

Climate and Health Addendum to  
2015 Green River Community Health Assessment



*Green River District*

HEALTH DEPARTMENT

September 2016

Daviess, Hancock, Henderson, McLean, Ohio,  
Union, and Webster Counties  
[www.healthdepartment.org](http://www.healthdepartment.org)

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# Table of Contents

Figures and Tables	iii
Executive Summary	1
Introduction	9
Climate and Health in Western Kentucky	9
Vulnerability of Rural Populations	9
Agriculture	12
Extreme Heat	14
Background	14
Economic Impacts of Increased Exposure to Heat	16
Health Effects of Extreme Heat	17
Extreme Heat Indicators for Green River District	25
Drought	28
Background	28
Economic Impacts of Increased Exposure to Drought	30
Health Effects of Drought	31
Drought Indicators for Green River District	35
Flooding	38
Background	38
Economic Impacts of Increased Exposure to Flooding	41
Health Effects of Flooding	42
Flooding Indicators for Green River District	48
Green River District Health Department Policy Recommendations	51
References	56
Appendix A: Climate and Health Indicators for Green River District Health Department	69
Appendix B: Flooding events in Green River District Counties (2000-2015)	75

## Figures and Tables

Table 1: Relative Vulnerability of Green River District Counties to Climate Change by Environmental Public Health Indicator. . . . .	7
Figure 1. Percentage population classified as rural, by county (KY: 2016, US: 2010). . . . .	10
Table 2. Unemployment rate in Green River District Counties, Kentucky, and U.S., June 2015 and June 2016. . . . .	11
Figure 2. Educational attainment for populations 25 and older in Green River District Counties, Kentucky, and U.S., 2010-2014. . . . .	12
Figure 3. Historical climate trends in Western Kentucky for air temperature and precipitation during summer months. . . . .	14
Table 3. Extreme heat exposure in Green River District Counties (2000-2012): Days with maximum temperatures greater than or equal to 95 degrees from May to September. . . . .	15
Figure 4. Current and future heat exposure in three Green River District counties. Defined by number of days over 90 degrees under low and high emissions models. . . . .	16
Table 4. Projections of reductions in crop yields in Kentucky related to increased heat. . . . .	17
Figure 5. Heat-related emergency department visits in Green River District by month and year (2008-2012). . . . .	19
Figure 6. Heat-Related emergency department visits per 10,000 in Green River District, by county (2008-2012) . . . . .	19
Figure 7. Heart disease death rate (2013), asthma hospitalization rate (2011-2013), and cerebro-vascular disease death rate (2011-2013) in Green River District counties. . . . .	20
Figure 8. Percentage adult population with obesity (2009), diabetes (2014) in Green River District counties. . . . .	21
Figure 9. Heat-related socioeconomic and demographic vulnerability (2010-2014) in Green River District counties. . . . .	23
Figure 10. Percentage households in Kentucky and U.S. that either do not have air conditioning or have it but do not use it (2009). . . . .	24
Figure 11. Percentage stressed housing in Green River District counties (2007-2011). . . . .	24
Table 5. Extreme heat indicators for Green River District. . . . .	26
Figure 12. Palmer drought severity index for the Western Climate Division, KY. . . . .	28
Figure 13. Percent population impacted by drought in Green River District counties (2007-2012). . . . .	29
Figure 14. Average daily concentration of particulate matter, PM <sub>2.5</sub> µg/m <sup>3</sup> (2011). . . . .	32
Figure 15. Percentage population with diabetes (2014), requiring mental health services (2013) in Green River District counties. . . . .	33

Figure 16. Chronic lower respiratory disease death rate (2010), asthma hospitalization rate (2011-2013) in Green River District counties. ....	34
Figure 17. Drought-related socioeconomic and demographic vulnerability (2010-2014) in Green River District counties. ....	35
Table 6. Drought indicators for Green River District. ....	36
Figure 18. Historical climate trends for precipitation and air temperature in Western Kentucky during spring months. ....	38
Figure 19. Historic river crests in Green River District counties (2005-2015). ....	39
Figure 20. Flooding events in Green River District by year and county (2000-2015). ....	40
Figure 21. Current and future flooding exposure in three Green River District counties. Defined by number of days with precipitation over 2 inches reported by weather stations annually. ....	41
Table 7. Flooding-related morbidity and mortality in the Green River District (2001-2015)). ....	42
Table 8. Total flood insurance policies in force (2016) by percentage population (2014). ....	43
Figure 22. Percentage population and percent area in Green River District counties located in 100-year FEMA floodplain (2011). ....	43
Figure 23. Unintentional carbon monoxide (CO) poisoning: emergency department visits (2008-2013). ....	45
Figure 24. Percentage population with diabetes (2014), requiring mental health services (2013), or suffering from ambulatory difficulty (2010-2014) in Green River District counties. ....	46
Figure 25. Long-term care beds per 10,000 in Green River District counties. ....	47
Figure 26. Flood-related socioeconomic and demographic vulnerability (2010-2014) in Green River District counties. ....	47
Table 9. Flooding indicators for Green River District. ....	49

# Executive Summary

## Purpose of this Report

Recognizing the role that weather and climate play in the human and economic health of rural regions such as the Green River District in Western Kentucky, this report was developed to supplement the findings of the 2015 Green River Community Health Assessment. It is designed to bring an evidence base to conversations about existing environmental hazards that may be exacerbated by climate change, as well as new hazards that may appear as temperatures warm. The report findings will be incorporated into the community engagement process for the 2018 Community Health Assessment update.

The report lays out the current state of the evidence linking exposure to climatic events with risks to the health of residents in the Green River District, a seven-county region encompassing Daviess, Hancock, Henderson, McLean, Ohio, Union, and Webster counties. It focuses on the three leading climatic conditions relevant to Western Kentucky: extreme heat, drought, and flooding. Each section reviews historical climatic trends for the environmental hazard in question, as well as possible future scenarios based on low and high emission climate models. It then assesses the strengths and vulnerabilities of the Green River District by displaying baseline data sets in each county for existing medical conditions, socioeconomic and demographic vulnerabilities, and environmental vulnerabilities that, according to the public health literature, can be associated with that particular hazard. In most cases, these data sets are contextualized by comparing county-level metrics with similar datasets for Kentucky and/or the U.S.

Vulnerable populations are emphasized throughout the report, both in data collection and in policy development; because, they are at a higher risk of negative health outcomes after exposure to a climatic event. The indicators outlined at the end of each section display an array of vulnerable populations: from existing health conditions to low socioeconomic status, demographics, and environmental conditions that place individuals at a disadvantage in comparison with the general population. Table 1, below, compiles the full set of indicators into a single, consolidated snapshot of high, medium, and low vulnerability by county. See Appendix A for an overview of the indicators by climatic hazard (extreme heat, drought, and flooding), the reason the indicator was included in the report, and the indicator's data source.

## Focus on Rural Communities and Agriculture

The Green River District is located in Western Kentucky, a predominantly rural area punctuated by population centers such as Owensboro and Henderson. All seven counties in the District have a higher percentage of rural residents than the national average (19.3%); and, five of the seven exceed the commonwealth average of 41% (Figure 1).

Rural communities face unique health challenges in the face of climate change. Rural populations are at higher risk of climate-related morbidity and mortality than urban populations, both due to environmental factors (low density, remote locations, and less robust infrastructure) which increase the difficulty of providing emergency services during and following events [1, p. 339]; and, because, on average, their

underlying socioeconomic and health status are lower than urban populations, resulting in a less resilient population overall.

Similar to many other rural areas, agriculture is a major economic driver in the Green River District. Outdoor professions account for over 40% of employment in Hancock County and over 30% of employment in Ohio, Union, and Webster counties, well over the national average of 18.6% (Figure 9). It both is highly sensitive to changes in the climate and contributes to greenhouse gas emissions through the use of fossil fuels in farm equipment, fertilizers, and pesticides. Given the interconnected relationship between agriculture and the Green River District's economy, population health, and contribution to global greenhouse gas emissions, this report considers it central to an understanding of the current and likely future effects of climate change on the region.

## Climatic Hazards in Green River District

### EXTREME HEAT

Heat waves are an existing and growing health threat to the Green River District. Extreme heat events accounted for 16% of natural hazard events in the Green River District from 2010-2015. [2, Figure 4-1] By 2020-2039, Kentucky is projected to experience up to 23 days per year with temperatures exceeding 95 °F. From 2040-2059, up to 44 days per year could exceed 95 °F. Western Kentucky is projected to warm more than other regions in the commonwealth [3, pp. 44-45]. Higher temperatures are projected to increase heat-related mortality in Kentucky by as much as 300 additional deaths from 2020-2039 and by as much as 460 additional deaths from 2040-2059 [3, p. 45].

### Primary Impacts of Warming Temperatures on Green River District

#### Economic Impacts

- Strain on electrical grid, due to increased air conditioning demand.
- Reduced crop yields, livestock yields, productivity of agricultural workers.

