5 considers a “stabilization” scenario, suggesting that both 2050 and 2100 are likely to show similar increases (0.3 to 0.4 inches) in the RCP 4.5 scenario. In contrast, RCP8.5 (Figure 3-13) shows a clear upward trend in the 100-year storm through the end of the century, when an approximately 8% increase is projected for Montgomery County.

It is important to note that the downscaled GCM precipitation output only provides simulated daily total values. Because of the Clausius-Clapeyron relation between temperature and pressure, as temperature increases the atmosphere can hold more moisture, which leads to higher-intensity events. Thus, while 24-hour higher-frequency storm events (1-year, 2-year, and 10-year) are not projected to increase significantly in total depth of rainfall, it is very likely that the way the sub-daily precipitation events will occur could result in increased flash flood risk. The time resolution of the FLEx model output does not provide the level of detail to quantify changes to short-duration (< 24-hour) rainfall intensities.

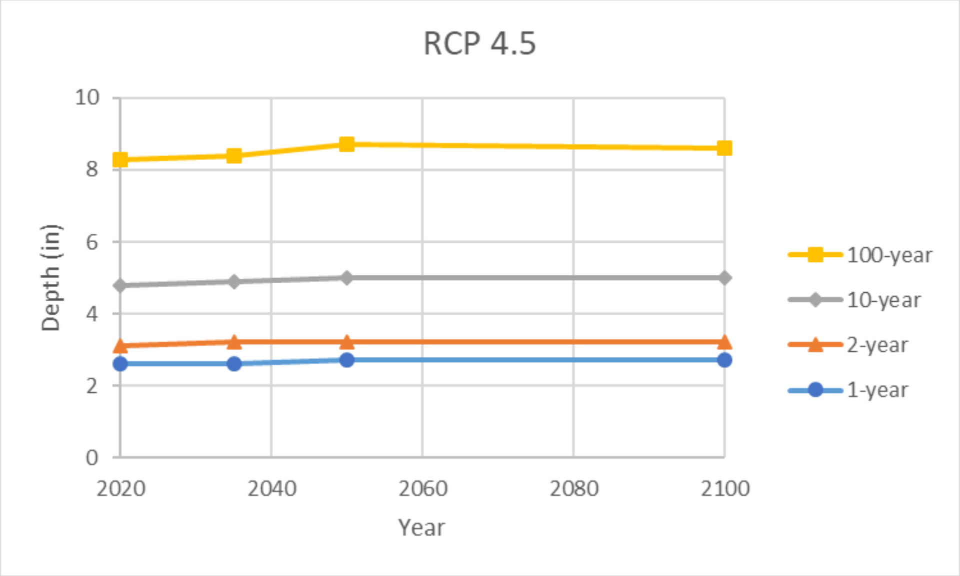

Figure 3-12. Future changes to return period storms (RCP4.5)

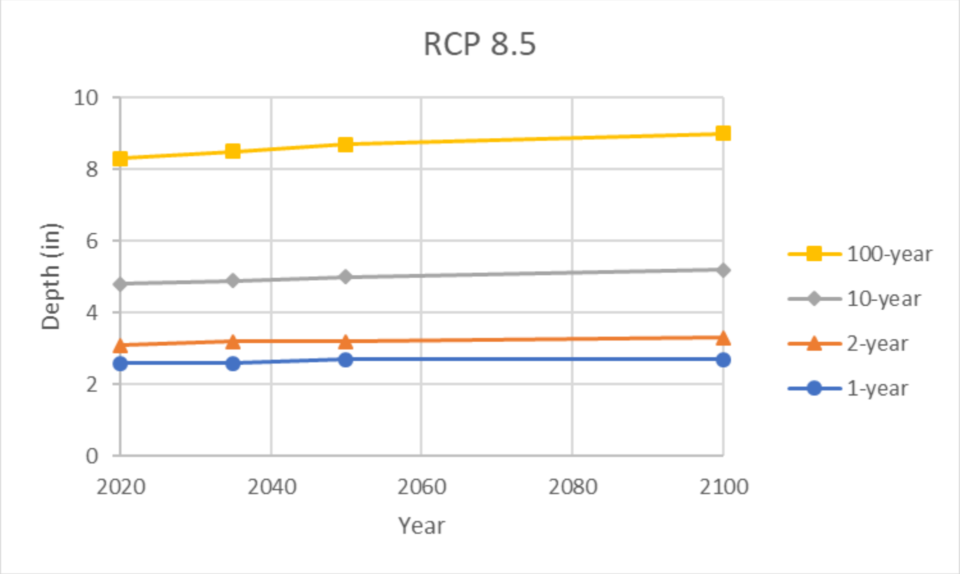

Figure 3-13. Future changes to return period storms (RCP8.5)

3.5 High Winds

Hurricanes, tornadoes, and derechos (straight-line wind events) could result in damage due to high-speed winds. These are not included in the FLEx tool outputs because of limited data of future wind speed predictions. Current wind data used for this analysis was based on the American Society of Civil Engineers' publication ASCE 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. The document provides building design guidance regarding structural loads including winds. The guidance is available for the following four risk categories:

- Risk Category I – buildings and other structures that are a low hazard to human life in the event of failure (e.g., minor storage facilities)
- Risk Category II – buildings and other structures except those listed in the other risk categories (e.g., single-family dwellings)
- Risk Category III – buildings and other structures that represent a substantial hazard to human life in the event of failure (e.g., buildings with an occupant load great than 300 people, schools, and water treatment facilities)
- Risk Category IV – buildings and other structures designed as an essential facility (e.g., fire stations, police stations, designated emergency preparedness facilities, and aviation control towers)

The design wind speeds for Montgomery County are listed in Table 3-3.

Table 3-3. Design Wind Speeds for Montgomery County

Risk Category	Design Wind Speed
I	105 mph
II	115 mph
III	119 mph
IV	124 mph

Although a direct evaluation of future wind conditions was not performed as a part of this analysis, regional projections and recent observations suggest that hurricanes and tropical storms, which bring with them high winds, are expected to increase in both frequency and intensity.[6]

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[6] *Dupigny-Giroux, L.A., E.L. Mecray, M.D. Lemcke-Stampone, G.A. Hodgkins, E.E. Lentz, K.E. Mills, E.D. Lane, R. Miller, D.Y. Hollinger, W.D. Solecki, G.A. Wellenius, P.E. Sheffield, A.B. MacDonald, and C. Caldwell, 2018: Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18.*

3.6 Uncertainty and Spatial Distribution of Climate Hazards

In any robust analysis, it is necessary to consider possibilities for error and uncertainty. In general, extreme temperature and precipitation events involve significant uncertainty. Additionally, extreme precipitation is more difficult to represent in GCMs than extreme temperature due to limited observational data as well as the fact that model spatial resolutions are typically too coarse to resolve localized precipitation events.[7] Statistical downscaling uses historical spatial distributions of temperature and precipitation to improve GCM spatial resolution, though this approach is based on the fundamental assumption that the spatial distribution of past events is representative of the future.

Despite the limitations of climate models and the inherent uncertainty in projecting the future climate, the results of the future climate assessment remain an important window into a probable future for Montgomery County and provide an invaluable resource to guide planners and decisionmakers in preparing the community to face the certainly increasing climate hazards of the future.

In addition to the County-wide average climate statistics presented in Section 3.0 of this report, the statistically downscaled GCM output used in this analysis has high enough spatial resolution to provide a glimpse into the possible spatial distribution of climate hazards throughout the County. The following section (Section 4.0) includes several figures showing the spatial distribution of precipitation, temperature, and drought changes. Although this spatial data is useful for identifying especially vulnerable areas in the County at a high level, it is important to acknowledge that spatial distribution of precipitation can be highly variable and difficult to model and predict, while temperature projections are generally considered to be more reliable and spatially consistent.[8]

Statistically downscaled GCM output relies on finding historical high-resolution spatial distributions of precipitation and temperature on a local scale that are analogous to the low-resolution GCM output that is calculated on a global scale. In other words, historical spatial distributions of temperature and precipitation form the basis of these projections and, to some extent, limit the results. Using County-wide average values of the projected climate hazards is the preferred approach for avoiding a false sense of precision.

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[7] *Flato, G., J. Marotzke, B. Abiodun, P. Braconnot, S.C. Chou, W. Collins, P. Cox, F. Driouech, S. Emori, V. Eyring, C. Forest, P. Gleckler, E. Guilyardi, C. Jakob, V. Kattsov, C. Reason and M. Rummukainen, 2013: Evaluation of Climate Models. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*

[8] *Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Available: https://www.ipcc.ch/report/ar5/wg1/. Accessed November 18, 2020.*

4.0 Results of the Vulnerability Assessment

A typical natural hazard vulnerability assessment analyzes the threat to individual assets in three ways, by looking at: (1) exposure to the hazard, (2) sensitivity of the asset to that hazard, and (3) adaptive capacity of the particular asset. This vulnerability assessment is organized around the asset categories discussed in Section 2.0, and each asset category is assessed in regard to exposure, sensitivity, and adaptive capacity to each major natural hazard in the County. Assets are already exposed to these hazards; however, climate change is expected to intensify the severity of hazards.

The following sections describe the exposure of the assets to extreme precipitation, drought, and high winds. A discussion on sensitivity is also provided. In this report, sensitivity describes the capacity of the system to absorb impacts without suffering significant harm. Finally, the adaptive capacity of the asset is discussed. Adaptive capacity is the capability of the asset to cope with the hazard, for example through flexibility and redundancy to mitigate the negative impacts from the hazards.

4.1 Transportation

Hazard Exposure

Extreme Precipitation

The Federal Emergency Management Agency (FEMA) has modeled and mapped flood risks for the 100-year recurrence interval[9] and the Maryland-National Capital Park and Planning Commission (M-NCPPC) has mapped additional floodplains based on smaller basin sizes than in the FEMA study. Based on the existing floodplain data, there are approximately 1,600 road crossings over these floodplains with the County. The Maryland Department of Transportation (MDOT) keeps a database of frequently flooded roads, which includes 18 locations within the County (pictured in Figure 4-1) along with other known frequently flooded roads and the floodplains. Changes to the 10-year, 24-hour and 100-year, 24-hour return period storms are shown in Figure 4-2 and Figure 4-3, respectively. In general, extreme precipitation events are projected to increase in intensity, with the greatest increases corresponding to the most extreme events. Therefore, in the absence of corrective measures, more flooded road crossings, and more frequent and longer-duration road closures, are expected. Table 4-1 lists Ride On bus routes and bikeways that are also currently impacted by stormwater flooding. Localized flooding can disrupt operation of all modes of transport.

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[9] *Federal Emergency Management Agency, 2006. Flood Insurance Study: Montgomery County, Maryland And Incorporated Areas.*

Table 4-1. Ride On Bus Routes and Bikeways Impacted by Frequently Flooded Roads

Ride On Bus Routes Impacted by Frequently Flooded Roads
8-Silver Spring-Wheaton
10-Twinbrook Station-Hillandale
21-Silver Spring-Briggs Chaney P&R
22-Silver Spring-Hillandale
26-Montgomery Mall-Glenmont
29-Bethesda-Glen Echo-Friendship Hghts
33-Glenmont-Medical Center
34-Aspen Hill-Friendship Heights
36-Bethesda-Potomac-via Hillandale
38-Wheaton-White Flint Station
48-Wheaton-Rockville
52-Olney-Mont. General Hosp.-Rockv.
53-Shady Grove-Glenmont
61-Shady Grove-Germantown Transit
71-Shady Grove-Kingsview P & R
75-Clarksburg Correctional-Germantown
78-Shady Grove-Kingsview P & R
90-Shady Grove-Damascus
L8-Aspen Hill-Friendship Heights
T2-Rockville-Friendship Heights
Bikeways Impacted by Frequently Flooded Roads
Beach Drive
Blue Mash Trail
Bradley Blvd
C & O Canal Towpath
Connecticut Ave
Dennis Ave
Emory Ln
Falls Rd
Frederick Rd
Glenhaven Dr
Gold Mine Rd
Gridley La
ICC Trail
Riffle Ford Road
River Rd
Rock Creek Trail
Sligo Creek Trail
Veirs Mill Rd

Extreme Heat

The transportation system within Montgomery County will be exposed to extreme heat. Figure 4-4 shows the increase in the number of days in a year that are expected to be above 95°F for the years 2035, 2050, and 2100. The RCP4.5 and 8.5 scenarios are presented to see the projected range for these projections. Direct exposure to hot ambient temperatures has a negative impact on assets and people.

Drought

Drought is not considered a notable hazard to transportation assets.

High Winds

Transportation assets will likely have increased exposure to high winds and the effects thereof. All modes can be affected, but especially public, private, and military airports in the County

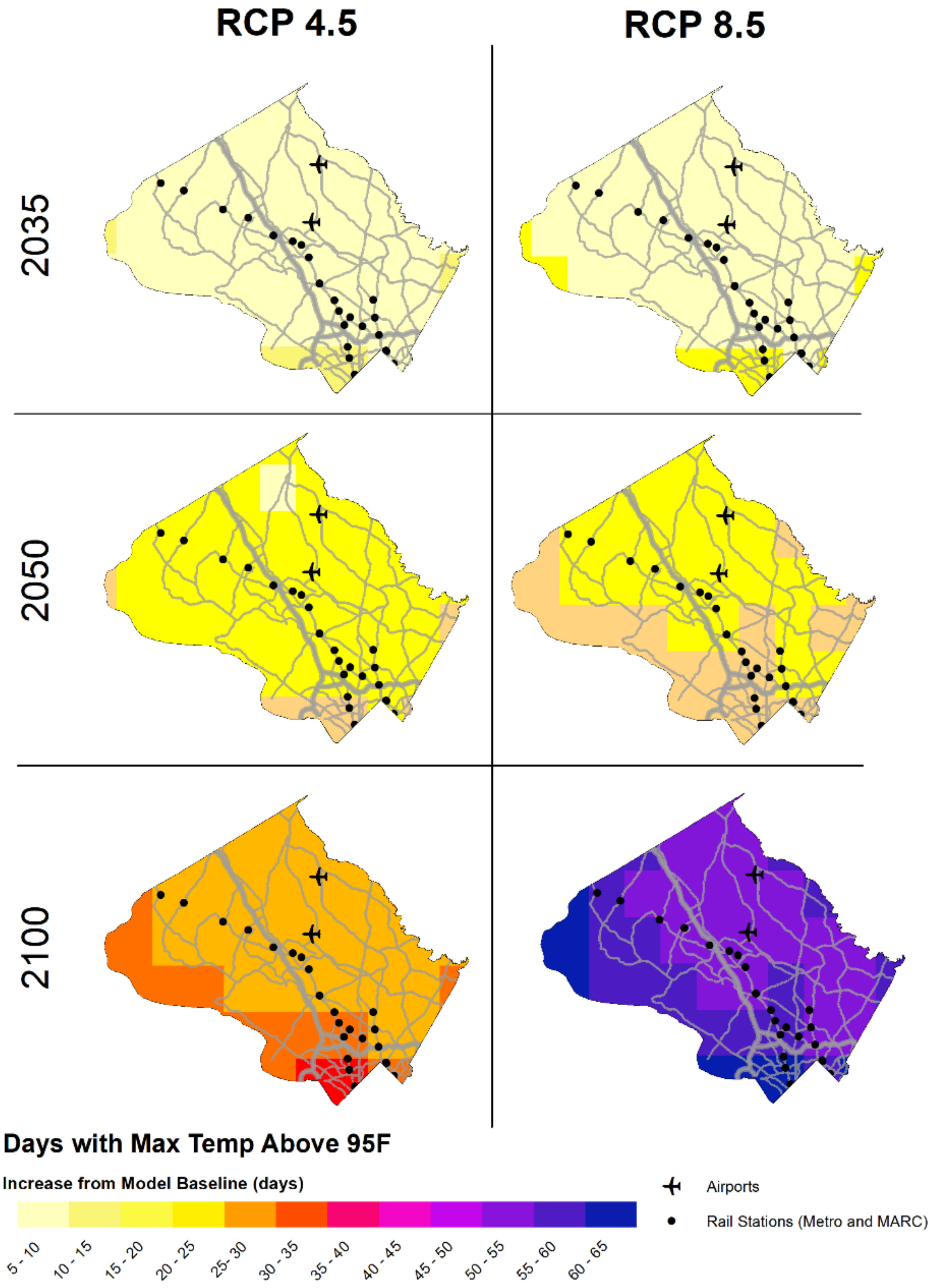
RCP 4.5
RCP 8.5
2035
2050
2100
Days with Max Temp Above 95F
Increase from Model Baseline (days)
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
Airports
Rail Stations (Metro and MARC)

Figure 4-4

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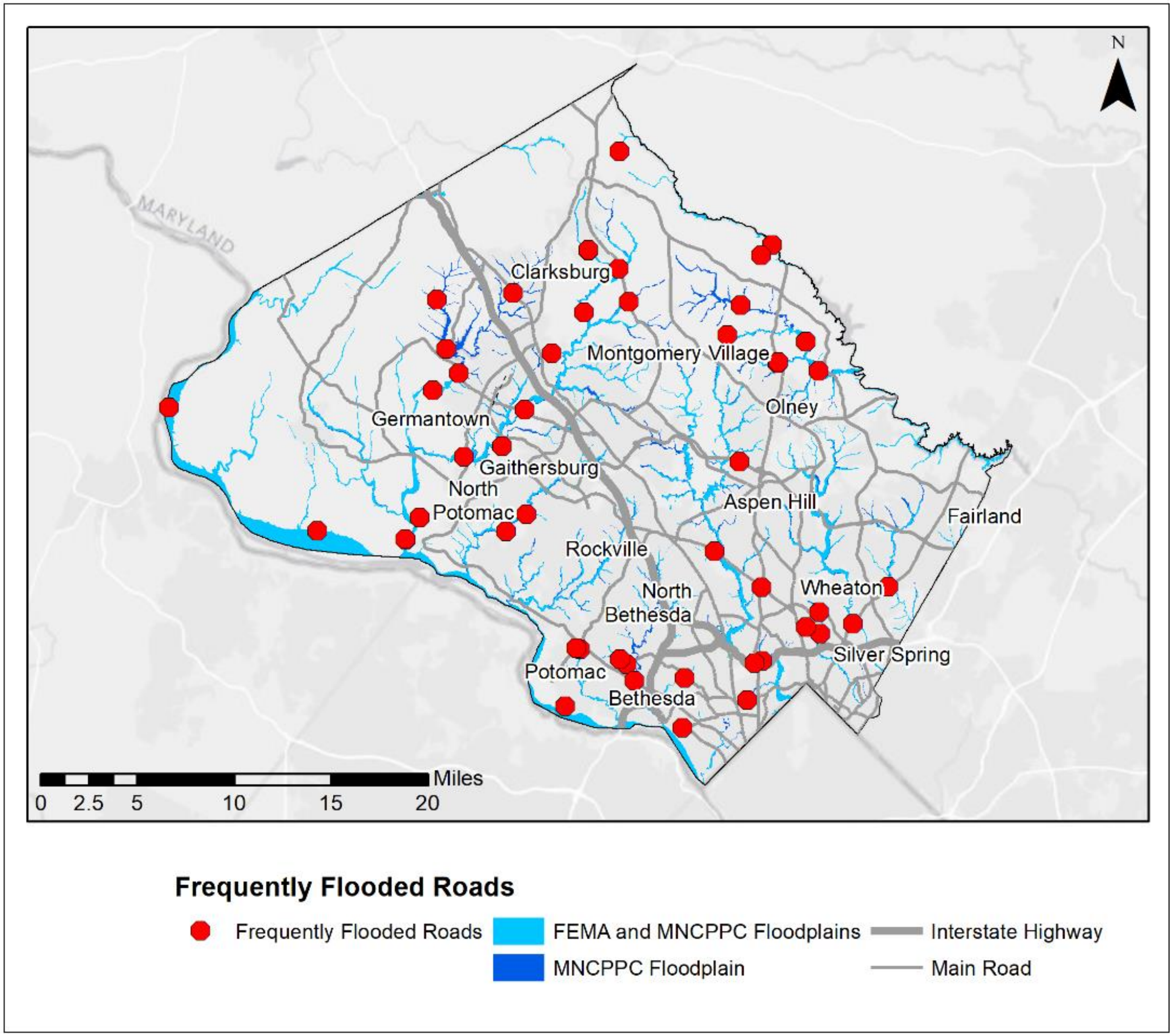

Figure 4-1 Frequently flooded roads with FEMA and M-NCPPC floodplains

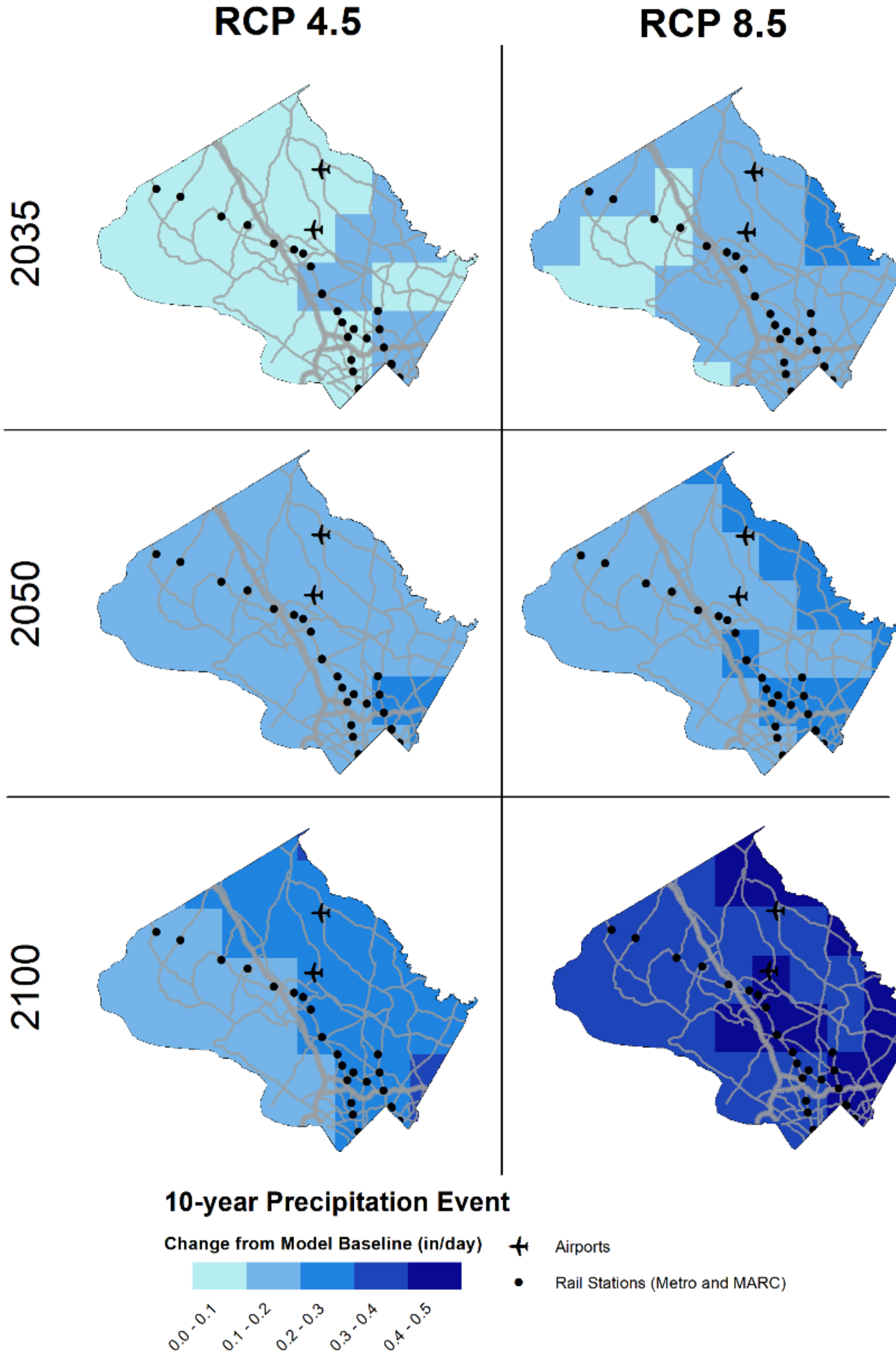

Figure 4-2. Change over the baseline for the 10-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for transportation assets

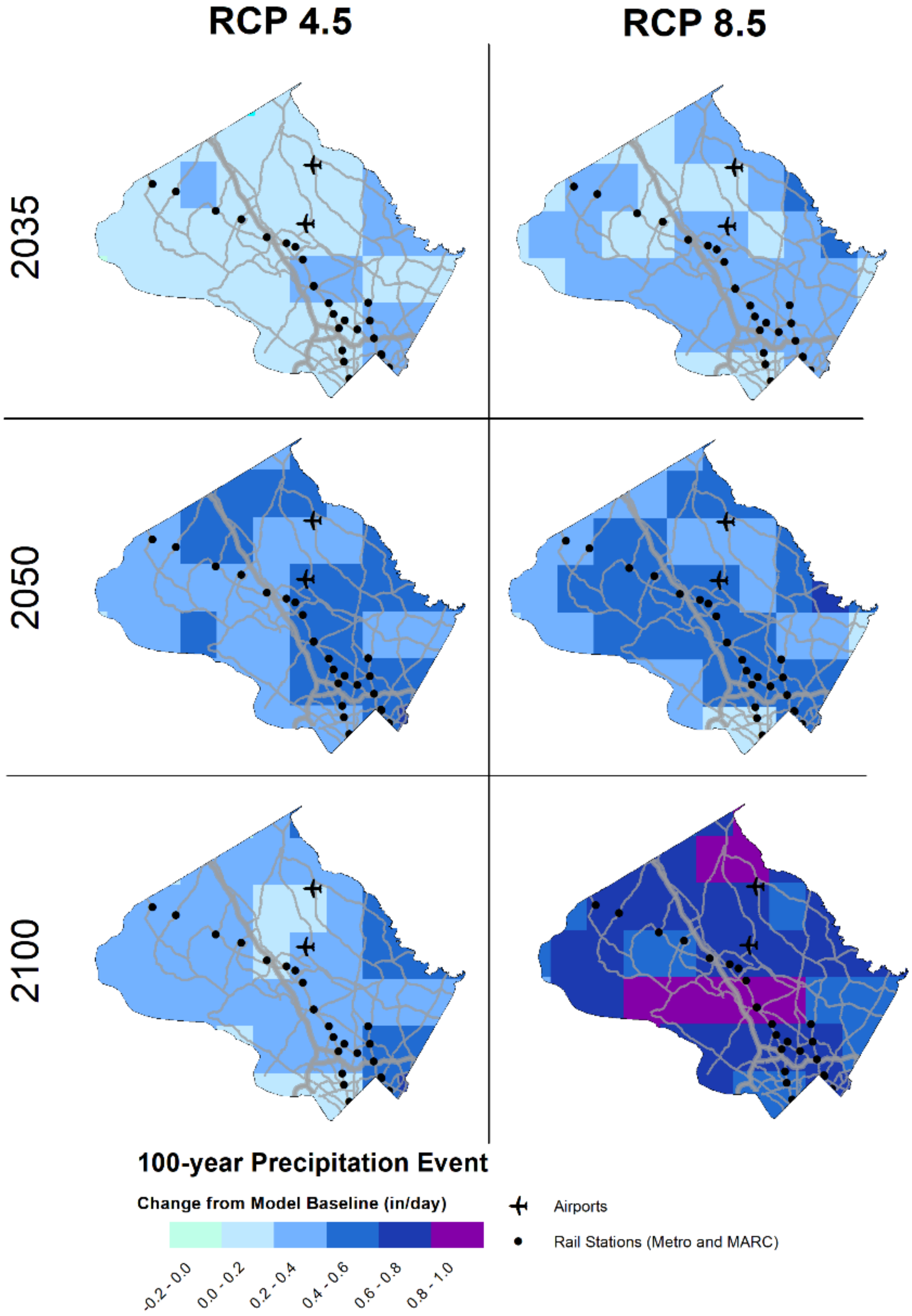

Figure 4-3 Change over the baseline for the 100-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for transportation assets

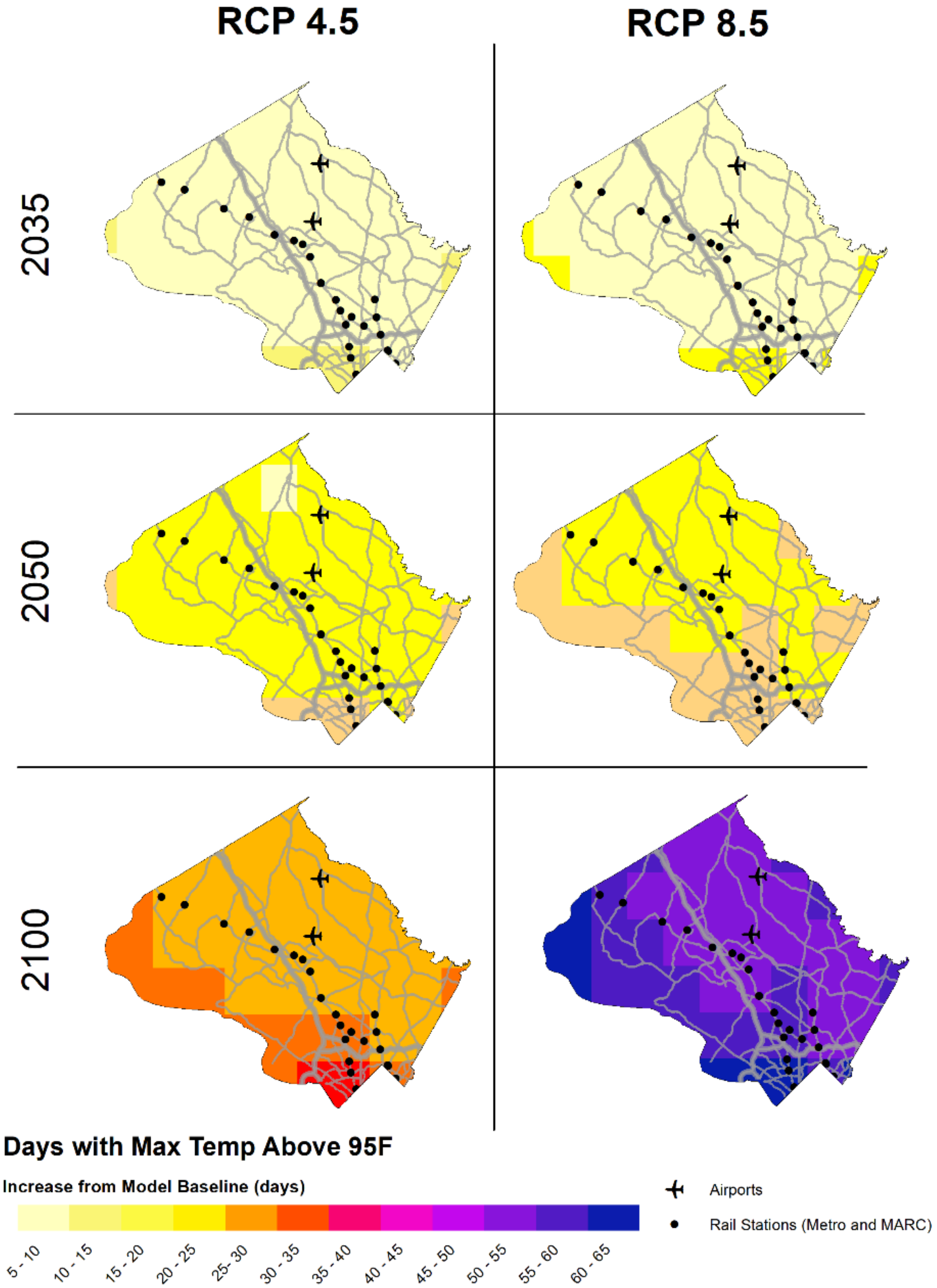

Figure 4-4. Increase in the number of days >95°F per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5), showing roads, airports, and rail stations

Sensitivity

During a storm that took place on July 8, 2019, Montgomery County Fire and Rescue Services carried out more than 60 water rescues. One of the incidents involved a washed out roadway that stranded a community in Potomac.

Source: *https://wjla.com/news/local/several-active-water-rescues-underway-in-montgomery-co*

Floods can wash out roads, bridges, and other structural components, forcing detours that can cause congestion and traffic delays, impacting the overall function of the system. Increased frequency and intensity of flooding events will likely have a compounding impact that will decrease the service life of structural system components over time. Electrical components are particularly sensitive to flooding and, if exposed, can create deadly hazards and lengthy system interruptions to public transportation. Post-event debris cleanup is costly and time consuming. Driving through floodwater is dangerous and results in deaths for dozens of people in the U.S. annually.[10] Flooded bike paths significantly affect bike commuters, and may expose riders when they use detours along congested and dangerous roads.

Extreme heat can result in unsafe aircraft operations and the closure of airports. At very high temperatures, asphalt roads soften, concrete roads can crack apart, and train rails expand and buckle. Extreme heat can make bus and train stops uncomfortable or even dangerous for people waiting to take public transportation and may exacerbate health conditions. Transportation employees that are frequently required to work outdoors to perform construction, operations, and maintenance may be limited or unable to perform their duties. In general, more power will be used for air conditioning in airports, buses, and trains, and consistently higher demands on these systems will result in increased maintenance costs and possibly failures. High temperatures could make bike commuting unsafe.

High winds can stop bus and rail traffic, cause downed trees to block streets and bike routes, and make driving hazardous. Neither bus nor rail will be operating during tropical cyclones, which will be more frequent and severe; therefore, there will be impacts on service and revenue. These events may disrupt operations at the public, private, and military airports in the County, as well as heliports, which could impact medical emergency transport to hospitals. High winds affect sustainable forms of mobility such as bicycling and walking.

Transportation assets are not sensitive to drought.

Adaptive Capacity

Some areas of the County transportation network have little or no adaptive capacity where flooding of streams and insufficient drainage capacity associated with extreme precipitation events is a problem even in existing conditions. Retrofitting existing structures and adjusting design requirements of new structures can improve the system's ability to adapt to increased precipitation. Adaptive capacity also includes efficient detours for flooded roads and sheltered waiting areas that keep temperatures lower and minimize sun exposure for transit users on high heat days. Transportation workers may need to adjust schedules to work nights and early mornings, when temperatures will be lower.

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[10] *Driving flood fatalities for 2010-2020. Available: https://www.weather.gov/arx/usflood*

4.2 Critical and County Resources

Hazard Exposure

Extreme Precipitation

Of the 435 buildings included as critical and County resources, none of the structures are in the FEMA floodplain. However, as extreme precipitation increases, expansions of the floodplain are likely. Although this vulnerability assessment did not estimate the extent of floodplains in the future, the current floodplain was buffered by 500 feet to identify buildings close enough that could potentially be impacted by an expanded floodplain.[11] This information is provided in Table 4-2. A map of the critical and County resources within the floodplain or up to 500 feet from the floodplain is shown in Figure 4-5.