#### Health Impacts

- Increased risk of heat-related hospital visits and mortality, particularly among outdoor occupations.
- Exacerbated chronic health conditions such as heart disease, asthma, cerebro-vascular disease, obesity, and diabetes.
- Increased risk of carbon monoxide poisoning during power outages.

#### Vulnerable Populations

- Children, Elderly, Pregnant Women, Non-Hispanic Blacks, Homeless, Outdoor Workers, Low Socioeconomic Status,
- Residents of Stressed Housing and/or Reduced Access to Air Conditioning

## DROUGHT

Droughts are likely to become more common in regions like the Green River District as the climate changes, due to a combination of warmer temperatures and increased variability in precipitation. Drought has increased 12-14% in the southeastern U.S. since 1970. [4] According to the U.S. Environmental Protection Agency, Kentucky experienced a trend of increasing drought conditions from 1958 to 2007. [5] In the Green River District, Daviess, McLean, Ohio, and the eastern half of Webster counties experienced, on average, 15-33 days per year of extreme low flow from 2000-2009. [6] Furthermore, every county in the District experienced either extreme or exceptional drought conditions in September and October 2007 and July and August 2012 (Figure 13). From 2010-2015, droughts accounted for 12% of natural hazard events in the district. [2, Figure 4-1]

### Primary Impacts of Drought on Green River District

#### Economic Impacts

- Reduced crop and livestock yields.
- Increased water demand for agricultural and power generation uses.
- Increased risk of wildfire.
- Delayed product shipments via waterways.

#### Health Impacts

- Reduced access to potable water, compromised water quality, increased risk of waterborne diseases.
- Increased exposure to particulate matter (PM) in the form of airborne dust.
- Increased exposure to vector-borne diseases (e.g., mosquitoes, rodents).
- Exacerbated chronic health conditions such as asthma, hypertension, diabetes, chronic lower respiratory disease (CLRD).
- Mental health concerns.

#### Vulnerable Populations

- Children, Elderly, Women, Non-Hispanic Blacks, Immuno-compromised.
- Residents of Stressed Housing.

## FLOODING

Historically, Western Kentucky has experienced an average of 55 thunderstorm days per year. These events can cause flooding, particularly in the winter and spring months. [7] Flooding and severe thunderstorms accounted for 42% of natural hazard events and 92% of related property damage in the Green River District from 2010-2015. [2, Figures 4-1 & 4-2] Serious floods occur, on average, every two years. [2, p. 109] All of the counties in the Green River District experienced at least 15-23 days of extreme high water flow, on average, from 2000-2009. Areas next to the Ohio River and Henderson, Hancock, Union, the western half of Webster, and the northeastern quadrant of Daviess counties experienced more than 23 days of high flow, on average, during the same time period. [6] Average annual precipitation in the District is projected to increase close to 2% under a low emissions scenario and up to 6% under a high emissions scenario [8, p. 16].



## **Primary Impacts of Flooding on Green River District**

### Economic Impacts

- Damage to property and infrastructure.
- Delay in shipments via road, rail, and/or waterways.
- Reduced crop and livestock yields.

### Health Impacts

- Increased risk of drowning-related injury and death.
- Increased risk of gastrointestinal illnesses and infections of the eye, ear, nose, throat, or skin.
- Increased risk of carbon monoxide poisoning during power outages and during flooding cleanup activities.
- Risk of exposure to contaminated water.
- Mental health concerns.

### Vulnerable Populations

- Populations living in floodplains and/or stressed housing.
- Children, Elderly, Women, Non-Hispanic Blacks, Hispanics, Disabled, Populations with Chronic Diseases (e.g., diabetes), Populations Requiring Regular Medical Treatment, Immuno-compromised, Medical Patients and Long-term Care Residents, Low Socioeconomic Status, Limited English Proficiency.

## **Green River District Health Department Policy Recommendations**

The report concludes with a set of policy recommendations developed by the Green River District Health Department in response to the report's findings.

### **EXISTING GREEN RIVER DISTRICT HEALTH DEPARTMENT POLICIES**

The Green River District Health Department (GRDHD) provides services, support activities and has policies in place that address hazards from natural disasters, the specific needs of vulnerable populations, and the importance of reducing the prevalence of chronic disease. However, at this time, the department does not have formal agency policies and has not undertaken program activities specifically aimed at climate change or the negative health effects associated with climate change.

Areas of local health existing practice that could be expanded to incorporate climate change considerations include:

- Epidemiology Program
- Public Health Preparedness Program
- Community Health Assessment and Health Improvement Planning

## RECOMMENDED ACTIONS

The findings of the report suggest the following four actions to reduce population vulnerability to the health effects of climate change in the Green River District:

1. Routinely monitor, track, update and report new data for the environmental public health indicators identified in this report.
2. Integrate the tracking and reporting of the climate risks and environmental public health indicators into future annual updates and revisions of the Community Health Assessment.
3. Establish new policies and practices related to surveillance of negative health outcomes associated with extreme heat events, flooding, and drought.
4. Establish public education message toolkits to be utilized during extreme heat, drought, and flooding events.

## OPPORTUNITIES TO STRENGTHEN POLICIES AND INTERVENTIONS LED BY PARTNERS

The Green River District Health Department has also identified opportunities for the data compiled in this report to inform ongoing work led by community partners. For example:

1. In coordination with regional healthcare preparedness and emergency preparedness partners, use the environmental public health indicators to inform the development and revision of response recovery plans to events related to extreme heat, flooding, and drought.
2. Incorporate the health and hazard indicators into the 2021 revision of the Green River Area Development Districts (GRADD) Hazard Mitigation Plan.
3. Partner with local community and outreach organizations to customize preparedness educational materials to be shared throughout the region. These partners may include county coalitions, the Medical Reserve Corps, Voluntary Organizations Active in Disaster (VOAD), and Citizen Corp agencies.
4. Coordinate with businesses and services that work with vulnerable populations to ensure that environmental hazard awareness is included in outreach to their clients. This goal includes the development of specialized materials to account for differently abled and language barriers.

## OPPORTUNITIES TO EXPAND AND ADD VALUE TO PROJECT OUTCOMES

Finally, the foundational work presented in this report could be expanded and improved in the following ways:

1. Perform more robust analysis of the data compiled during this project to specifically examine the links between historical extreme heat and flooding events in the Green River District and expected health outcomes. Use this information to refine thresholds for action

(such as when to open cooling centers). Conduct additional geocoded analysis to identify locations where multiple vulnerabilities are clustered.

2. Identify indirect environmental health risks and indirect health outcomes not addressed specifically or fully in this report. Indirect effects to be researched may include: mental health, respiratory and cardiovascular conditions related to air quality, economic impact, and behavioral health.
3. Coordinate at the state or regional level to create a broader policy or plan to address climate change hazards and outcomes. Possible partners include: other local health departments in Kentucky, as well the Kentucky Department for Public Health.

Table 1: Relative Vulnerability of Green River District Counties to Climate Change by Environmental Public Health Indicator

Environmental Exposure							
	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
HIGH	Exposure to heat waves Exposure to drought Exposure to air pollution Exposure to heavy precipitation events						
MODERATE							
LOW							
Human Health Outcome*							
	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
HIGH	Flooding-related morbidity		Heat-related morbidity	Heat-related morbidity	Flooding-related morbidity	Heat-related morbidity	Heat-related morbidity
MODERATE	Heat-related morbidity		Flooding-related morbidity		Heat-related morbidity	Flooding-related morbidity	Flooding-related morbidity
LOW	Heat-related mortality	Heat-related morbidity & mortality	Heat-related mortality	Heat-related mortality	Heat-related mortality	Heat-related mortality	Heat-related mortality
	Flooding-related mortality	Flooding-related morbidity & mortality	Flooding-related mortality	Flooding-related morbidity& mortality	Flooding-related mortality	Flooding-related mortality	Flooding-related mortality
Population Vulnerability							
	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
HIGH	Children	Children	Children	Children	Children	Elderly	Elderly
	Elderly	Elderly	Elderly	Elderly	Elderly	Outdoor Workers	Outdoor Workers
	Homeless	Outdoor Workers	Diabetes	Outdoor Workers	Poverty	Obesity	Obesity
	Mental Health	Diabetes	CLRD	Diabetes	Outdoor Workers	Heart Disease	Diabetes
	Long-term Care	Heart Disease	Asthma	Heart Disease	Diabetes	Cerebro-vascular Disease	Heart Disease
		CLRD	Cerebro-vascular Disease		Heart Disease		CLRD
		Long-term Care		Cerebro-vascular Disease	Long-term Care		Asthma
				Long-term Care		Cerebro-vascular Disease	

	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
MODERATE	Poverty	Obesity	Poverty	Poverty	Homeless	Poverty	Children
	Heart Disease	Cerebro-vascular Disease	Outdoor Workers	CLRD	Obesity	Non-Hispanic Blacks	Poverty
	CLRD		Obesity	Asthma	CLRD		Mental Health
	Cerebro-vascular Disease	Mental Health	Heart Disease	Mental Health	Cerebro-vascular Disease	CLRD	Long-term Care
			Mental Health		Mental Health	Mental Health	
LOW	Non-Hispanic Blacks	Poverty	Non-Hispanic Blacks	Non-Hispanic Blacks	Non-Hispanic Blacks	Children	Non-Hispanic Blacks
	Outdoor Workers	Non-Hispanic Blacks	Homeless	Limited English Proficiency	Limited English Proficiency	Limited English Proficiency	Limited English Proficiency
	Limited English Proficiency	Limited English Proficiency	Limited English Proficiency	Obesity	Asthma	Diabetes	Ambulatory Difficulty
	Obesity	Ambulatory Difficulty	Ambulatory Difficulty	Ambulatory Difficulty	Ambulatory Difficulty	Asthma	
	Diabetes					Ambulatory Difficulty	
	Asthma					Long-term Care	
	Ambulatory Difficulty						
<b>Environmental Vulnerability</b>							
	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
HIGH	FEMA Floodplain	FEMA Floodplain	FEMA Floodplain	FEMA Floodplain	FEMA Floodplain	FEMA Floodplain	
			Stressed Housing				
MODERATE							
LOW	Stressed Housing	Stressed Housing		Stressed Housing	Stressed Housing	Stressed Housing	FEMA Floodplain
							Stressed Housing

**Note:** \*Drought reportable human health outcomes to be determined.

**Legend:**

High: Falls short of both Kentucky and U.S. indicators, or, if no larger scale data is available, in comparison with other Green River District (GRD) counties.

Moderate: Falls short of either Kentucky or U.S. indicators or in comparison with other GRD counties.

Low: Improvement over Kentucky and U.S. indicators or in comparison with other GRD counties.

# Introduction

## Climate and Health in Western Kentucky

Climate change refers to the global, long-term trend of warming temperatures that has been observed since the Industrial Revolution. There is strong certainty among scientists that the warming observed over the past half-century was primarily caused by human activities – mainly through burning fossil fuels such as coal, oil, and gas and through clear-cutting forests, which are major absorbers of carbon dioxide [9, p. 7]. The health effects of climate change range from injury and death after exposure to an extreme weather event to more indirect health effects, such as exacerbating existing conditions such as asthma, heart disease, and diabetes [10, p. 46].

This report lays out the current state of the evidence linking exposure to climatic events in the Green River District with human health. It focuses on the three leading climatic hazards relevant to Western Kentucky: extreme heat, drought, and flooding. Each section reviews historical climatic trends for the environmental hazard in question, as well as possible future scenarios based on low and high emission climate models. The report then assesses the strengths and vulnerabilities of the Green River District by displaying baseline data sets in each county for existing medical conditions, socioeconomic and demographic vulnerabilities, and environmental vulnerabilities that, according

to the public health literature, can be associated with that hazard. In most cases, these data sets are contextualized by comparing county-level metrics with similar datasets for Kentucky and/or the U.S.

## Vulnerability

Vulnerable populations are more sensitive to the effects of exposure to a climatic event than the general population. And, they are less able to recover or adapt to changing conditions. Vulnerability is also influenced by the social determinants of health, such as socioeconomic status, which can place subpopulations at an advantage or disadvantage prior to exposure to an extreme weather event [11, pp. 103-104].

This report emphasizes vulnerable populations both in data collection and in policy development; because, they are at a higher risk of negative health outcomes after exposure to a climatic event. The indicators outlined at the end of each section display an array of potential vulnerabilities: from existing health conditions to low socioeconomic status, demographics, and environmental conditions that place individuals at a disadvantage in comparison with the general population.

## Vulnerability of Rural Populations

Rural populations are at higher risk of climate-related morbidity and mortality than urban populations, both due to environmental factors (low density, remote locations, and less robust infrastructure) which increase the difficulty of providing emergency services during and following events [1, p. 339]; and, because, on average, their underlying socioeconomic and

health status are lower than urban populations, resulting in a less resilient population overall [12,13].

They are also at higher risk of being exposed to hazardous substances such as pesticides, herbicides, and fertilizers [14,15]. Exposure can occur via airborne dust and/or stormwater runoff

#### Key Vulnerability Characteristics of Rural Populations Compared with Urban Areas

- **Demographics:** older, less affluent, less well educated, higher levels of unemployment
- **Access to Care:** spend a higher proportion of their income on medical services
- **Health Outcomes:** higher rates of age-adjusted mortality, disability, and chronic disease
- **Built Environment:** low density, remote locations, and less robust infrastructure
- **Environmental Exposure:** exposure to hazardous substances such as pesticides, herbicides, and fertilizers

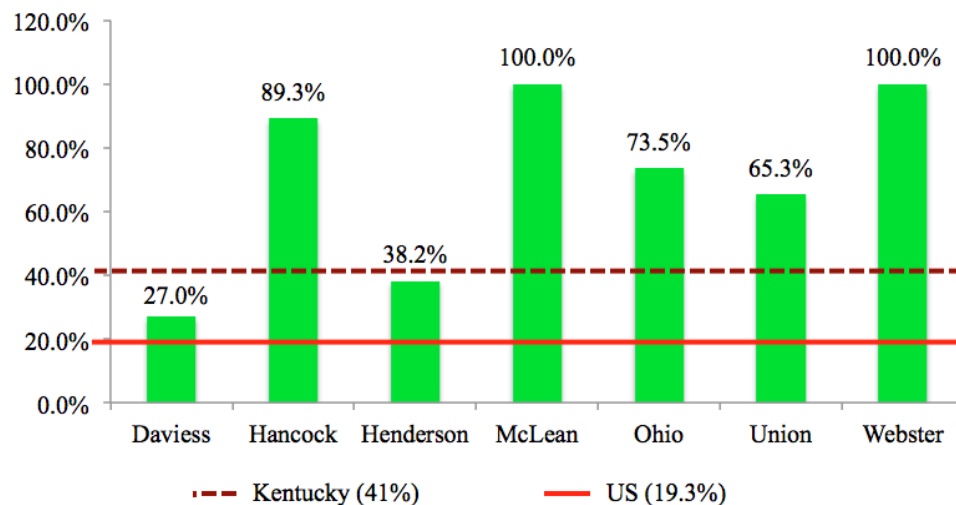
during transport, while filling containers, during application to cultivated areas, and after application.

Demographically, rural populations tend to be older, less affluent, less well educated, and with

higher levels of unemployment than their urban counterparts [12,13]. They also tend to spend a higher proportion of their income on medical services, in spite of reporting higher rates of age-adjusted mortality, disability, and chronic disease than urban populations [15]. These underlying social vulnerabilities are exacerbated by reduced access to health care services in sparsely populated areas [1, p. 339]. On the other hand, the strong social connections formed in small communities may counteract their underlying vulnerability to some extent during and after natural disasters [16].

The Green River District is located in Western Kentucky, a predominantly rural area punctuated by population centers such as Owensboro and Henderson. All seven counties in the District have a higher percentage of rural residents than the national average (19.3%); five of the seven exceed the Kentucky average of 41%; and, two counties (McLean and Webster) are classified as 100% rural (Figure 1).

**Figure 1. Percentage population classified as rural, by county (KY: 2016, US: 2010).**



**Sources:** KY (2016): County Health Rankings, <http://www.countyhealthrankings.org>

US (2010): U.S. Census Bureau, Population Division, <http://www.census.gov>

Regarding the demographic risk factors listed above, all Green River District counties have a slightly higher proportion of elderly (aged 65+) than the national average (14.5%) or the commonwealth of Kentucky (14.8%) – ranging from 15% in Union County to 18.6% in McLean County (Figure 9). Every county except for Hancock (13.8%) also exceeds the national (14.8%) proportion of populations living in poverty. However, only Ohio County (19.7%) exceeds the Kentucky average of 19.1% (Figure 9).

Unemployment rates in the Green River District, on the other hand, were similar to the Kentucky (2015: 5.5%; 2016: 5.4%) and national (2015: 5.3%; 2016: 4.9%) rates for all counties except for Union (2015: 7.0%; 2016: 7.4%) and Ohio (2015: 6.4%; 2016: 6.9%) in June 2015 and June 2016 (Table 2).

The percentage of high school graduates among adults aged 25 and older is slightly lower than the Kentucky (83.5%) and national (86.3%) levels in all Green River District counties except for Daviess (87.9%), Hancock (87.1%), and

Henderson (85.2%). However, the educational gap widens for bachelors degrees. Only Daviess County (19.9%) approximates the Kentucky average (21.8%), which itself falls 7.5 percentage points short of the national average (29.3%) (Figure 2).