Table 4-2. Critical and County Resources within 500 feet of the FEMA Floodplain

Critical and County Asset Types	Total Structures	Buildings within 500 feet of FEMA Floodplain
High Schools	25	1
Middle Schools	40	2
Elementary Schools	135	8
Recreation Centers	42	3
Libraries	24	0
HHS Nursing Homes	34	4
Police Stations	6	2
Fire Stations	38	4
Hospitals	10	3
Emergency Shelters	28	0
Multi-Agency Buildings	53	1
TOTAL	**435**	**28**

Overland flooding caused by drainage deficiencies is also a potential risk for critical and County assets as extreme precipitation increases. This type of flooding is closely tied to the stormwater management system, but buildings that are in areas of the County with the highest projected increase in extreme precipitation are more likely to experience overland flooding. The change over the baseline for the 10-year and 100-year rainfall events for three future years and two climate scenarios is shown in Figure 4-6 and Figure 4-7, respectively.

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[11] *Note: This analysis does not consider topography and likely overestimates the number of assets that may be impacted by riverine flooding.*

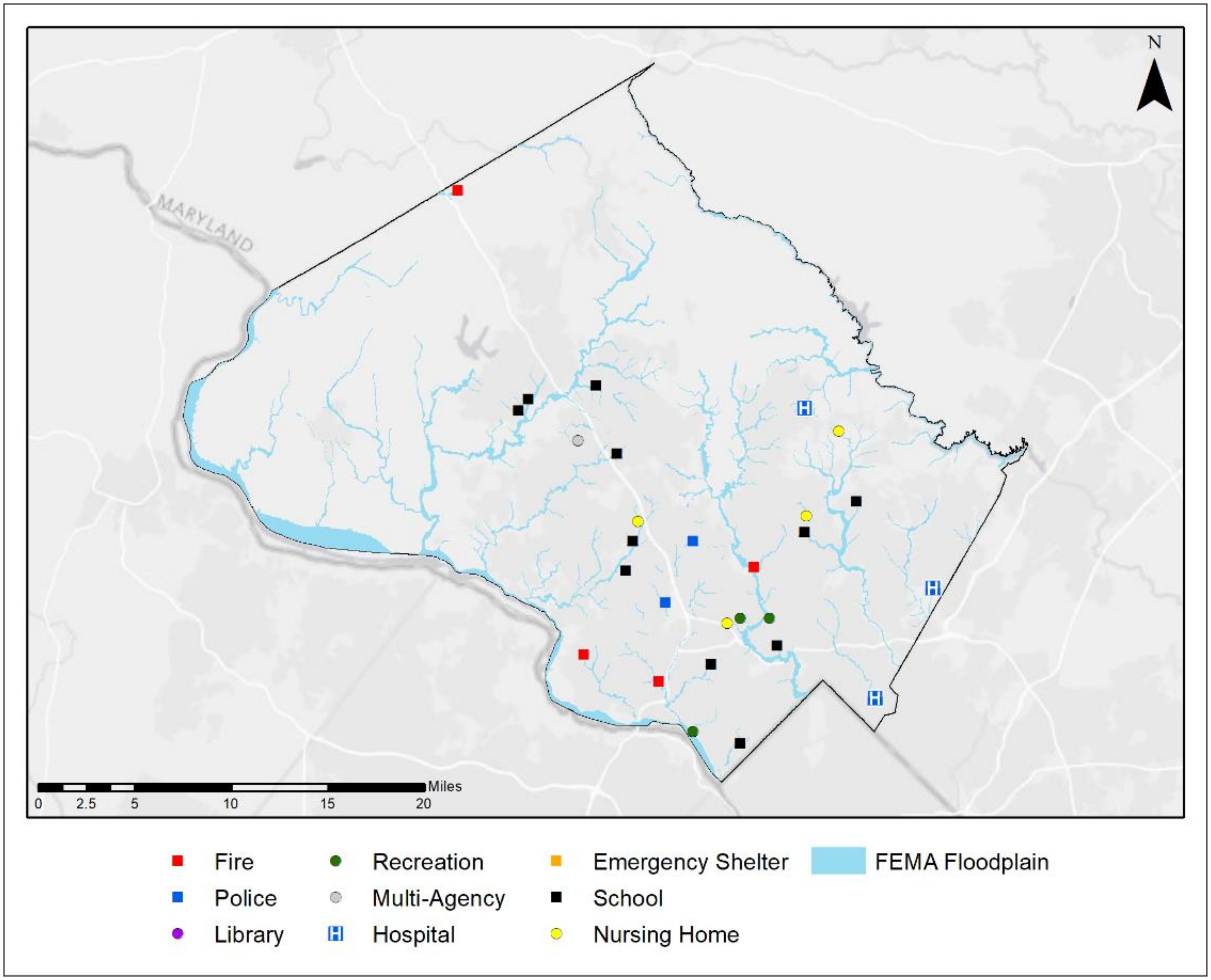

Figure 4-5. Critical and County resources within 500 feet of the FEMA floodplain

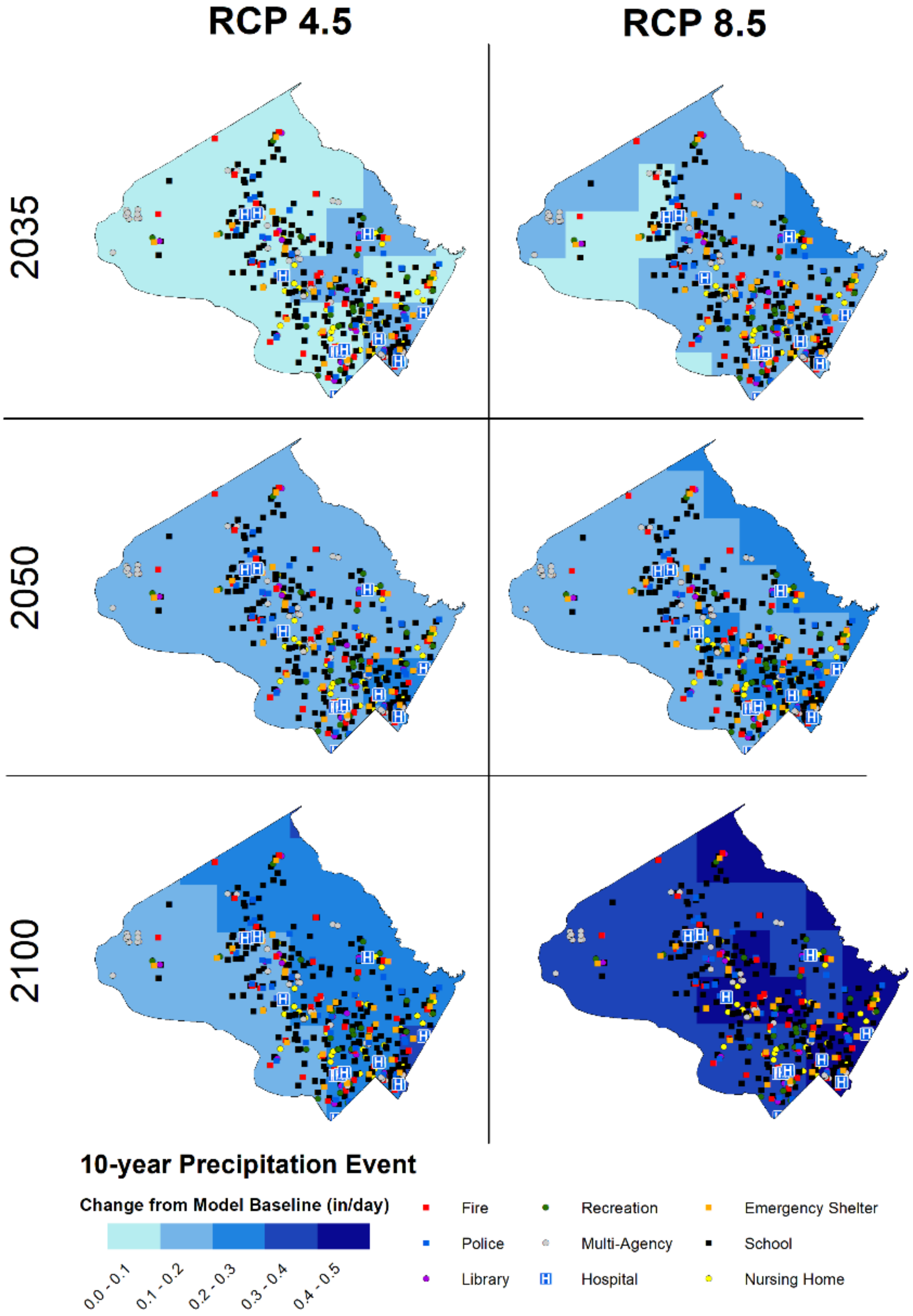

Figure 4-6. Change over the baseline for the 10-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for critical and County resources

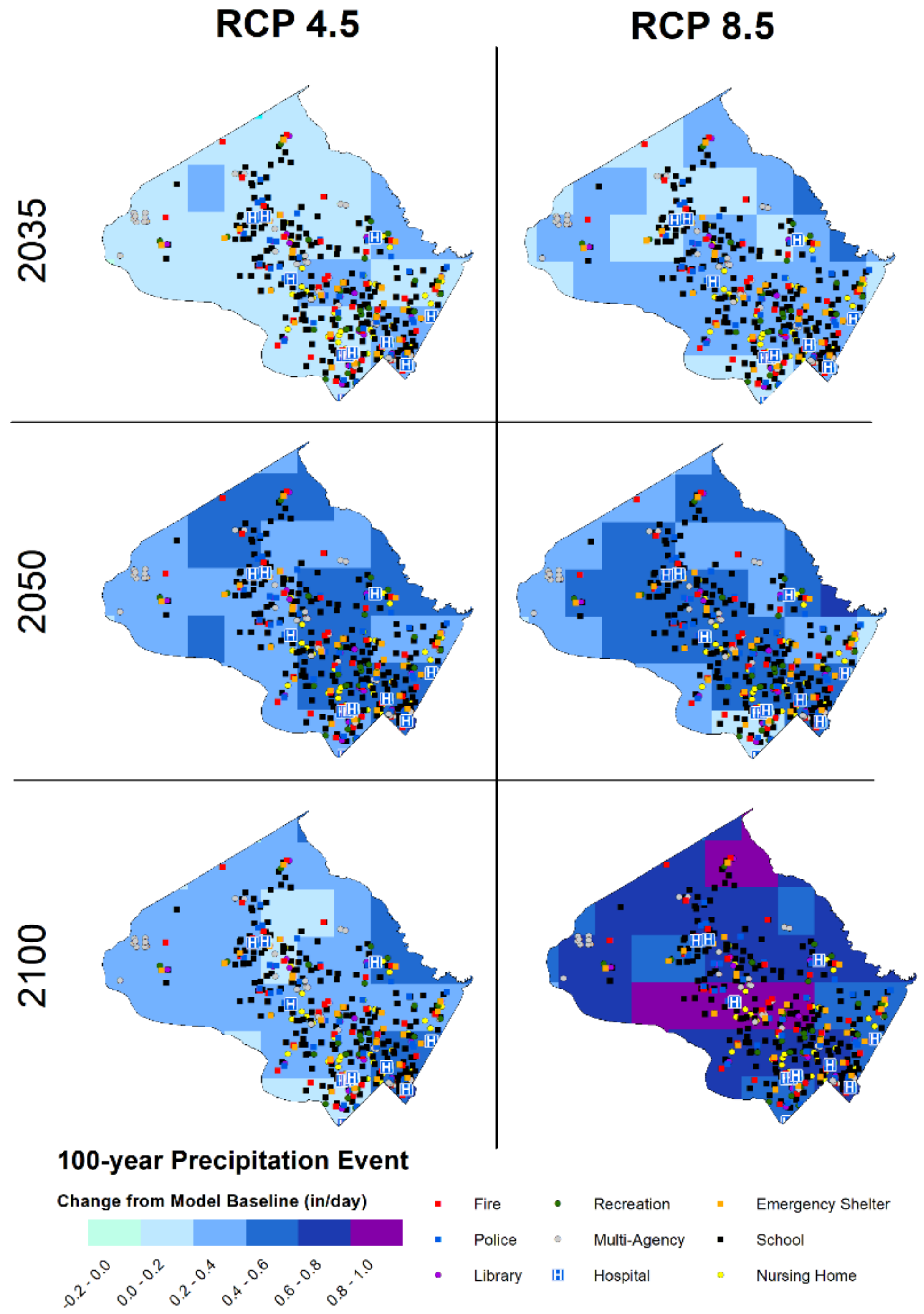

Figure 4-7 Change over the baseline for the 100-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for critical and County resources

Extreme Heat

Extreme heat exposure is projected to increase Countywide. Critical and County assets considered in this category are buildings that in themselves provide shelter from extreme temperatures, so extreme heat is not considered to be a notable hazard.

High Winds

Critical and County resources will likely experience increased exposure to high winds and the effects thereof.

Drought

Droughts are projected to increase in frequency and severity and may significantly impact the operations of many critical and County assets such as hospitals, nursing homes, and schools.

Sensitivity

Critical and County resources are sensitive primarily to flooding, as this hazard can cause the most damage to buildings. In cases of the critical buildings (such as hospitals, fire stations, etc.), closure could be catastrophic to County members in need of these services.

Buildings are only sensitive to high heat in that they will need more robust air-conditioning systems to maintain comfortable temperatures inside. If the HVAC system fails during times of high temperature, the building will not be usable, and temperatures could impact technology systems (computers, servers, etc.) stored within the buildings.

Though the buildings themselves will not be particularly sensitive to drought, the primary functions of many critical and County resources will be significantly impacted by drought conditions, as patients, students, and workers will need access to drinking water. As a result, these assets are considered highly sensitive to drought.

Buildings within Montgomery County are designed to withstand high winds. High winds are not likely to significantly damage buildings that have been built to code, but with increasing frequency and severity of high wind events, sensitivity may increase in the future. Building access can also be sensitive to downed trees, and downed powerlines may render the building unusable for a time.

Adaptive Capacity

The critical and County resource buildings have some redundancy throughout the County. Multiple hospitals, libraries, and recreation centers exist throughout the County, though capacity is finite. Students from one school may be able to move to another building if one is closed for a natural hazard-related reason as periodically occurs when facilities close temporarily for renovations. Remote learning options are also available, as has been demonstrated in the 2020 COVID-19 pandemic. However, for some critical resources, there could be a dramatic difference, such as in the outcome of a fire if the nearest fire station is inoperable and a station that is farther away has to be called into action. In general, though, there is some adaptive capacity built in to the critical and County resources. There may be a need for expanded hours for emergency shelters and other buildings that serve as cooling centers. The emergency shelter locations are shown in Figure 4-8.

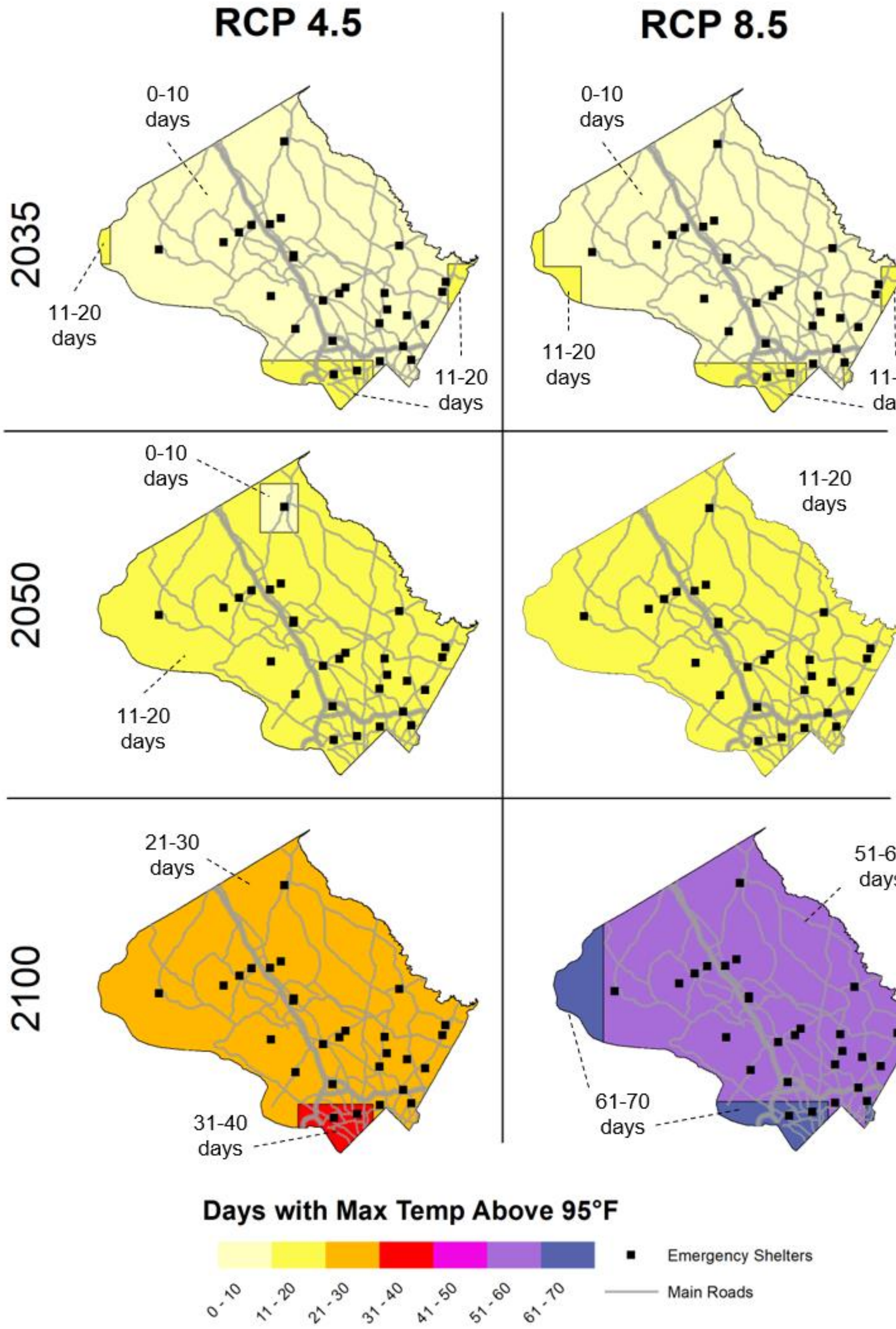

Figure 4-8. Increase in the number of days >95°F per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for emergency shelters

4.3 Utilities

Hazard Exposure

Extreme Precipitation

The FEMA floodplain was buffered by 500 feet to see how many assets would be impacted by an expanded floodplain.[12] This information is provided in Table 4-3.