Of the chronic diseases that can increase vulnerability to the negative health effects of extreme heat, drought, and flooding – obesity, diabetes, heart disease, chronic lower respiratory disease (CLRD), asthma, and cerebro-vascular disease – many of the counties in the Green River District report higher levels of diabetes (11.3% - 17.5%, compared with 12.5% in KY and 9.3% in the U.S.), heart disease (180.6 per 100,000 - 237.1 per 100,000, compared with 207.1 in KY and 171.6 in the U.S.), CLRD (44.7 per 100,000 - 88.2 per 100,000, compared with 64.0 in KY and 44.7 in the U.S.), asthma (10.1 per 10,000 - 16.7 per 10,000, compared with 13.1 in KY and 11.1 in the U.S.), and cerebro-vascular disease (38.4 per 100,000 – 56.3 per 100,000, compared with 43.5 in KY and 37.0 in the U.S.) than the commonwealth of Kentucky or the U.S. as a whole (Figures 7, 8, 16).

**Table 2. Unemployment rate in Green River District Counties, Kentucky, and U.S. (June 2015, June 2016).**

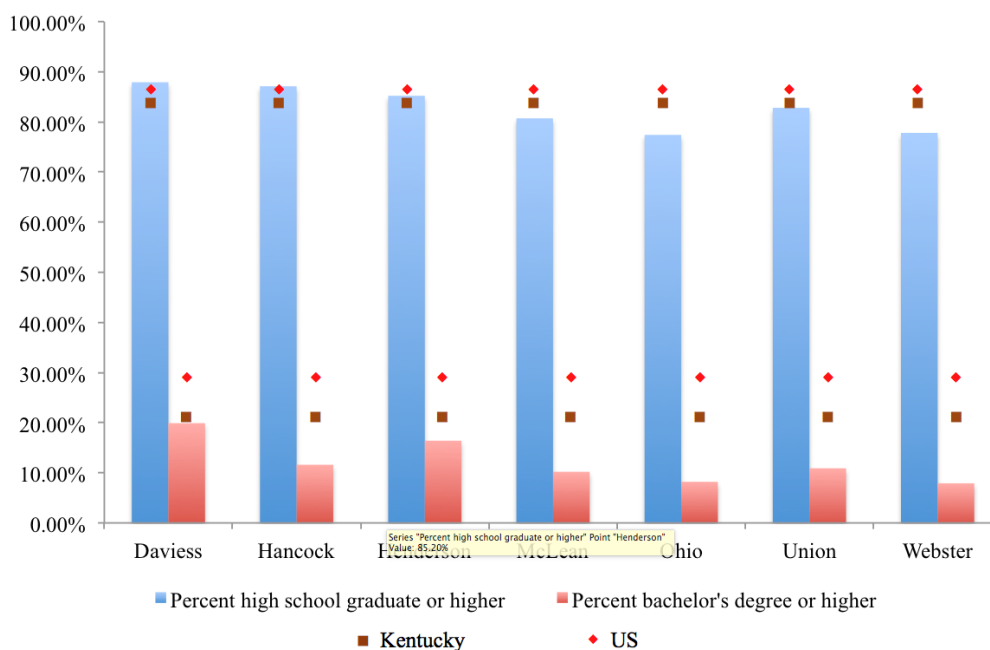
	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
<b>June 2015</b>	4.9%	5.0%	5.1%	5.3%	6.4%	7.0%	5.4%	5.5%	5.3%
<b>June 2016</b>	4.8%	5.6%	5.1%	4.8%	6.9%	7.4%	5.9%	5.4%	4.9%

**Sources:** Kentucky Labor Market Information. Labor Market Statistics, Local Area Unemployment Statistics Program. Available at: <https://kylmi.ky.gov>

U.S. Department of Labor, Bureau of Labor Statistics. Unemployment Rate. Available at: <http://data.bls.gov/timeseries/LNS14000000>



**Figure 2. Educational attainment for populations 25 and older in Green River District Counties, Kentucky, and U.S. (2010-2014).**



	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
Percent high school graduate or higher	87.90%	87.10%	85.20%	80.70%	77.40%	82.80%	77.80%	83.50%	86.30%
Percent bachelor's degree or higher	19.90%	11.60%	16.40%	10.20%	8.20%	10.90%	7.90%	21.80%	29.30%

**Source:** Educational Attainment (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

## Agriculture

Natural conditions such as calcium-rich soil, abundant rain, and moderate temperatures create supportive conditions for agriculture in Kentucky. The commonwealth hosts 76,000 farms covering 13 million acres of land (roughly half of its surface area) [3, p. 45]. In 2012, the Green River District hosted 3,819 farms, totaling more than a million acres of land [2, p. 283]. The highest value crops in the commonwealth are soybeans, corn, and hay, with the combination of soybeans and corn alone generating \$1.7 billion in revenue each year. In

### Relationship between Agriculture and Climate Change

- **Sensitive to Changes in Climate:** particularly changes in temperature and precipitation
- **Contributes to Global Greenhouse Gas Emissions:** microbial decay, controlled burns, animal releases, excessive fertilizer use, production of nitrogen fertilizers and synthetic pesticides, fossil fuels used in agricultural machinery, energy input to run irrigation systems

spite of these cash crops' dominance, livestock (notably chicken and beef cattle farming) represent two-thirds of Kentucky's agricultural economy [3, p. 45].

Agriculture is also a major economic driver in the Green River District, with outdoor professions accounting for over 40% of employment in Hancock County and over 30% of employment in Ohio, Union, and Webster counties, well over the national average of 18.6% (Figure 9).

Agriculture is highly sensitive to changes in climate, due to its dependence on specific temperature ranges and precipitation patterns to set planting and harvesting patterns, control pests, and maximize yields. Extreme weather events can decimate crops [1, pp. 336-337]. Long-term changes to the climate may lead farmers to increase irrigation use, shift to new crops, and/or increase use of pesticides and herbicides [17] – with their corresponding risks to human health [1, p. 336]. By mid-century, the combination of temperature increases and changes in precipitation patterns is projected to result in declining crop yields and agricultural profits in the U.S. [18,19]. Over the long term, the variability year to year of production and profits is likely to increase [20,21]. These changes will place additional pressure on the already uncertain economics of farming, taking a toll on rural communities, which tend to host a

smaller range of economic opportunities than urban areas [1, p. 334].

Agriculture is also a major emitter of the greenhouse gases causing global climate change. According to the Intergovernmental Panel on Climate Change (IPCC), agriculture and forestry contribute 24% of total human-caused greenhouse gas emissions each year [22, p. 44]. However, this number only addresses direct emissions. For example, Carbon Dioxide (CO<sub>2</sub>) is released through microbial decay and controlled burns. Methane (CH<sub>4</sub>) is released by livestock and by flooding rice fields. And, Nitrous Oxide (N<sub>2</sub>O) is released when Nitrogen-rich fertilizers are applied to fields [23]. Agriculture's share would increase if indirect emissions were included in the calculation, such as the production of nitrogen fertilizers, synthetic pesticides, and fossil fuels used in agricultural machinery, and the energy input required to run irrigation systems [24].

Given agriculture's influence on population health in rural areas such as Western Kentucky, its vulnerability to changes in temperature and precipitation patterns, and its contribution to global greenhouse gas emissions, this report considers it central to an understanding of the effect that climate change is currently exerting and will likely continue to exert on population health in the seven counties comprising the Green River District.

# Extreme Heat

## Background

The buildup of greenhouse gases in the Earth's atmosphere has led to warming ambient air temperatures around the globe. Temperatures in the U.S. have increased from 1.3 °F to 1.9 °F since 1895, when the first records were documented. And, they are projected to increase from 3 °F to 10 °F by the end of the century. Furthermore, the frequency and intensity of heat waves have increased over the past century, while the number of intense cold spells has decreased [10, p. 45].

Climate Central ranks the Commonwealth of Kentucky as one of the 10 worst affected states in the U.S. for extreme heat by 2050 [25]. From 1901 to 2008, average annual temperatures in Kentucky increased close to 1 °F, with the most notable warming occurring in winter months [8]. The trend was more pronounced from 1970 to 2008, showing an average annual increase of 1.4 °F [26, p. 111]. By 2050, the average annual temperature in the Green River District is projected to increase from close to 4 °F (under a low emissions scenario) to 5 °F (under a high emission scenario) [8, p. 15]. The top half of Figure 3 shows air temperature variations in Western Kentucky during the summer season from 1890 to 2015. The heavy red line, representing a 30-year moving average, displays a consistent upward trend in summer temperatures starting in 1970.

Extreme heat events accounted for 16% of natural hazard events in the Green River District from 2010-2015 [2, Figure 4-1]. Heat waves, defined in this report as three or more days with maximum temperatures greater than or equal to 95 degrees, occur regularly in Western Kentucky during the summer. From 2000 to 2012, the average duration of heat waves in the Green River District was 6.25 days. Union and Webster counties, two of the most rural counties in the District, reported the highest number of heat

### Primary Impacts of Warming Temperatures on Green River District

#### Economic Impacts

- Strain on electrical grid, due to increased air conditioning demand.
- Reduced crop yields, livestock yields, agricultural worker productivity.

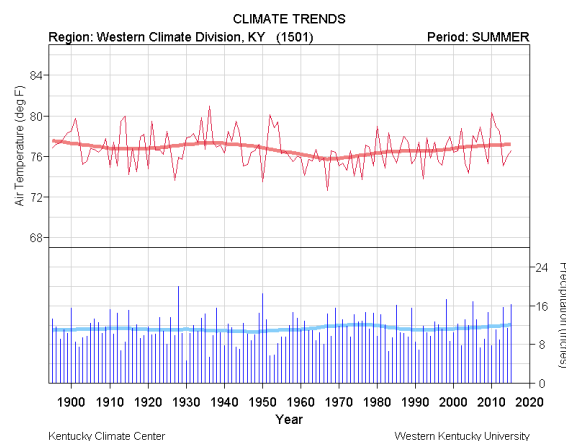
#### Health Impacts

- Increased risk of heat-related hospital visits and mortality, particularly among outdoor occupations.
- Exacerbated chronic health conditions such as heart disease, asthma, cerebro-vascular disease, obesity, and diabetes.
- Increased risk of carbon monoxide poisoning during power outages.

#### Vulnerable Populations

- Children, Elderly, Pregnant Women, Non-Hispanic Blacks, Homeless, Outdoor Workers, Low Socioeconomic Status,
- Residents of Stressed Housing and/or Reduced Access to Air Conditioning.

**Figure 3. Historical climate trends in Western Kentucky for air temperature and precipitation during summer months.**



**Note:** Heavy line displays 30-year moving average.

**Source:** Kentucky Climate Center, Department of Geography and Geology, Western Kentucky University. Accessed May 3, 2016.

waves during this time (Union: 22; Webster: 19). However, the entire District was affected during the worst heat events: 25 days in 2007 (July 31-August 24), eight days in 2010 (August 8-15), and a 14-day heat wave in 2012 (June 27-July 10) followed immediately by a 26-day heat wave (July 15-August 9) (Table 3).

Climate projections predict that historical warming trends will continue in the future. Over the past 30 years, summertime temperatures in Kentucky as a whole have exceeded 95 °F on average 4 days per year [3, pp. 44-45]. By 2020-2039, Kentucky is projected to experience up to 23 days per year with temperatures exceeding 95 °F – almost a six-fold increase. From 2040-2059,

up to 44 days per year could exceed 95 °F. Western Kentucky is projected to warm more than other regions in the commonwealth [3, pp. 44-45].

Figure 4 displays the number of days over 90 degrees in three Green River District counties (Henderson, Ohio, and Webster) from 2005-2010, as well as low emission and high emission scenarios for these counties through 2050. While the climate projections cannot predict annual variability in weather patterns (as is clearly shown in the data from 2005-2010), both emissions scenarios anticipate a strong trend towards increasing frequency of heat exposure days in all three counties from 2020-2050.

**Table 3. Extreme heat exposure in Green River District Counties (2000-2012): Days with maximum temperatures greater than or equal to 95 degrees from May to September.**

Years	Extreme Heat Exposure	Counties Affected
2000	8/28/00 - 8/30/00	Union, Webster
2001	No dates met exposure definition.	
2002	8/02/02 - 8/04/02 9/07/02 - 9/10/02	Union Henderson, Union, Webster
2003	No dates met exposure definition.	
2004	No dates met exposure definition.	
2005	7/24/05 - 7/26/05 8/09/05 - 8/14/05	Union Henderson, McLean, Union, Webster
2006	7/18/06 - 7/21/06 7/30/06 - 8/03/06 8/06/06 - 8/10/06	Union Union, Webster Union
2007	7/31/07 - 8/24/07 8/27/07 - 8/29/07* 9/02/07 - 9/05/07*	All counties Henderson, McLean, Union, Webster Daviess, Henderson, McLean, Union, Webster
2008	No dates met exposure definition.	
2009	No dates met exposure definition.	
2010	7/23/10 - 7/25/10* 8/01/10 - 8/04/10 8/08/10 - 8/15/10 8/19/10 - 8/22/10 8/31/10 - 9/02/10 9/19/10 - 9/23/10	Hancock All counties All counties All counties All counties All counties
2011	8/31/11 - 9/03/11	All counties
2012	6/18/12 - 6/21/12 6/23/12 - 6/25/12 6/27/12 - 7/10/12 7/15/12 - 8/09/12 8/23/12 - 8/25/12* 8/28/12 - 8/31/12**	Henderson, McLean, Union, Webster Henderson, McLean, Webster All counties All counties Daviess, Henderson, McLean, Union, Webster All counties

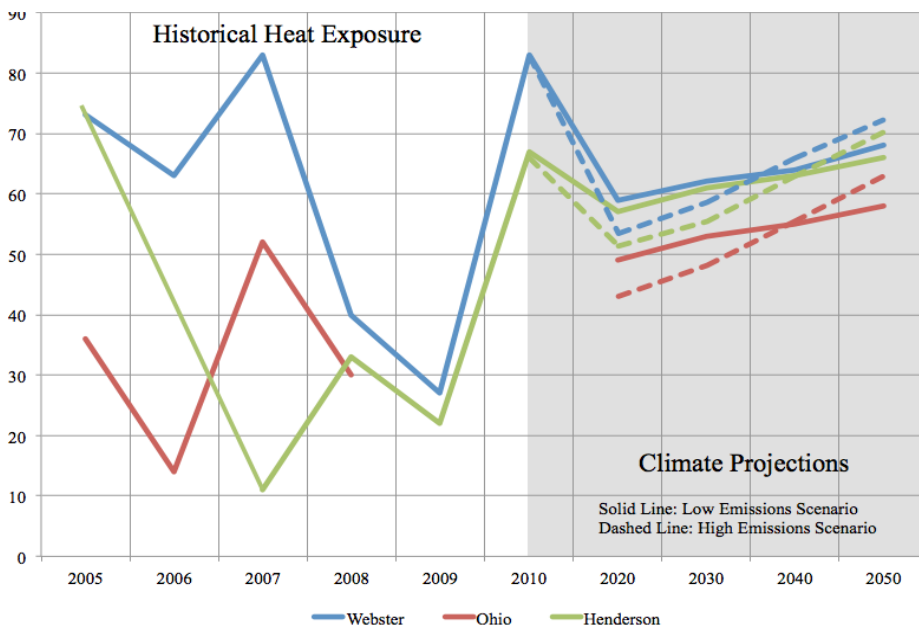
**Notes:**

\* All other counties reached threshold for 2 days.

\*\* Hancock County reached one degree shy of threshold on 8/29/12.

**Source:** National Environmental Public Health Tracking Program, <http://ephtracking.cdc.gov/>

**Figure 4. Current and future heat exposure in three Green River District counties. Defined by number of days over 90 degrees under low and high emissions models.**



	Historic Data						Low Emissions Projection				High Emissions Projection			
	2005	2006	2007	2008	2009	2010	2020	2030	2040	2050	2020	2030	2040	2050
Webster	73	63	83	40	27	83	59	62	64	68	55	60	67	73
Ohio	36	14	52	30	n/a	n/a	49	53	55	58	45	50	57	64
Henderson	76	n/a	11	33	22	67	57	61	63	66	53	57	64	71

**Source:** Kentucky Climate Center, Department of Geography and Geology, Western Kentucky University. Accessed June 2016.

## Economic Impacts of Increased Exposure to Heat

Increasing temperatures put stress on the electrical grid by increasing air conditioning demand. Sustained higher temperatures will eventually lead to the need to construct additional power plants to support increased air conditioning use, thereby increasing electricity rates. Rates are anticipated to increase 5% in Kentucky from 2020-2039 and 9% from 2040-2059 [3, pp. 47-48]. If demand outstrips electricity capacity, it is likely that power outages will occur simultaneously with extreme heat events. This situation will increase the risk to vulnerable populations, as it will reduce access to the most prevalent form of heat adaptation: air conditioning [27].

Increasing annual temperatures are projected to reduce crop yields significantly in Kentucky, particularly for corn and soybeans, as seen in Table 4 [3, pp. 46-47]. Other estimates project a decrease in corn yields of 4.6% per 1°F increase in average growing season temperature [28] and a decrease in yields of 1.7% per 1°F increase in air temperature [20]. Soybeans yields are projected to decrease 0.7% per 1°F increase in air temperature [28].

Air temperatures in the region are already reaching or exceeding optimal levels for corn [20]. It is therefore likely that, without adaptations like shifting the growing season or

switching to more heat-tolerant plant varieties, crop yields will start to decline in coming years.