Table 4-3. Utility Assets within 500 feet of the FEMA Floodplain

Utilities Asset Types[13]	Total Structures	Buildings within 500 feet of FEMA Floodplain
Substations	89	14
Pump Stations (Rockville only)	3	1
TOTAL	**92**	**15**

In addition to the substations and pump stations listed in the table above, the Montgomery County Resource Recovery Facility was found to be within 500 feet of the FEMA floodplain. Drinking water reservoirs that serve the County will experience increased frequency and intensity of extreme precipitation. The change over the baseline for the 10-year and 100-year rainfall events for three future years and two climate scenarios are shown in Figure 4-9 and Figure 4-10, respectively.

Extreme Heat

Utility assets will be increasingly exposed to extreme temperatures and heat waves. Highly exposed asset subgroups such as substations, power lines, and drinking water reservoirs will unilaterally be subjected to significantly longer periods of extreme heat.

Drought

Drought exposure is primarily of concern for the drinking water systems and wastewater collection systems. Droughts have occurred in recent years, and future projections indicate increases in drought frequency and severity. Projected increases in severe droughts are shown in Figure 4-11.

High Winds

Power distribution is primarily impacted by high wind exposure to overhead lines and damage from fallen trees. Exposure to high winds is projected to increase in the future.

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[12] *Note: This analysis does not consider topography and likely overestimates the number of assets that may be impacted by riverine flooding.*

[13] *Note: There are other infrastructure assets that could be exposed to flooding; however, power substations and the pump stations in Rockville are the ones for which information was available and used for this assessment.*

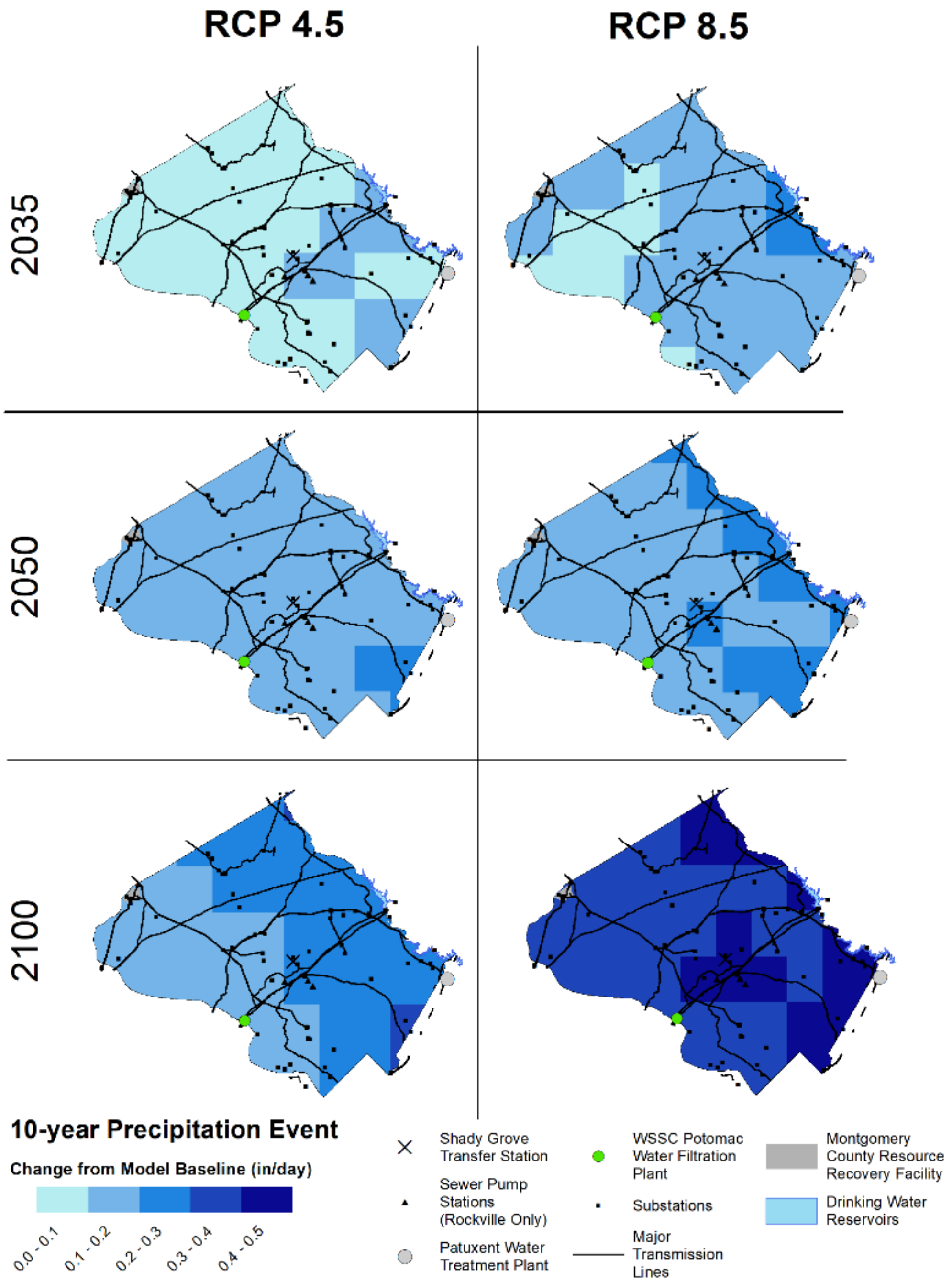

Figure 4-9. Change over the baseline for the 10-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5)

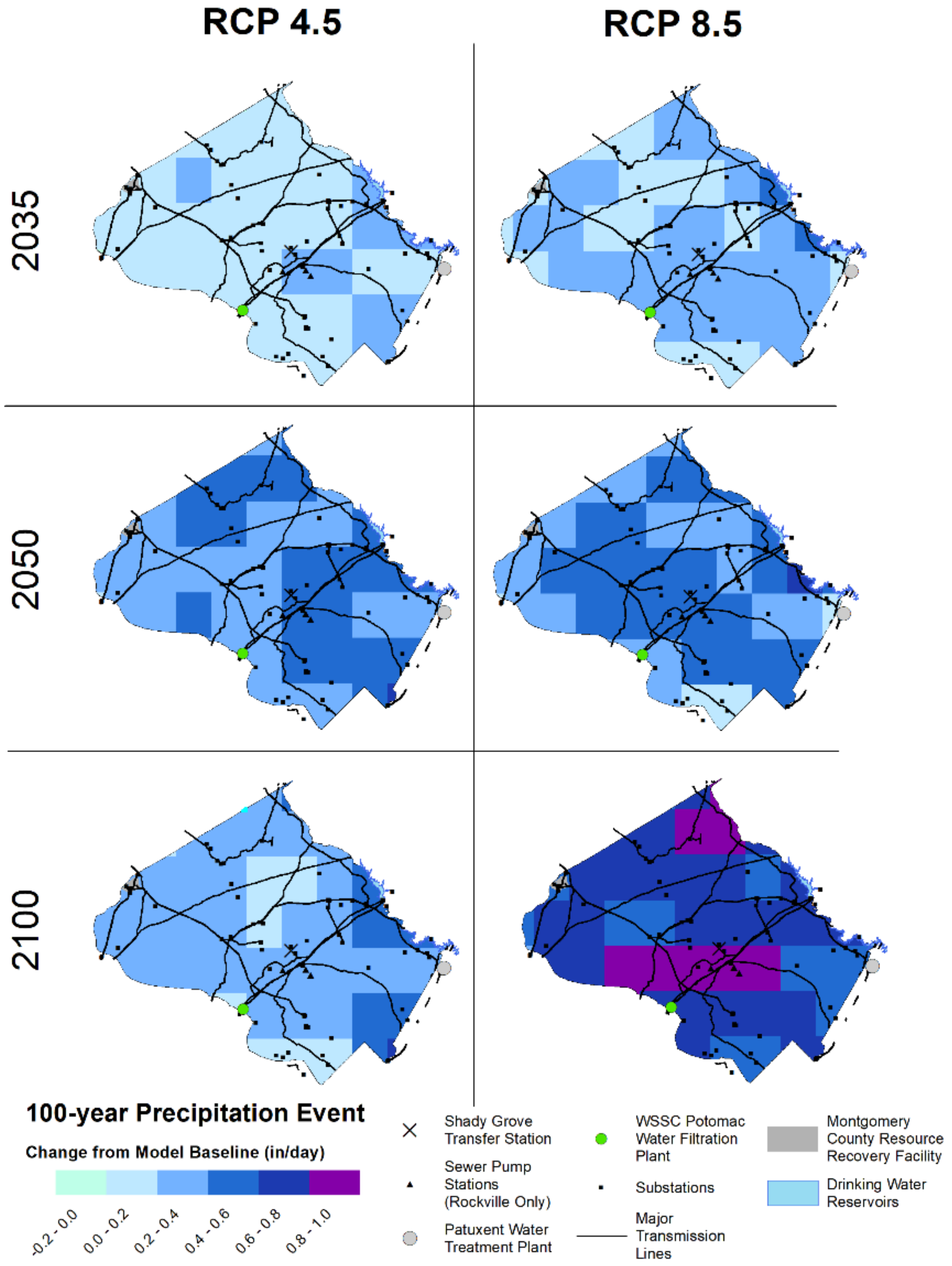

Figure 4-10. Change over the baseline for the 100-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5)

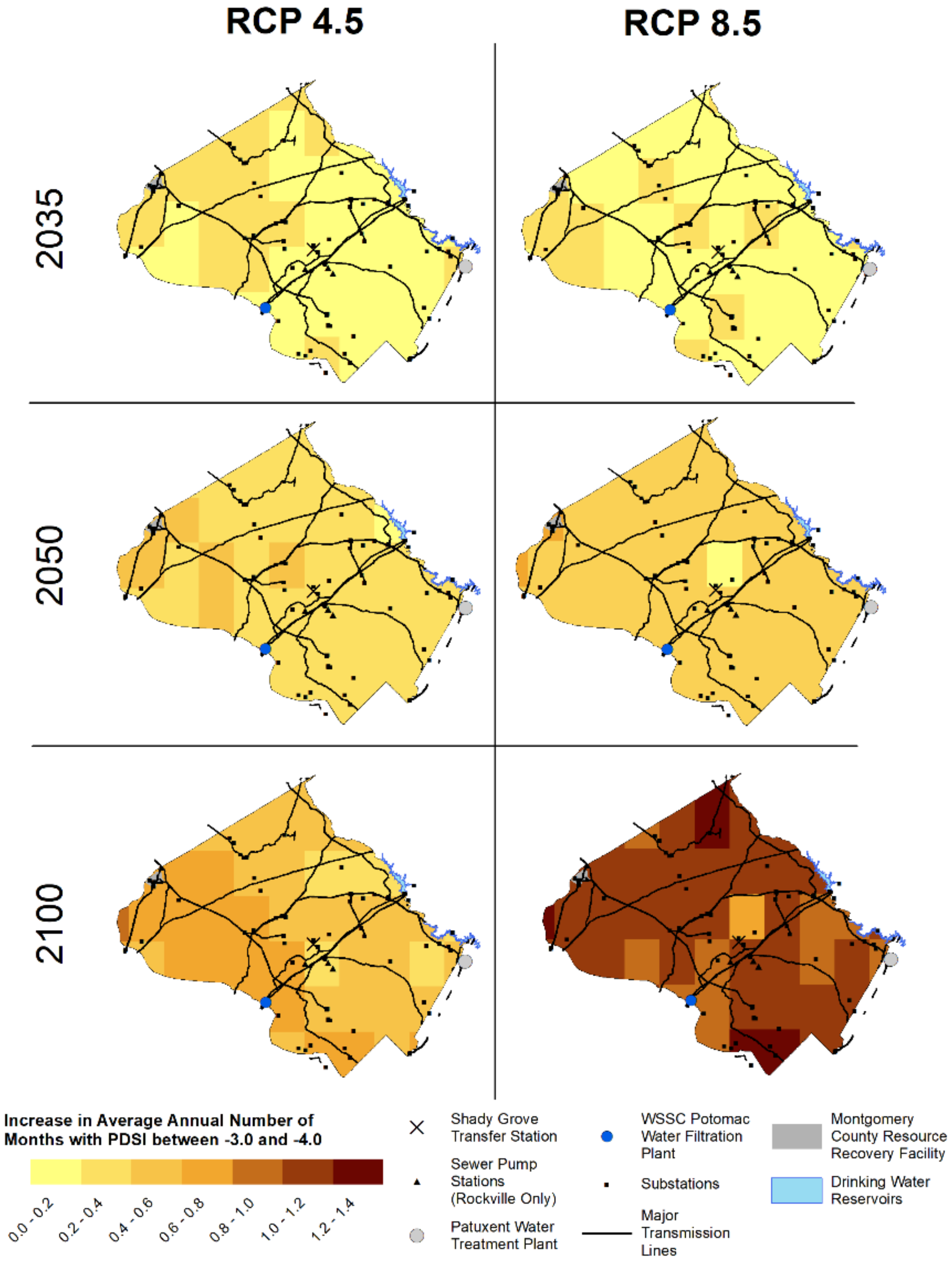

Figure 4-11. Changes to average number of severe drought (PDSI between -3.0 and -4.0) months per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5)

Sensitivity

Electrical components of utility assets are very sensitive to flooding and extreme precipitation. Extreme precipitation events can also impact the operations of drinking water reservoirs, which, depending on available storage, may become very sensitive to additional precipitation. Although unlikely, extreme precipitation could impact the stability of the Brighton Dam or the T. Howard Duckett Dam on the Patuxent River, increasing the risk of a catastrophic failure and devastation downstream. Failure of these dams would also impact the supply of drinking water for the County. Intense rainfall can create challenges for water filtration plants and may cause larger flows in wastewater collection and treatment facilities, which could lead to backflows and overflows, as well as impacts on the treatment processes.

Power lines and other open-air electrical components are sensitive to extended extreme heat exposure, which can compound with existing system heat generation, cause thermal expansion, degrade protective layers, and significantly exacerbate small system imperfections, which can lead to failures and power outages. Extreme heat also increases evapotranspiration and can add additional stress to drinking water resources.

Drinking water systems are particularly sensitive to extended periods of drought. Although drought-triggered water restrictions in the region are uncommon, increased frequency and severity of droughts may lead to increased frequency and severity of the corresponding restrictions. Drought can also impact wastewater systems as sediment accumulation increases with low system flows. Generation of gas in pipe networks due to low flows and increased temperatures could become a health and safety hazard.

During high wind events, open tanks and filter beds in water treatment plants can be blown out, mechanical equipment and electrical power and controls can be damaged, and the treatment process and finished water storage can become contaminated by debris on treatment plant sites. Facility access can also be interrupted or restricted due to debris and damaged roads. Piping and appurtenances (e.g., fire hydrants, valves, and stream crossings) can suffer airborne debris impacts. They can also be damaged if nearby buildings are damaged or destroyed. Severe water and pressure loss can occur due to ruptured service lines. Also, high winds can down power lines and trees, resulting in power outages.

Adaptive Capacity

Vulnerable utility assets can be raised or floodproofed, and installing submersible pumps where needed can mitigate flood risks and provide adaptive capacity. Correcting infiltration and inflow problems in piping systems can reduce flows to the treatment plant during extreme precipitation events.

During drought periods, the drinking water system has historically been able to manage water supply needs effectively through upstream resources as well as voluntary restrictions in the region. But as droughts become more frequent and more severe, additional water conservation actions will be necessary.

Utility companies can do many things to adapt to high winds. If needed, they can retrofit buildings to meet building code requirements, anchor or relocate rooftop equipment, and build protective structures around critical equipment to reduce the possibility of puncture by windborne projectiles. The electric system has limited adaptive capacity in the face of high winds and downed powerlines. An effective adaptation measure is to bury all overhead utilities, which can be done gradually as part of new development and re-development projects.

4.4 Stormwater Management System

Hazard Exposure

Extreme Precipitation

Increased precipitation, especially short and intense storms, can lead to significant hazard exposure. The map of the stormwater management system along with images of nearby buildings shows how important this system is for keeping the roads and nearby buildings dry. In order to further identify stormwater assets that may experience high exposure to extreme precipitation, National Weather Service (NWS) flood reports as well as the MDOT frequently flooded roads were buffered by 500 feet to see how many of the 12,096 assets considered would be impacted by stormwater flooding[14] as shown in Table 4-4. The previously flooded area locations are shown in Figure 4-12 along with the corresponding precipitation event associated with the flooding (for NWS reports). Figure 4-13 shows the changes to the 10-year, 24-hour storm projected for the future.

Table 4-4. Stormwater Management Assets within 500 feet of NWS Flood Reports and MDOT Frequently Flooded Roads

Stormwater Management Asset Types	Total Structures	Buildings within 500 feet of Previously Flooded Areas
Culvert	2,560	45
Dry Well	5,798	48
Infiltration Trench	1,086	2
Underground Detention	619	3
Pond (Wet/Dry)	1,227	4
Swale/Bioswale	806	1
TOTAL	**12,096**	**103**

Sensitivity

The stormwater management system is particularly sensitive to increased rainfall. Undersized pipes or decreased flow due to sediment or debris can cause choke points, which leads to extensive flooding and the need for post-storm maintenance and repair. Stormwater management ponds can be overtopped, and bioretention facilities can be washed out.

Stormwater management assets are not directly sensitive to drought, extreme heat, or high winds. However, high temperatures can reduce water quality and impact downstream assets. Sediment can accumulate in stormwater conveyance during a drought and block flow when it rains again. Extended drought conditions can kill plants in green infrastructure stormwater controls. Additionally, high winds can carry debris, causing blockages, asset damage, and possibly blowing out vegetation and soil from green infrastructure.

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[14] *Note: This analysis does not consider topography or historical ponding extents and may overestimate or underestimate the number of assets that are impacted by stormwater flooding. It does, however, provide some sense of the potential current and future risks.*

Adaptive Capacity

The stormwater management system has limited adaptive capacity, particularly as storms become more intense in the future, and the existing system is under-designed. Conveyance may be over-dimensioned as a safety factor, creating inherent additional storage in the stormwater collection network. As upgrades are made and new components are added, there is a chance to design for future conditions, which would provide adaptive capacity. Green infrastructure adds adaptive capacity to the system by decentralizing stormwater management and spatially distributing the amount of storage available for runoff capture. Regular and comprehensive maintenance and debris removal can significantly improve system performance and maximize inherent adaptive capacity.

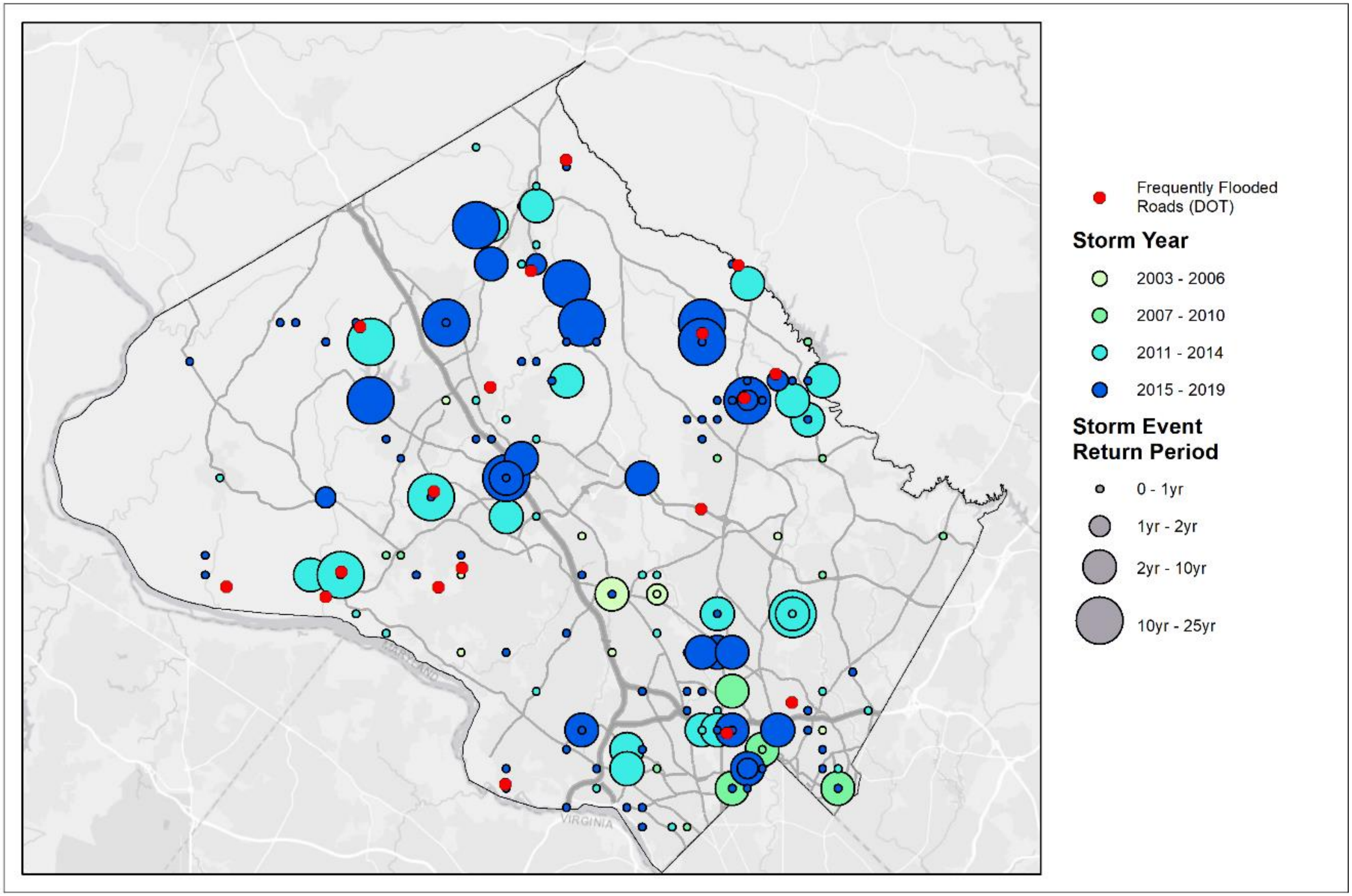

Figure 4-12. NWS flood reports and MDOT frequently flooded roads

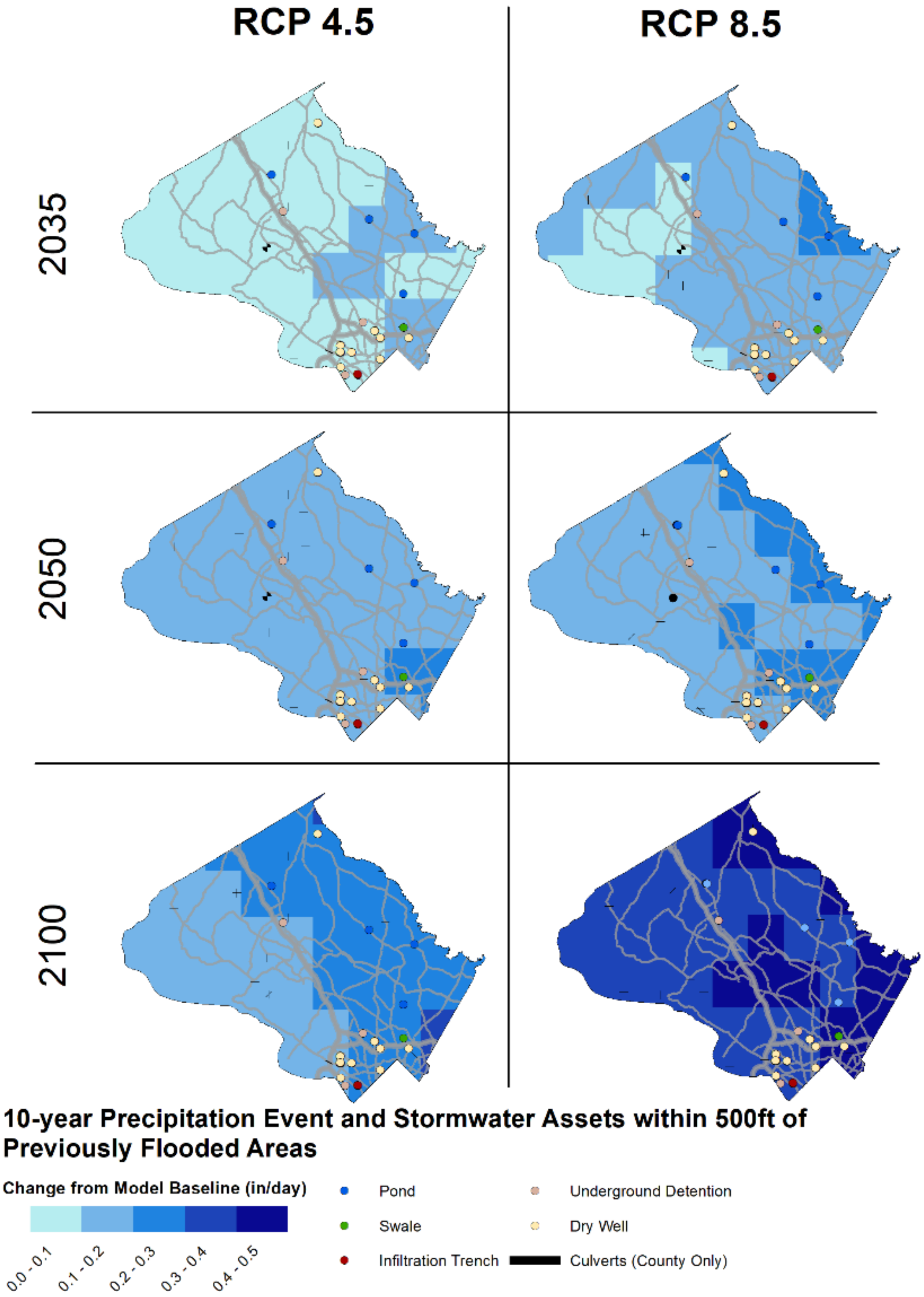

Figure 4-13. Change over the baseline for the 10-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for stormwater management assets within 500 feet of NWS flood reports and MDOT frequently flooded roads

4.5 Agricultural Resources

Hazard Exposure

The agricultural reserve lands cover a large portion of the County to the west and north. This asset category is likely to experience impacts of extreme precipitation, extreme heat, drought, and high winds, making this one of the most vulnerable asset categories. The hazard exposure is shown in Figure 4-14 (100-year precipitation), Figure 4-15 (risk of severe drought months per year), and Figure 4-16 (number of days above 95°F per year). Along with increased exposure to extreme events, agricultural resources may stand to benefit to some extent from an increased growing season as the winter-spring transition shifts.[15]

Sensitivity

Crops can vary in sensitivity to various climate hazards, but for the purposes of this analysis, this asset category is considered sensitive to temperatures, drought, intense rainfall, and even high winds.

Adaptive Capacity

During times of drought, additional water will be needed, and if that is available, crop production can continue. Temperatures outside the normal range (high or low) are detrimental to crops and are difficult to mitigate in large areas where providing temperature-controlled shelters such as greenhouses requires significant investment. Famers may be able to change crops in the future to those better suited for a changing climate, but for one season with extreme temperatures, there is not very much adaptive capacity.

Extreme precipitation can be effectively managed by improving soil texture and organic carbon content, which dramatically increases the infiltration capacity of soil.[16] Regenerative agricultural practices help maintain soil structure and infiltration capacity.

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[15] *Dupigny-Giroux, L.A., E.L. Mecray, M.D. Lemcke-Stampone, G.A. Hodgkins, E.E. Lentz, K.E. Mills, E.D. Lane, R. Miller, D.Y. Hollinger, W.D. Solecki, G.A. Wellenius, P.E. Sheffield, A.B. MacDonald, and C. Caldwell, 2018: Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18.*

[16] *Rattan, L. 2016. “Soil health and carbon management.” Food and Energy Security 5(4). P. 2048-3694.*

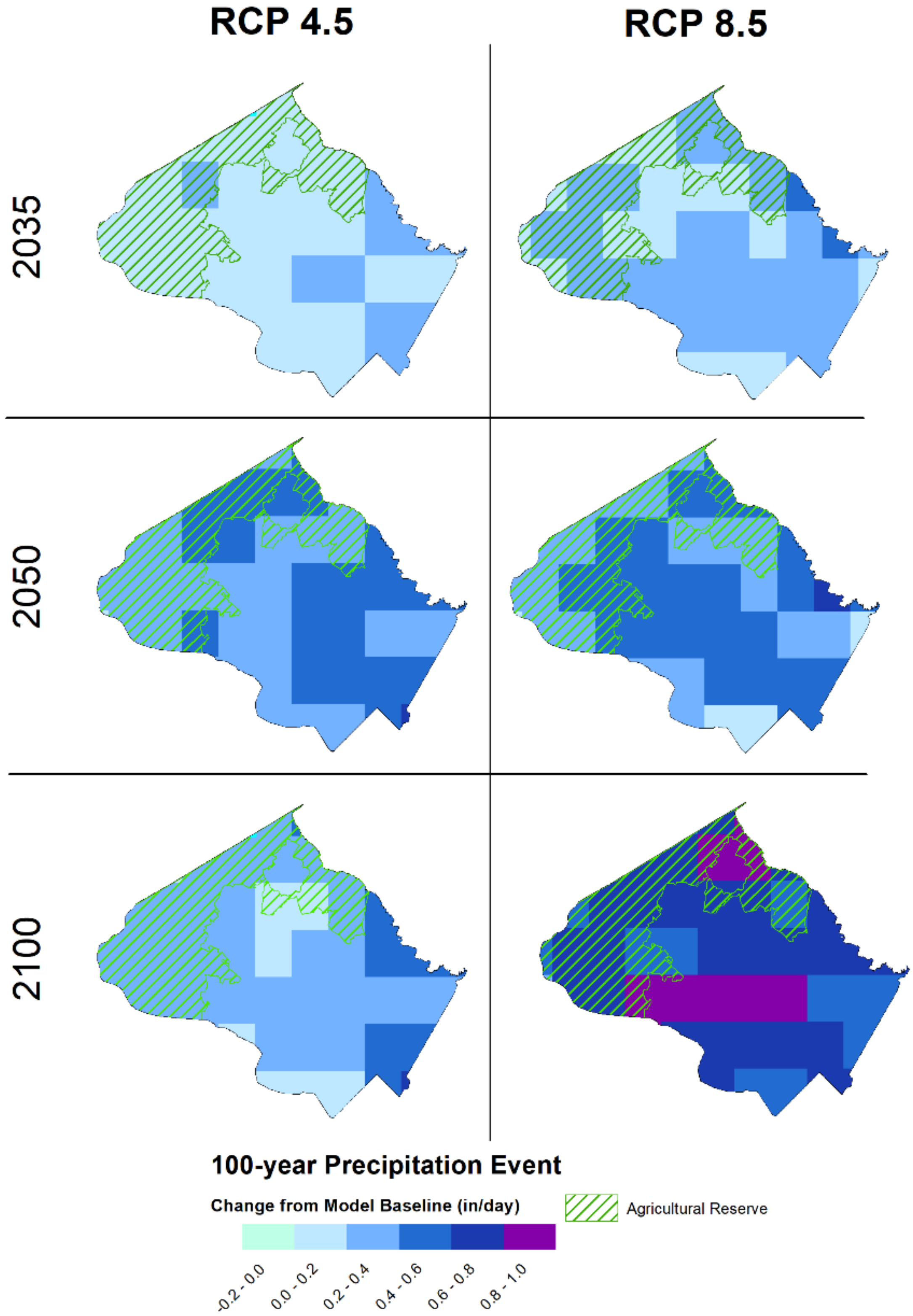

Figure 4-14. Change over the baseline for the 100-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for agricultural reserve