The picture is far less clear for a crop like soybeans. It is difficult to predict with accuracy the collective impact that warming temperatures, elevated CO<sub>2</sub> levels, changes in water availability, and changes in pest and disease behavior will have on soybean yields [29, pp. 16-17]. For example, while soybeans will suffer from increased temperatures, increasing CO<sub>2</sub> levels to 550-585 ppm could accelerate plant growth by up to 16% [30]. And increasing CO<sub>2</sub>

levels have been shown to increase plant water use efficiency, partially offsetting the reduced water availability in the soil due to increases in evapotranspiration when temperatures rise [31, pp. 779-790].

Some adaptations themselves could exacerbate the effects of climate change. For example, introducing irrigation could put an added strain on water resources that are projected to tighten as a result of climate change

**Table 4. Projections of reductions in crop yields in Kentucky related to increased heat.**

Crop	Projected Maximum Yield Reduction, 2020-2039	Projected Maximum Yield Reduction, 2040-2059
Corn	21.5%	46.5%
Soybeans	12.5%	29.4%

**Source:** Come Heat and High Water: Climate Risk in the Southeastern US and Texas. Risky Business: The Bottom Line on Climate Change. July 2015. Available at: <http://riskybusiness.org/site/assets/uploads/2015/09/Climate-Risk-in-Southeast-and-Texas.pdf>. Accessed April 4, 2016. PP. 46-47.

## Health Effects of Extreme Heat

### OVERVIEW

Extreme heat can inhibit the body's ability to regulate its internal temperature, leading to illnesses such as: heat cramps, heat exhaustion, heat stroke, and hyperthermia during heat waves. If the heat wave also includes warm nighttime temperatures, it becomes increasingly difficult for the human body to recover each evening from exposure to higher than optimal temperatures during the day. Exposure to heat can also exacerbate chronic conditions such as cardiovascular disease, respiratory disease, cerebro-vascular disease, and complications related to diabetes. In particular, prolonged exposure to heat may lead to increases in hospital admissions for individuals suffering from cardiovascular, kidney, or respiratory disease [10, p. 46]. Obesity (BMI 30+) also increases sensitivity to high ambient temperatures [32, p. 34].

It is important to note that the definition of extreme heat exposure in the previous section is simply a marker of heightened risk. It does not imply direct health outcomes. Small departures from the optimal temperature range (both high and low) have been associated with increased mortality [35–37] and heat-related illness, depending on demographics, pre-existing health conditions, environmental triggers, and the type and duration of exposure to high ambient air temperatures [10, pp. 46-47]. Furthermore, heat waves occurring early in the summer months (before populations have acclimatized to warmer weather [38]) have been associated with a higher rate of mortality than those occurring later in the year [39].

From 2006 to 2010, mortality in the U.S. directly attributed to extreme heat was conservatively estimated at 670 deaths per year



[40]. However, that number is likely an underestimate, because heat is often only one of several causes of death. And, it is often not listed on the death certificate [40,42]. Some statistical models have estimated that more than 1,300 deaths per year in the U.S. can be attributed directly or indirectly to exposure to extreme heat [39,59]. Increases in future mortality have been projected to reach the thousands to tens of thousands of additional premature deaths nationally before 2100 [60–67].

Higher temperatures are projected to increase heat-related mortality in Kentucky by as much as 300 additional deaths from 2020-2039 and by as much as 460 additional deaths from 2040-2059 [3, p. 45]. A recent study of 290 U.S. cities projected an increase of 100-200 temperature-related deaths during summer months by 2100 in Evansville, IN (the closest location in the study to the Green River District) [68].

Heat-related morbidity is also projected to increase as annual temperatures rise [69,70]. The Healthcare Utilization Project conservatively estimates a current average rate in the U.S. of 21.5 emergency department visits per 100,000 per year due directly to heat complaints [34]. Future indirect health effects could include increasing numbers of hospital admissions due to respiratory, hormonal, urinary, genital, and renal complaints [69,70].

Rural areas show higher rates of emergency department visits related to heat waves than urban centers, particularly among working age men [33,34]. For example, in North Carolina, over 70% of heat-related emergency department visits from 2007-2008 were made by males (mostly in the 19-44 age group), nearly three times the rate of females. Rural areas of the state also showed a steeper spike in emergency department visits per 1 °C increase in temperature than urban areas, in spite of the fact that these areas did not experience the highest mean temperatures [33].

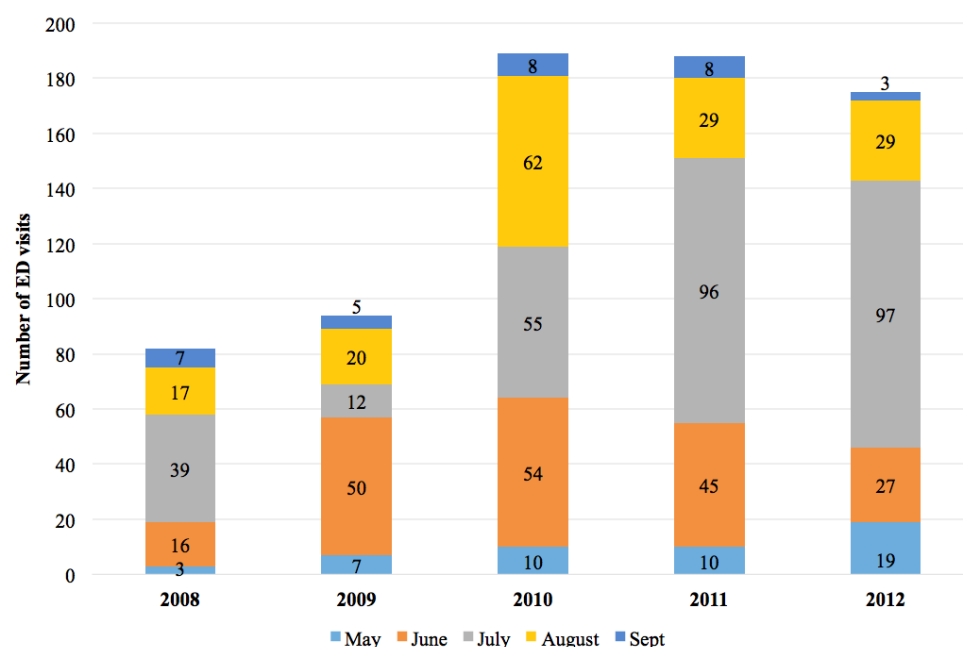
This trend may be related to the stronger presence of outdoor professions in rural areas than in urban centers. Two other demographic characteristics of rural areas may also increase their vulnerability to the negative health effects of extreme heat: their tendency to be older and lower income than populations in urban areas. In a national study, populations aged 65 and older had the highest rates of hospital admittance and death in the emergency department after exposure to an extreme heat event. And, populations in the lowest income quartile were more likely to visit the emergency department with a heat-related illness than the population as a whole [34].

## HEAT-RELATED HEALTH OUTCOMES AND VULNERABILITIES IN THE GREEN RIVER DISTRICT

From 2008-2012, the Green River District saw the highest number of heat-related emergency department (ED) visits during the months of June, July, and August (Figure 5) – particularly from 2010-2012. These results generally correspond with the periods of extreme heat exposure outlined above in Table 3.

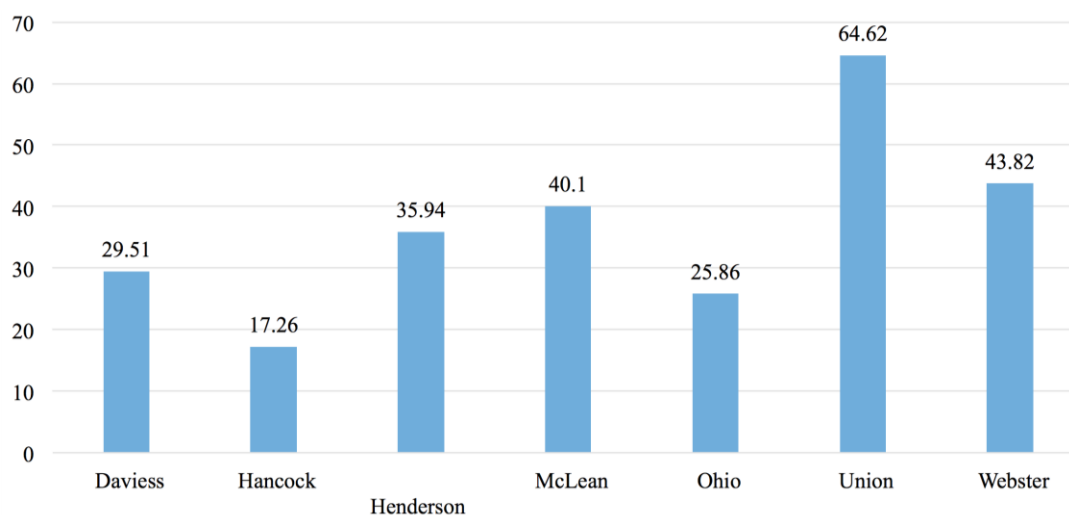
The rate of ED visits in Union County far outstripped other counties in the District at 65 per 10,000 in population (Figure 6). Mirroring the urban/rural divide highlighted in the North Carolina study described above, the rate in Union County was more than double the rate in Daviess County (the most urban county in the District), which might have been assumed to suffer more than other parts of the District from increased ambient temperatures due to the urban heat island effect. The high ED visits rate in Union County may be partially explained by the high percentage of outdoor employment among its residents: over 33%, compared with 22% in Kentucky and 19% in the U.S. as a whole (Figure 9).