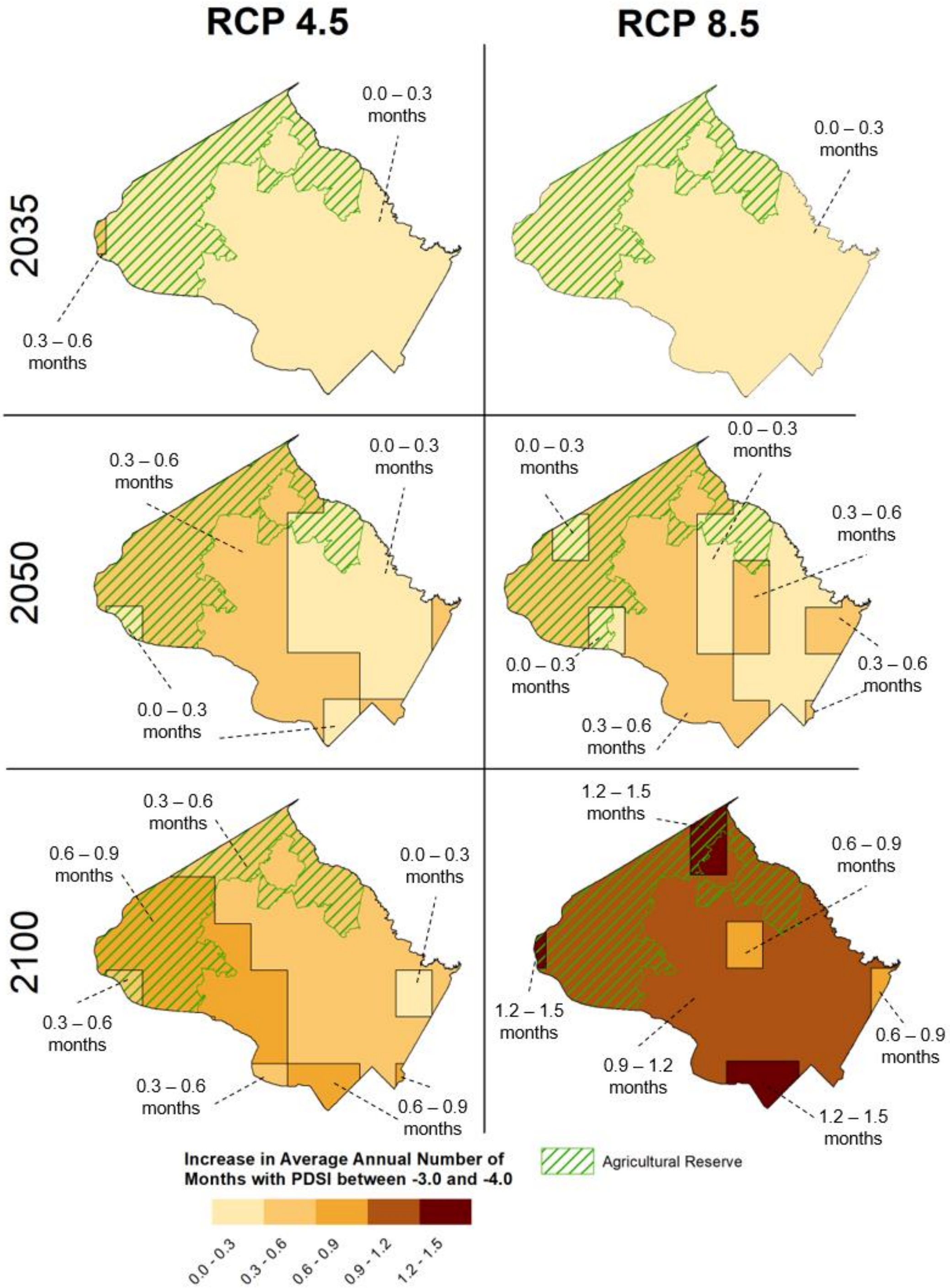

Figure 4-15. Changes to average number of severe drought (PDSI between -3.0 and -4.0) months per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for agricultural reserve

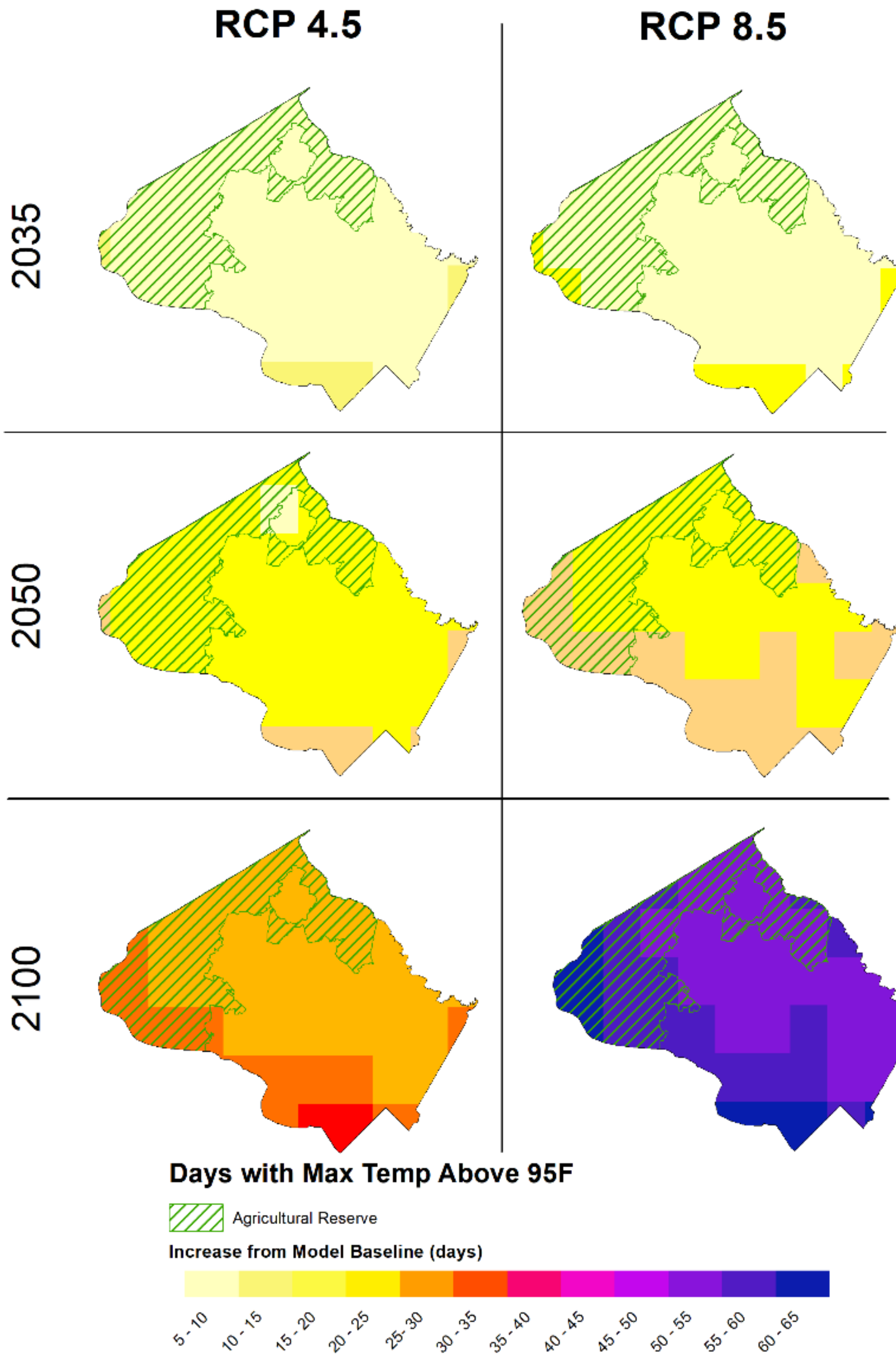

Figure 4-16. Increase in the number of days >95^{o}F per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for agricultural reserve

4.6 Parks, Wetlands, and Trees

Hazard Exposure

Parks, wetlands, and trees are a valuable part of Montgomery County's ecosystem. Trees provide shade and help keep ambient and building temperatures lower during times of high heat. Drought, high heat, extreme precipitation, and high winds can all impact the built and natural systems in the parks and other preserved lands. Figure 4-17 and Figure 4-18 show future hazard exposure to the 100-year precipitation event and the number of days greater than 95°F, respectively, for park and wetland layers.

Tree locations are a cross-over asset category encompassing homes, critical and County resources, the agricultural reserve, and parks. They are included in this asset category for ease of categorization of actions in Section 5.0 of this report. Figure 4-19 shows how the temperature increases compared to areas of existing tree cover throughout the County.

Sensitivity

A changing climate can alter the natural habitat of both plants and animals that make their homes in parks and wetlands. Public parks in more urban areas are not considered particularly sensitive to natural hazards because they are typically home to more robust plant and animal species. Wetlands, however, may be much more sensitive to changes in water patterns, salinity, temperature, and drought. Trees can be damaged in high winds, but they are generally suited for the current rain and temperature climate; however, they may become more sensitive to invasive species and diseases as the climate changes. Public access to parks may be restricted or suspended if trails and other park facilities are affected by flooding, extreme heat, or extreme winds.

Adaptive Capacity

Within the parks and wetlands areas, adaptation is possible as long as there is space. If increased precipitation changes lake levels, boat launches may need to be moved or beaches may be inundated. This will change the experience of the park, but should not significantly diminish County residents' ability to interact with these places. Wetlands may have less adaptive capacity if they are unable to encroach on higher elevations with the changing climate due to surrounding land use limitations. Replacing lost trees with new trees can take a long time, so trees are not considered to have high adaptive capacity.

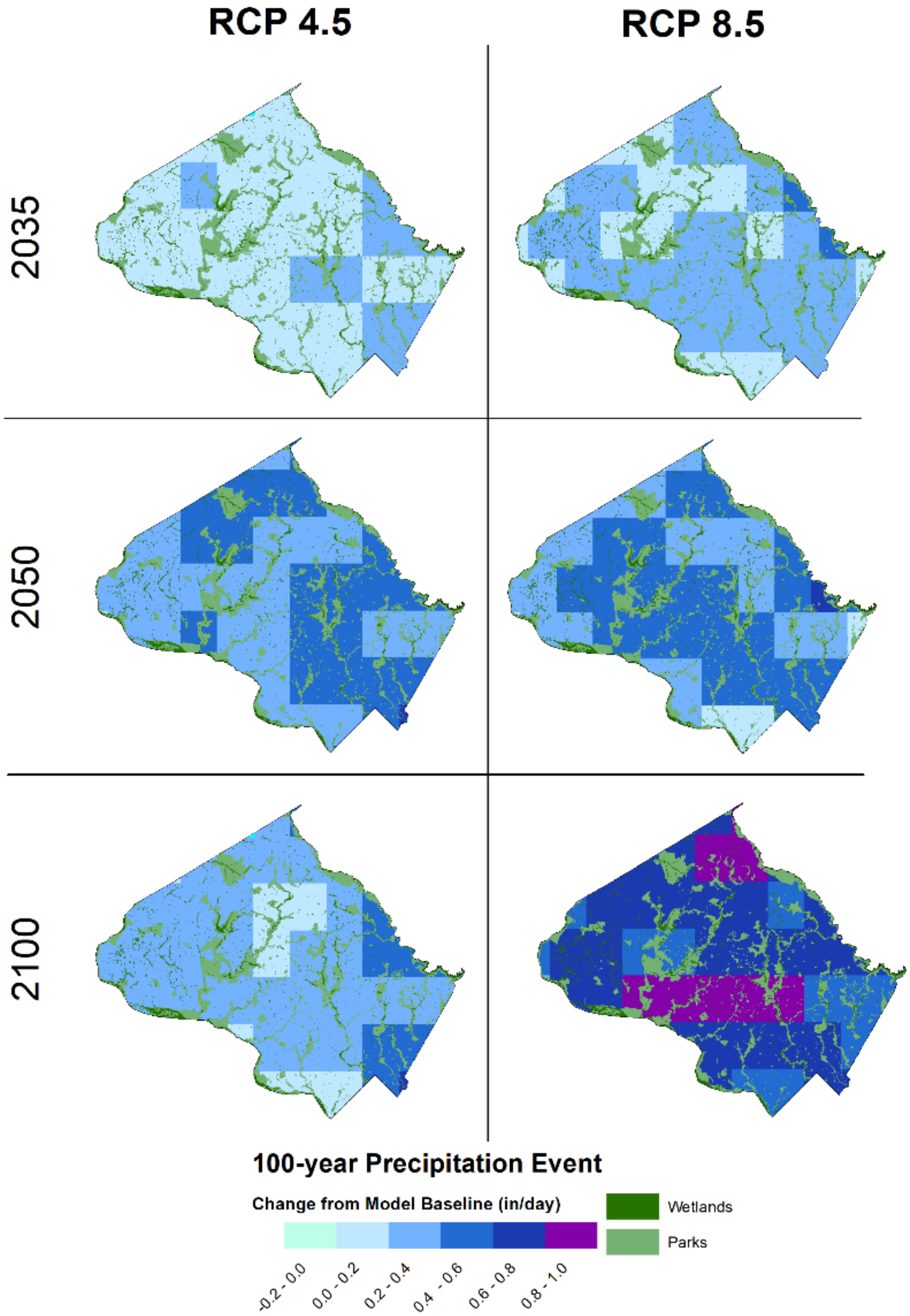

Figure 4-17. Change over the baseline for the 100-year rainfall event for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for park and wetland areas

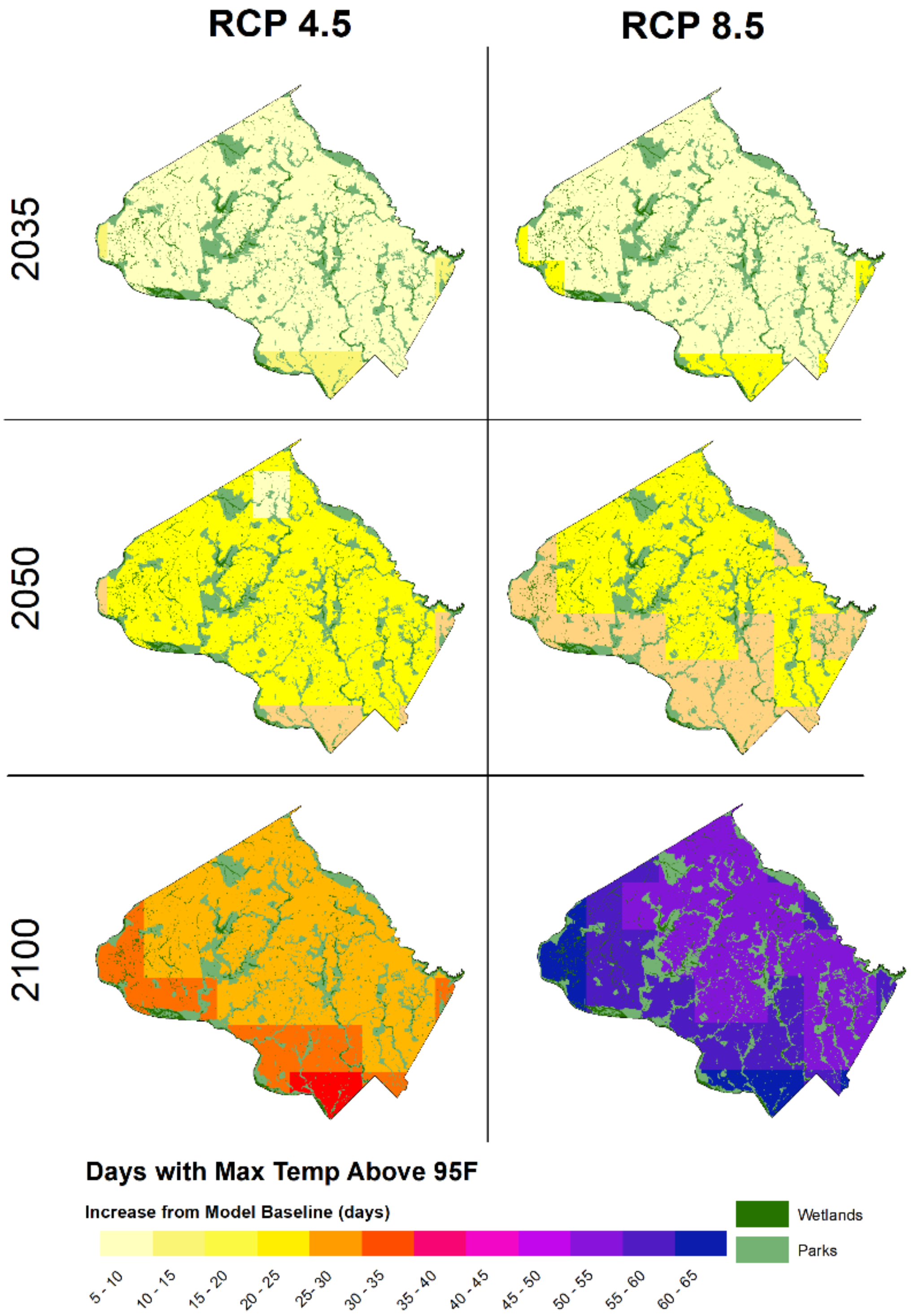

Figure 4-18. Increase in the number of days >95°F per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for park and wetland areas

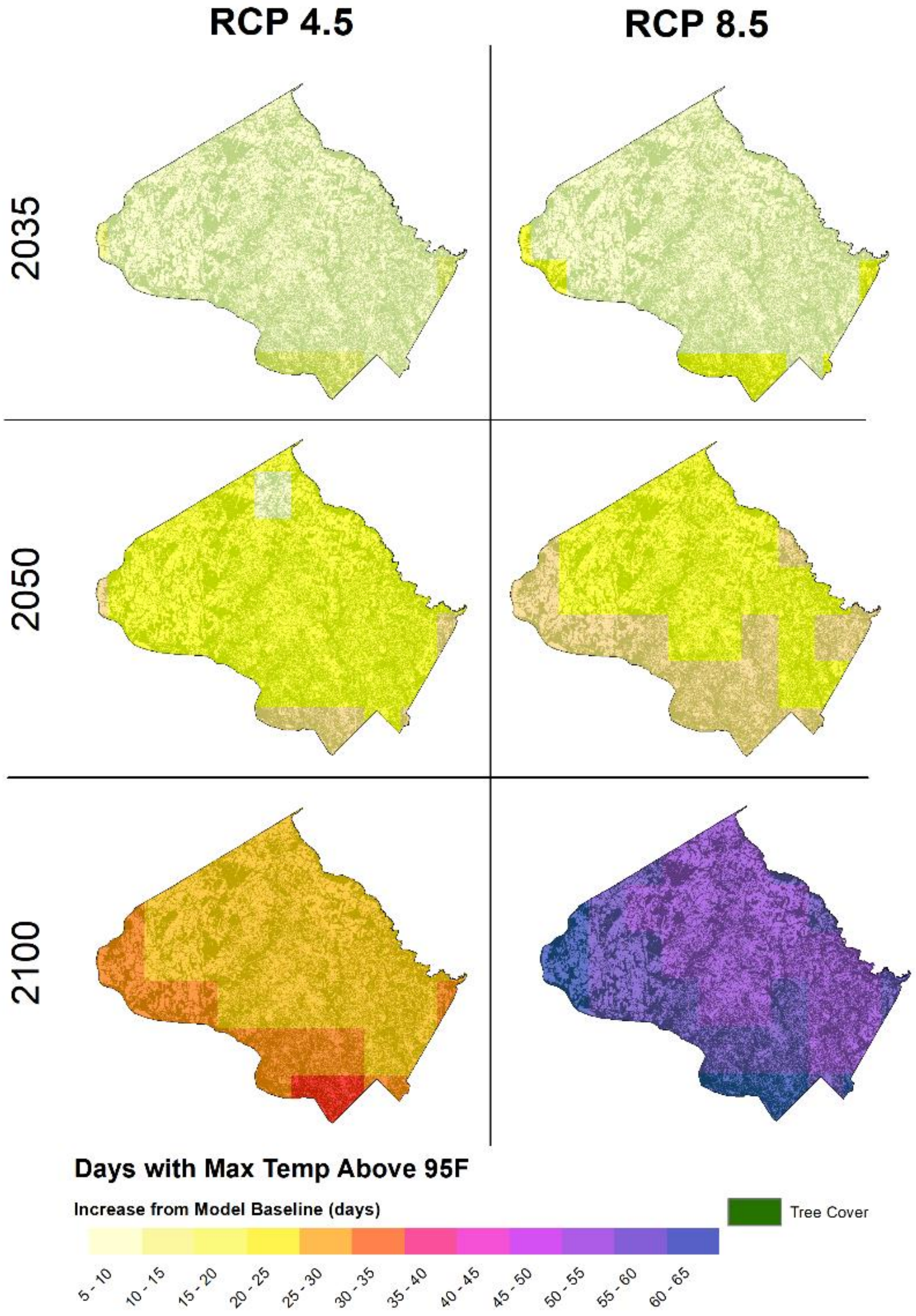

Figure 4-19. Increase in the number of days >95^{o}F per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) for areas with tree cover

4.7 People and Homes

Hazard Exposure

Extreme Precipitation

A database of building footprints throughout the County was used to examine the flooding risk on homes, although this analysis includes businesses as well as the critical and County resources discussed in Section 4.2. The number of homes obtain from the database is shown in Table 4-5.