**Figure 5. Heat-related emergency department visits in Green River District by month and year (2008-2012).**



**Source:** Kentucky Inpatient Hospitalization and Outpatient Services Claims Files at the Kentucky Cabinet for Health and Family Services, Office of Health Policy. Retrieved by the Kentucky Injury Prevention and Research Center at the University of Kentucky.

**Figure 6. Heat-Related emergency department visits per 10,000 in Green River District, by county (2008-2012).**



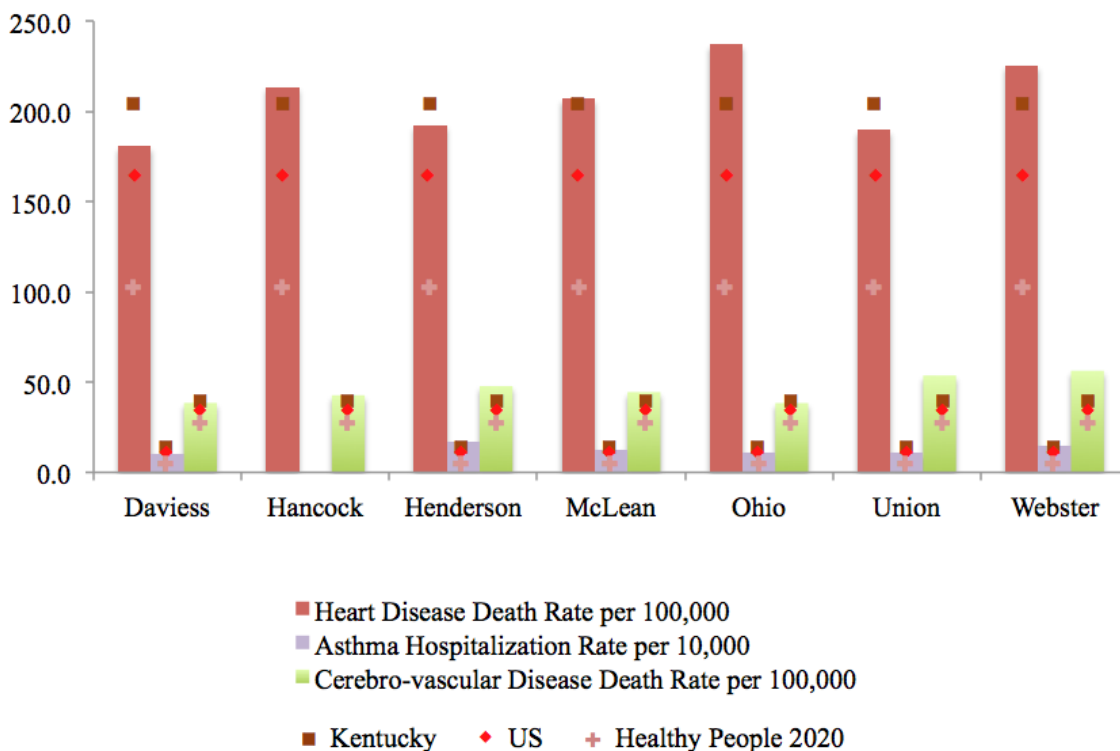
**Source:** Kentucky Inpatient Hospitalization and Outpatient Services Claims Files at the Kentucky Cabinet for Health and Family Services, Office of Health Policy. Retrieved by the Kentucky Injury Prevention and Research Center at the University of Kentucky.



Figures 7 and 8 compare health-related vulnerabilities in the Green River District with commonwealth and national benchmarks and applicable Healthy People 2020 goals. All of the counties in the Green River District reported higher heart disease death rates, asthma hospitalization rates, and cerebro-vascular disease death rates than the national average, which itself exceeds Healthy People 2020 Goals. The exception is the asthma hospitalization rate in Daviess County (10.1 per 10,000), which is slightly lower than both the U.S. rate of 11.1 per

10,000 and the Kentucky rate of 13.1 per 10,000. The picture for obesity and diabetes is more varied. The percentage population in Kentucky with obesity, 33%, is slightly lower than the national average of 35.7%. Of the seven counties in the Green River District, only Union County (36%) and Webster County (37%) exceed the national average. And, Daviess and McLean counties (31%) are very close to meeting the Healthy People 2020 Goal of 30.5%.

**Figure 7. Heart disease death rate (2013), asthma hospitalization rate (2011-2013), and cerebro-vascular disease death rate (2011-2013) in Green River District counties.**



**Note:** Heart Disease Healthy People 2020 Goal: HDS-2, Reduce coronary heart disease deaths  
 Asthma Healthy People 2020 Goal: RD-2.2, Reduce hospitalizations for asthma (5 to 64 years)  
 Cerebro-vascular Disease Healthy People 2020 Goal: HDS-3, Reduce stroke deaths

	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.	Healthy People 2020
<b>Heart disease death rate per 100,000</b>	180.6	213.6	192.4	207.1	237.1	189.7	225.5	207.1	171.6	103.4
<b>Asthma hospitalization rate per 10,000</b>	10.1	not available	16.7	12.6	10.8	10.9	14.9	13.1	11.1	8.7
<b>Cerebro-vascular disease (stroke) death rate per 100,000</b>	38.5	42.7	47.8	44.5	38.4	53.7	56.3	43.5	37.0	34.8

**Sources:** Heart Disease (2013): U.S. Centers for Disease Control and Prevention, Interactive Atlas of Heart Disease and Stroke, <http://nccd.cdc.gov/dhdspatlas/>

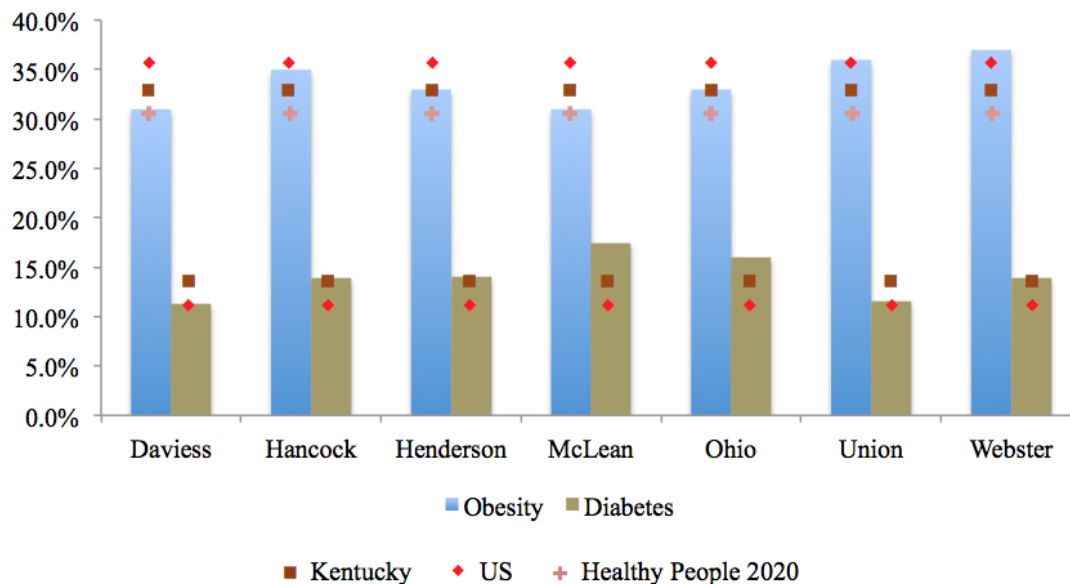
Asthma

KY (2011-2013): U.S. Centers for Disease Control and Prevention, Environmental Public Health Tracking Network, <http://www.cdc.gov/ephtracking>

US (2007): Healthy People 2020, <https://www.healthypeople.gov> (ages 5-64)

Cerebro-vascular Disease (2011-2013): U.S. Centers for Disease Control and Prevention, Interactive Atlas of Heart Disease and Stroke, <http://nccd.cdc.gov/dhdspatlas/>

**Figure 8. Percentage adult population with obesity (2009), diabetes (2014) in Green River District counties.**



**Note:** Healthy People 2020 Goal for Obesity: NWS-9, Reduce the proportion of adults who are obese

	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.	Healthy People 2020
<b>Obesity - Percentage adult population with BMI 30+</b>	31.0%	35.0%	33.0%	31.0%	33.0%	36.0%	37.0%	33.0%	35.7%	30.5%
<b>Percentage adult population diagnosed with diabetes</b>	11.3%	13.9%	14.0%	17.5%	16.0%	11.6%	13.9%	12.5%	9.3%	

**Sources:** Obesity (2009): U.S. Centers for Disease Control and Prevention, Behavioral Risk Factor Surveillance System (BRFSS), <http://www.cdc.gov/brfss/>

Diabetes (2014): Kentucky Department of Health, Kentucky BRFSS Data Reports, <http://chfs.ky.gov/dph/info/dpqi/cd/Kentucky+BRFSS+Data+Reports.htm>

## POPULATIONS WITH HIGH VULNERABILITY TO EXTREME HEAT

A number of populations are at a higher risk of negative health outcomes than the general population after exposure to an extreme heat event. Children and the elderly share a limited capacity to regulate their internal temperature and acclimatize to changing conditions [38]. Additionally, older adults living alone or living with limited mobility are at high risk [40–44]. Health outcomes for the elderly during temperature extremes include increased cardiovascular and respiratory morbidity and mortality [40,42,43,45].