Table 4-5. Number of Homes in, within 250 feet, and within 500 feet of the FEMA Floodplain

Total Homes in Montgomery County	Homes in FEMA Floodplain	Percent of Total Homes	Homes within 250 feet of FEMA Floodplain	Percent of Total Homes	Homes within 500 feet of FEMA Floodplain	Percent of Total Homes
404,057	3,384	1%	17,761	4%	38,491	10%

Currently, 3,384 homes are located within the effective FEMA floodplain.[17] When looking at nearby buildings, this expands to over 17,000 homes located 250 feet or less from the floodplain and more than doubles to over 38,000 homes when looking just 500 feet from the floodplain (see Figure 4-20).

Additionally, overland flooding related to stormwater flooding during increased precipitation impacts people on the sidewalks and streets as well as homes.

Flooding disproportionately affects socially vulnerable groups, as they tend to be concentrated in dense metro areas and live in the lowest-lying areas within or adjacent to floodplains, in neighborhoods with little or no green spaces to capture stormwater, and in areas that have historically received less flood protection investment.

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[17] *https://msc.fema.gov/portal/search*

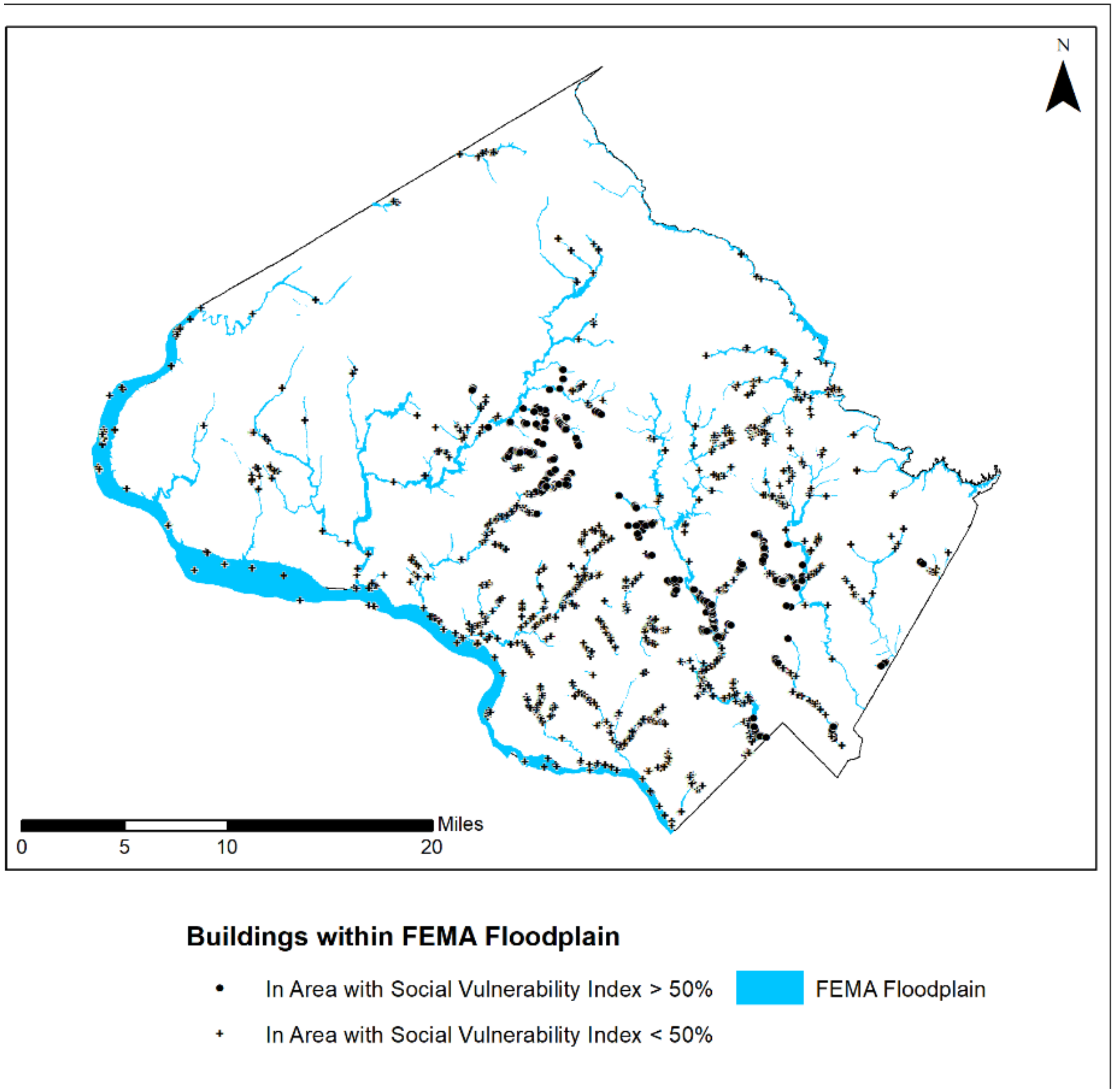

Figure 4-20. Buildings within 500 feet of the FEMA floodplain by SVI rating

Extreme Heat

Significant temperature increases are projected throughout Montgomery County, including hotter days (>95°F and >105°F) and an increase in the number of warm nights (>75° F). While increased temperatures will be experienced by people in all areas of the County, socially vulnerable populations will experience significantly greater exposure, as shown by the following list of causes:

- Homes that do not have air conditioning
- People who experience high energy burdens[18] and energy poverty[19]
- Higher-density residential areas with fewer trees and more impermeable surfaces
- Reduced property size and increased number of occupants
- Automobiles with limited or no air conditioning
- Reliance on high-exposure modes of transportation such as biking, walking, and public transit
- High-exposure occupations (e.g., construction, landscaping, etc.)

Projected increases to average temperatures and heat waves can be exacerbated by a phenomenon commonly referred to as the urban heat island effect. Urban heat islands can be defined as developed urban areas that experience consistently higher temperatures than surrounding areas with lower population density and more pervious ground cover (unpaved area that allows water to flow through) and vegetation. The urban heat island effect is the result of multiple factors often associated with urbanization, such as a concentration of construction materials that absorb and store more heat than the natural environment and then re-emit that heat when temperatures would normally decrease, minimal or no evapotranspiration (transfer of water from land to the atmosphere) due to lack of exposed soil and vegetation, concentrated heat generation from air conditioning and vehicle exhaust, and diminished wind flow due to building placement and concentration. The urban heat island effect was not directly quantified as a part of the climate vulnerability assessment, but it would likely increase extreme temperature experienced in urban parts of the County. Figure 4-21 and Figure 4-22 show the areas of the County with impervious surfaces (paved roads or surfaces that do not allow water to pass through) and tree coverage, outlining sections of the County with a CDC SVI of 50% or greater. The map highlights that many of the areas of the County with the most vulnerable communities also have high concentrations of impervious surfaces, which contributes to the urban heat island effect and increased temperature.

High Winds

High winds may have a limited impact directly on buildings through wind damage, but loss of electricity is more hazardous to human health, especially in times with increased heat.

Drought

Drought impacts people when water restrictions are put into place. Droughts are projected to increase in frequency and severity.

Sensitivity

People and homes are very sensitive to the impacts from these natural hazards. People will experience the changing climate as they commute and recreate. Flooding can damage or destroy homes as well as lead to the development of mold infestations, which can cause or exacerbate respiratory conditions. Increasing flood frequencies may result in higher insurance premiums, and homeowners who may not have been required to purchase flood insurance may find themselves within newly expanded floodplains. Communities will have to deal with the impacts of drought when

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18 Note: High energy burden is defined as energy bills exceeding 6% of the household income, annually.

19 Note: Energy poverty is defined as energy bills exceeding 10% of the household income, annually.

water supplies are limited. Air conditioning will become even more important as future temperatures rise, and the costs associated with operating and maintaining these systems will rise accordingly. High winds can result in loss of electricity and flooding impacts on both people and homes. High winds can also prove extremely dangerous to pedestrians, drivers, and cyclists who may be impacted by flying debris and falling trees or who may simply lose control and cause serious accidents.

As reported in the 2016 *Maryland Climate and Health Profile Report*, extreme heat events can increase heart attack risk, particularly among non-Hispanic Blacks aged 65 or older.[20] Extreme heat and precipitation have also been associated with increased risk of hospitalization for asthma in Maryland.[21]

Socially vulnerable populations are significantly more sensitive to hazard exposure, as they often suffer from chronic health conditions and have limited access to medical treatment and support. Additionally, poorly maintained or inadequate infrastructure in socially vulnerable neighborhoods can focus impacts of exposure to areas where they will do the most significant damage. Figure 4-23 highlights how the increases in temperature will coincide with areas of social vulnerability.

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20 Maryland Climate and Health Profile Report (2016). Available: https://mde.maryland.gov/programs/Marylander/Documents/MCCC/Publications/Reports/MarylandClimateandHealthProfileReport.pdf

21 Soneja, Sutyajeet, et al. "Exposure to extreme heat and precipitation events associated with increased risk of hospitalization for asthma in Maryland, USA." Environmental Health 15.1 (2016): 57. Available: https://phpa.health.maryland.gov/OEHFP/EH/Climate%20Change%20Binder/Soneja%20EH2016.pdf

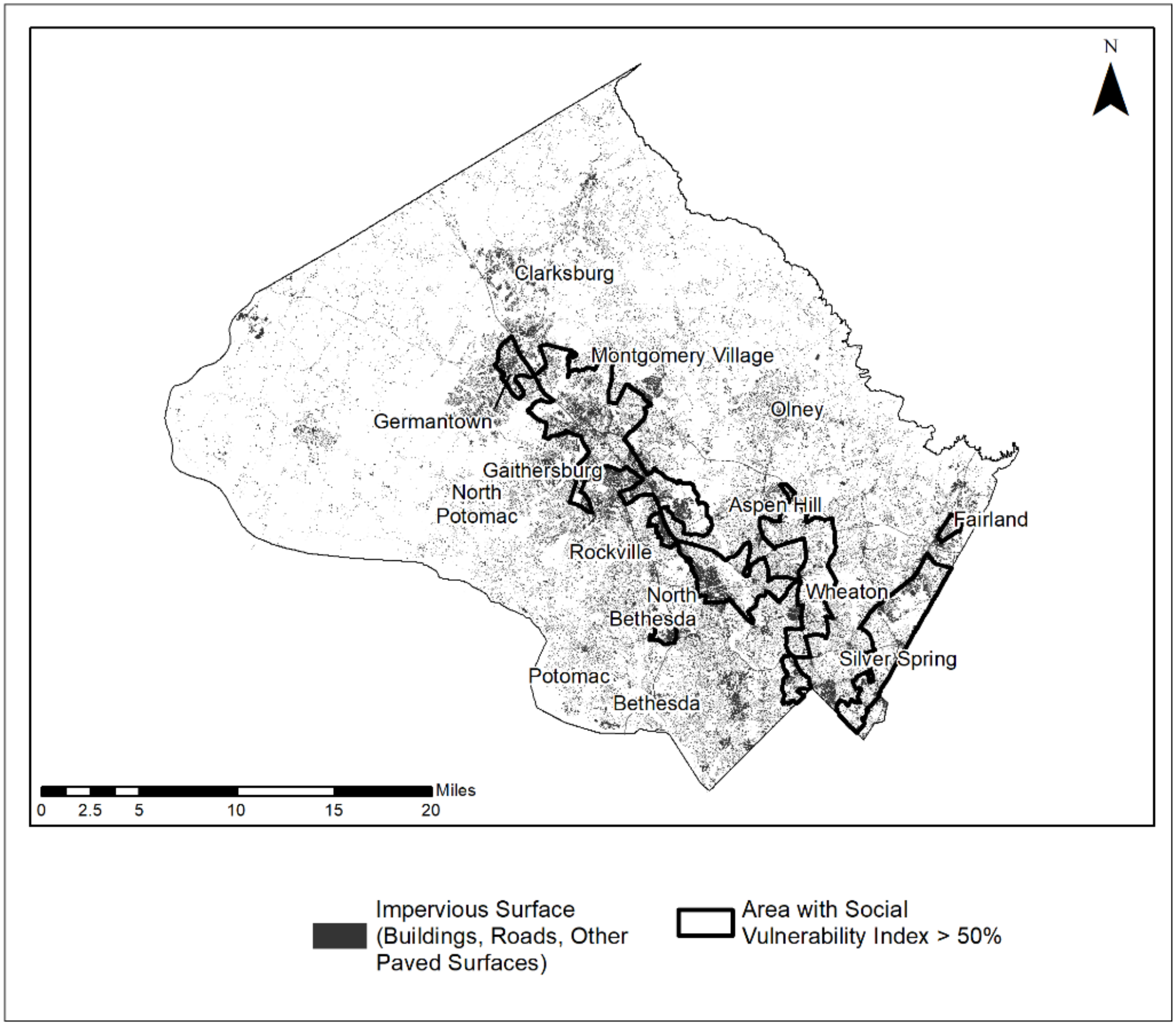


Figure 4-21. Impervious surface in Montgomery County, outlining areas ranked in the top 50% most vulnerable by the CDC SVI

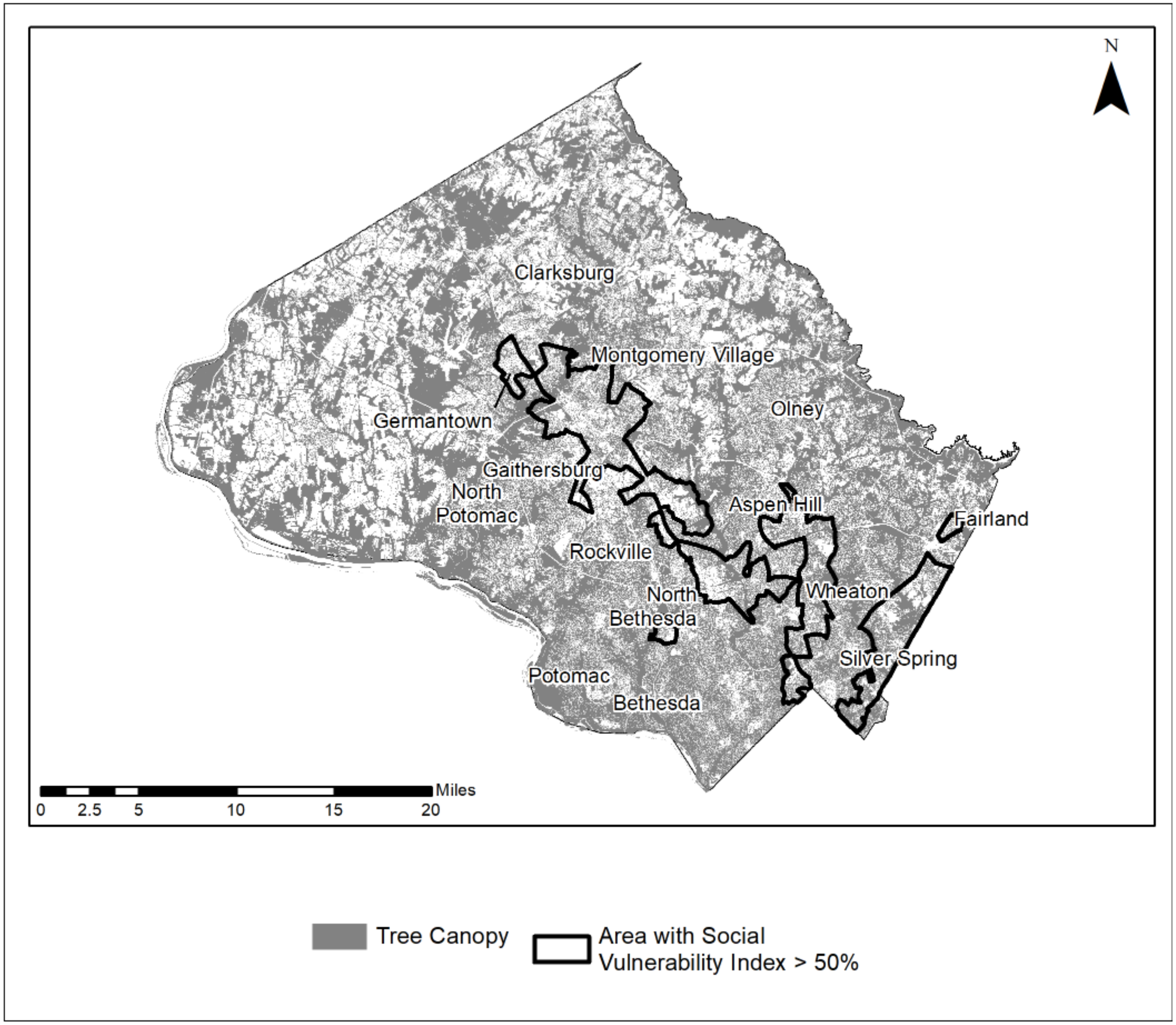


Figure 4-22. Tree canopy in Montgomery County, outlining areas ranked in the top 50% most vulnerable by the CDC SVI

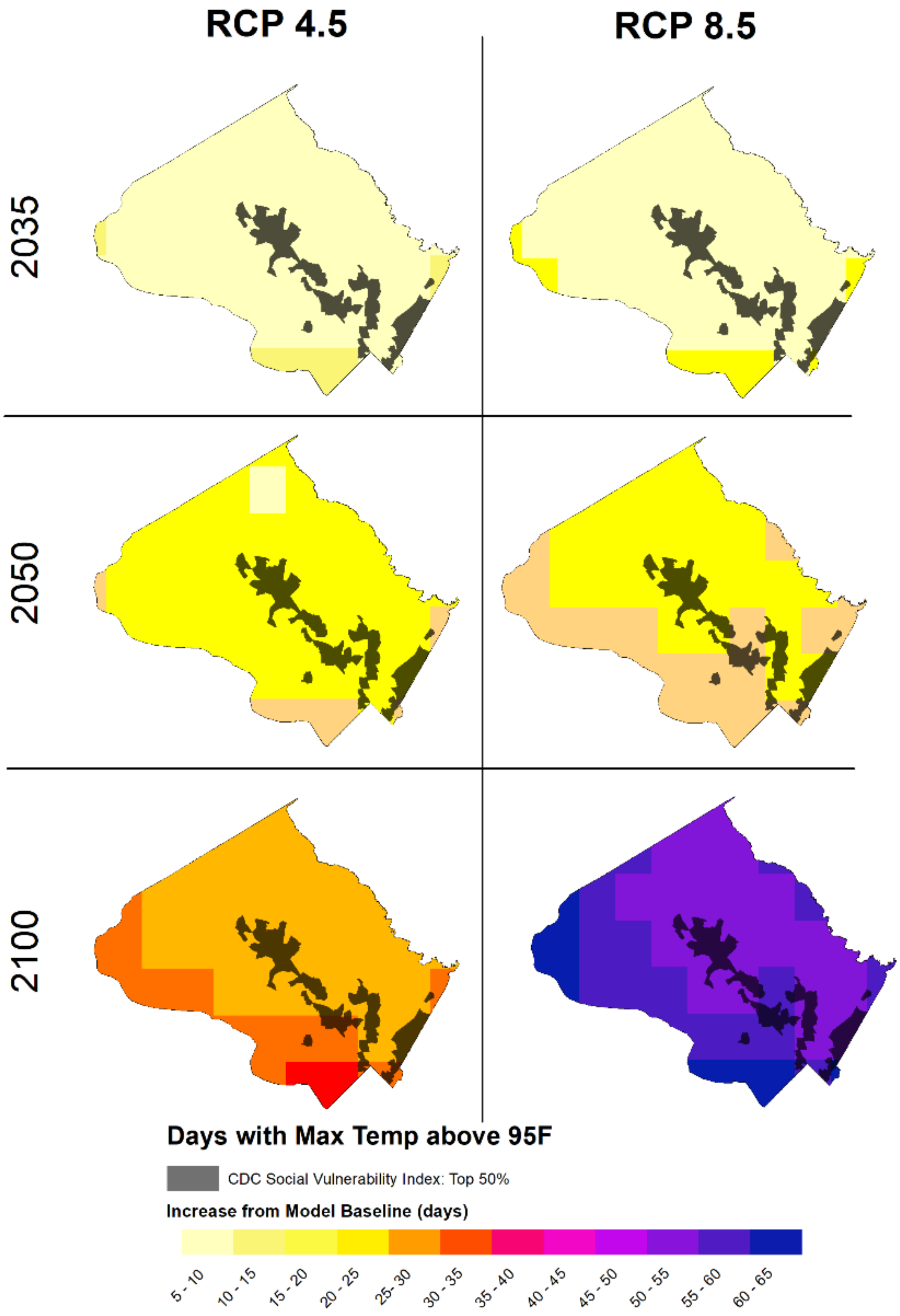


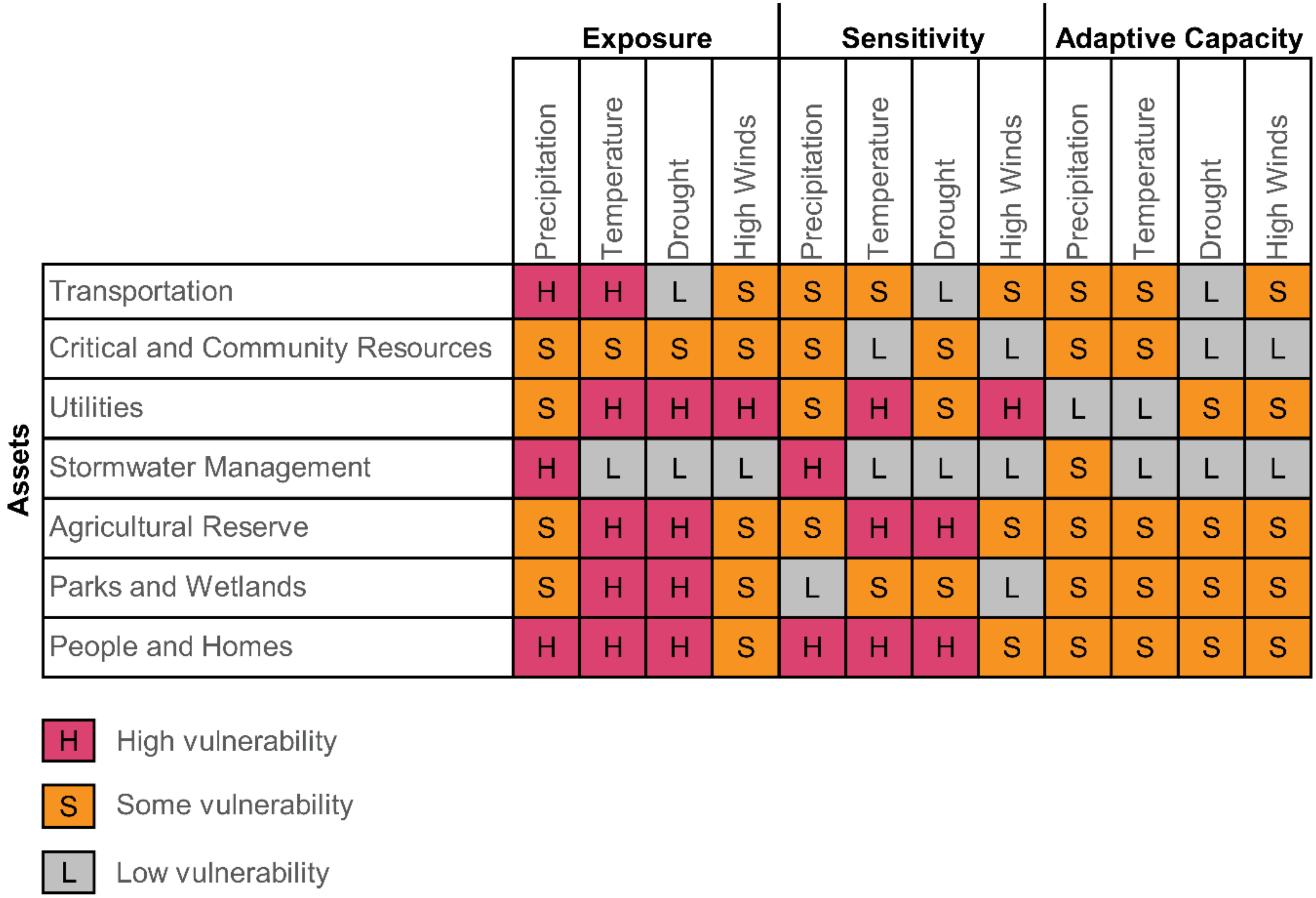
Figure 4-23. Increase in the number of days >95°F per year for three future years (2035, 2050, and 2100) and two climate scenarios (RCP4.5 and RCP8.5) compared to areas with higher social vulnerability

Adaptive Capacity

As seen during the COVID-19 pandemic, people are highly adaptable and will continue to be so as the climate changes. Adaptive capacity, however, is related to not just the human spirit, but also the resources available, such as more disposable income to make adjustments to housing. Language barriers could prevent homeowners from finding out about County incentive programs that provide support for resilience measures. The key to understanding adaptive capacity for people and homes is understanding the environmental justice barriers that might prevent equitable adaptive solutions for all County residents. Options like working remotely from home and limiting outdoor activity during a heat wave, extreme precipitation, or high wind event may not be available.

4.8 Results Summary

For each asset category, the general exposure, sensitivity, and adaptive capacity were ranked based on the perceived risk. This data is displayed in Figure 4-24. Red signifies more vulnerability, orange indicates some vulnerability, and gray indicates low vulnerability. However, when looking at the exposure and sensitivity categories, red indicates high exposure and high sensitivity, but when looking at adaptive capacity, it is low adaptive capacity (not high) that results in a red ranking.



	Exposure				Sensitivity				Adaptive Capacity			
Assets	Precipitation	Temperature	Drought	High Winds	Precipitation	Temperature	Drought	High Winds	Precipitation	Temperature	Drought	High Winds
Transportation	H	H	L	S	S	S	L	S	S	S	L	S
Critical and Community Resources	S	S	S	S	S	L	S	L	S	S	L	L
Utilities	S	H	H	H	S	H	S	H	L	L	S	S
Stormwater Management	H	L	L	L	H	L	L	L	S	L	L	L
Agricultural Reserve	S	H	H	S	S	H	H	S	S	S	S	S
Parks and Wetlands	S	H	H	S	L	S	S	L	S	S	S	S
People and Homes	H	H	H	S	H	H	H	S	S	S	S	S

H High vulnerability

S Some vulnerability

L Low vulnerability

Figure 4-24. Vulnerability ranking by asset category and hazard category

5.0 Conclusions and Next Steps

The most significant changes observed in the future conditions climate assessment appear to be related to extreme heat. Extreme heat poses great risks to human health as well as the natural environment, where agriculture and local plants and wildlife will struggle to adapt. Along with extreme heat, moderate to extreme drought is also expected to increase by the end of the century, impacting agriculture, water resources, and human health and well-being. Extreme precipitation is projected to show more modest increases, with the most frequent events showing little to no change. Though the higher-frequency events show little change, it is likely that flash flood risk will increase in sub-daily precipitation events. The most extreme precipitation events also show the largest increases in intensity, resulting in more widespread and severe impacts when they do occur. Moreover, vulnerable populations, as identified in this report using the CDC SVI (2016), will face greater impacts due to limited resources and access to adaptation and mitigation options.

Looking at the exposure, sensitivity, and adaptive capacity of the asset categories found throughout Montgomery County, the highest risk asset categories and hazard combinations are:

- **Transportation:** Precipitation and Temperature
- **Utilities:** Temperature, Drought, and High Winds
- **Stormwater Management:** Precipitation
- **Agriculture:** Temperature and Drought
- **People and Homes:** Precipitation, Temperature, and Drought

Although there is still some risk from other hazards beyond the major hazards for the asset categories listed above, this risk is more limited. Additionally, there are lower risks for the asset categories Critical and County Resources and Parks, Wetlands, and Trees.

While this assessment takes the first steps in identifying vulnerable assets and communities within Montgomery County, further work is needed to adequately prioritize assets and select appropriate, site-specific adaptation strategies to reduce climate hazard risk. Many important assets such as natural gas lines, homeless shelters, transportation maintenance and operations facilities, urgent care facilities, and childcare facilities, to name a few, were not included in this assessment and should be considered in future discussions. Community and stakeholder coordination will be critical to ground-truth the needs and vulnerabilities of both assets and people. Complex systems such as transportation, power, water, and sewer will require a more focused consideration if limited resources are to be allocated and used effectively. Additionally, detailed hydraulic models should be used in conjunction with the projections of future extreme precipitation scenarios developed in this study to develop future conditions floodplains and prioritize stormwater system improvements.

This climate vulnerability assessment considers the potential risk and impacts of extreme heat, extreme precipitation, drought, and high winds. In the next phase of this study, the vulnerability assessment will be used to rank and prioritize climate actions and to develop equity-enhancing measures for priority actions. This assessment will help the County in identifying and preparing for the natural hazard vulnerabilities that exist now and will persist in the future.

Attachment A

Table A-1. Asset Data Sources

Asset	**Asset Category**	**Source Notes**	**Online Link*** (if applicable)
Bikeways	Transportation	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/bikeways
Ride On Bus Stops	Transportation	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/rideonbusroutes
Street Centerlines	Transportation	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/street-centerline
MARC Rail Stations	Transportation	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/marc
MARC Rail Lines	Transportation	Census TIGER	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
Metro Rail Lines and Stations	Transportation	National Capital Regional Transportation Planning Board	https://rtdc-mwcog.opendata.arcgis.com/datasets/0d90d7b18c644657ba7646149b72e2d1_1
Proposed Purple Line	Transportation	MCAtlas	https://mcatlas.org/tiles/00_Shapefiles/Purple%20Line.zip
Airports	Transportation	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/airport-pts
Schools	Critical and County Resources	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/schools-elementary
County Recreation Centers	Critical and County Resources	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/recreation-ctr
Libraries	Critical and County Resources	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/library
Health and Human Services Nursing Homes	Critical and County Resources	Montgomery County Department of Environmental Protection GIS Department	geocoded from the list here: https://data.montgomerycountymd.gov/Health-and-Human-Services/HHS-Nursing-Homes/7m4d-85ys/data
Hospitals	Critical and County Resources	Montgomery County Open Data GIS	https://www.arcgis.com/home/item.html?id=dfa6f313f07346b48e415181b9dc0116
Police Stations	Critical and County Resources	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/police-stations

Asset	**Asset Category**	**Source Notes**	**Online Link*** (if applicable)
Fire Stations	Critical and County Resources	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/fire-station-pts
Emergency Shelters	Critical and County Resources	Montgomery County Department of Environmental Protection GIS Department	
Multi-Agency Buildings	Critical and County Resources	Montgomery County Department of Environmental Protection GIS Department	
Drinking Water Reservoirs	Utilities	Maryland GIS Data Catalog	https://data.imap.maryland.gov/datasets/maryland-waterbodies-lakes-detailed
Wastewater Treatment Facilities	Utilities	Montgomery County Department of Environmental Protection GIS Department	
Pump Stations	Utilities	Montgomery County Department of Environmental Protection GIS Department	
Electrical Lines	Utilities	Montgomery County Department of Environmental Protection GIS Department	
Substations	Utilities	Montgomery County Department of Environmental Protection GIS Department	
Power Generation Stations	Utilities	Montgomery County Department of Environmental Protection GIS Department	
Dry/Wet Ponds	Stormwater Management System	Montgomery County Department of Environmental Protection GIS Department	
Swales and Bioswales	Stormwater Management System	Montgomery County Department of Environmental Protection GIS Department	
Infiltration Trenches	Stormwater Management System	Montgomery County Department of Environmental Protection GIS Department	

Asset	**Asset Category**	**Source Notes**	**Online Link*** (if applicable)
Undergrounds Detention Basins	Stormwater Management System	Montgomery County Department of Environmental Protection GIS Department	
Dry Wells	Stormwater Management System	Montgomery County Department of Environmental Protection GIS Department	
Culverts	Stormwater Management System	Montgomery County Department of Environmental Protection GIS Department	
Agricultural Reserve	Agricultural Reserve	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/agricultural-reserve?geometry=-78.959%2C38.770%2C-75.454%2C39.516
Parks	Parks, Wetlands, and Trees	Montgomery County Open Data GIS	https://data2018-mcgov-gis.opendata.arcgis.com/datasets/parks
Wetlands	Parks, Wetlands, and Trees	Maryland GIS Data Catalog	https://data.imap.maryland.gov/datasets/cd293a192f844ac49d9716ee5a107d7a_1
Tree Cover	Parks, Wetlands, and Trees	Maryland-National Capital Park and Planning Commission	

*Note: Online links accessed December 9, 2020