In addition to their physiological vulnerability, children are at high risk of exposure to extreme heat, because they are more active than most adults and spend more time outdoors [40,42,46,47]. They also rely on caregivers to protect them from the elements, particularly in indoor locations such as houses and cars [48]. The primary health effects displayed by children exposed to extreme heat include dehydration, electrolyte imbalance, fever, renal disease, heat stress, and hyperthermia [46].

All of the counties in the Green River District save Union (20.1%) equal or exceed the percentage of children in Kentucky (22.9%) and the U.S. (23.1%) (Figure 9). And, all seven counties exceed the percentage of elderly in Kentucky (14.8%) and the U.S. (14.5%) (Figure 9).

Pregnant women are also physiologically more sensitive to extreme heat than the general population, leading to higher risk of preterm births, low birth weight, and infant mortality [42,49,50].

The complex interplay of health and socioeconomic status and environmental justice concerns may partly explain the higher vulnerability of Non-Hispanic Black populations to extreme heat events at a national level when compared with other racial and ethnic groups [40,42,43,51,52].

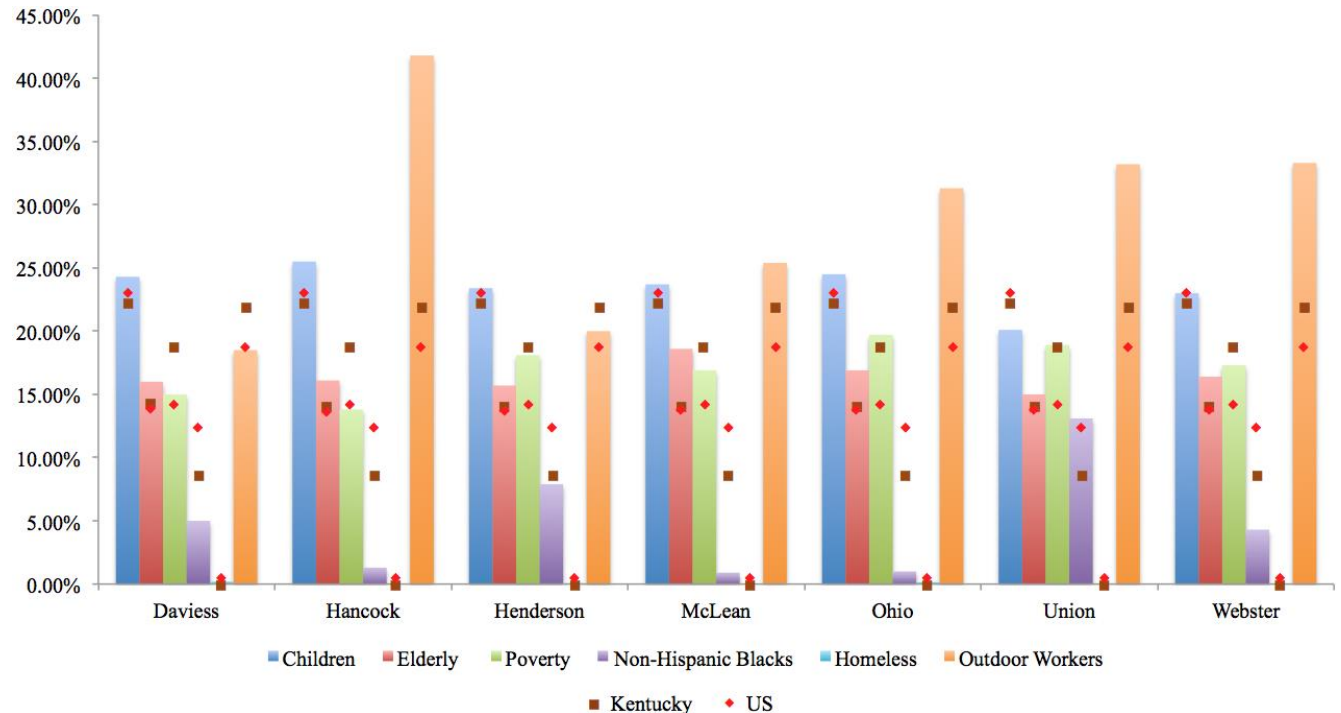
Out of the seven counties comprising the Green River District, only Union County (13.1%) approximates the percentage of Non-Hispanic Blacks in the U.S. as a whole (13.2%) and exceeds the percentage in the commonwealth of Kentucky (8.2%) (Figure 9).

Finally, populations that are more likely to be exposed to extreme temperatures are at higher risk of negative health outcomes. Homeless populations may combine increased exposure to heat and cold with other risk factors such as social isolation, psychiatric illness, and multiple chronic diseases [53]. Outdoor workers performing jobs requiring physical exertion, such as agricultural and industrial workers, are exposed to elevated temperatures during the heat of the day [44,54,55]. Providing accommodations to cool down is a particularly important protective measure for this demographic [56].

At 0.21%, Daviess County reports close to double the percentage of homeless populations in the commonwealth of Kentucky (0.11%) and a higher rate than the U.S. as a whole (0.18%) (Figure 9). In contrast, all seven counties report an equivalent or higher percentage population of outdoor workers than the U.S. (18.6%). And five counties (Hancock, 41.8%; McLean, 25.4%;

Ohio, 31.3%; Union, 33.2%; Webster, 33.3%) exceed the percentage in Kentucky (22.4%) (Figure 9).

**Figure 9. Heat-related socioeconomic and demographic vulnerability (2010-2014) in Green River District counties.**



	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
Percentage population children (Age < 18)	24.3%	25.5%	23.4%	23.7%	24.5%	20.1%	23.0%	22.9%	23.1%
Percentage population elderly (Age 65+)	16.0%	16.1%	15.7%	18.6%	16.9%	15.0%	16.4%	14.8%	14.5%
Percentage population living below federal poverty line	15.0%	13.8%	18.1%	16.9%	19.7%	18.9%	17.3%	19.1%	14.8%
Percentage population Non-Hispanic Black	5.0%	1.3%	7.9%	0.9%	1.0%	13.1%	4.3%	8.2%	13.2%
Percentage population Homeless	0.21%	no data	0.05%	no data	0.17%	no data	no data	0.11%	0.18%
Percentage population in outdoor profession - agriculture, industry, construction	18.5%	41.8%	20.0%	25.4%	31.3%	33.2%	33.3%	22.4%	18.6%

**Sources:** Children (2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Elderly (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Poverty (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Non-Hispanic Blacks (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Homeless:

KY (2014): Kentucky Housing Corporation K-Count, <http://www.kyhousing.org/Resources/Data-Library/Pages/K-Count-Results.aspx>

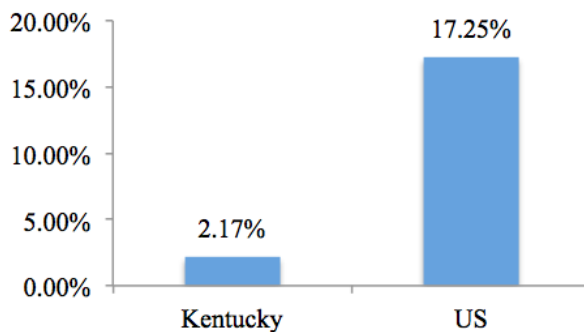
US (2014): HUD, Point-in-Time Estimates of Homelessness, <https://www.hudexchange.info/resource/3031/pit-and-hic-data-since-2007/>

Outdoor Workers (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Populations with low socioeconomic status are similarly at a higher risk of negative health outcomes during extreme heat events, because they may not have sufficient access to adaptations such as weatherized buildings and affordable air conditioning [40,42,43,51,57,58].

Only 2.17% of households in Kentucky report either not using or not having air conditioning, compared with 17.25% in the U.S. (Figure 7). Similarly, six of the seven counties in the Green River District report a lower percentage of stressed housing than the average in Kentucky (27.1%) and in U.S. (28.1%). Henderson County, on the other hand reports 28.5% stressed housing (Figure 11).

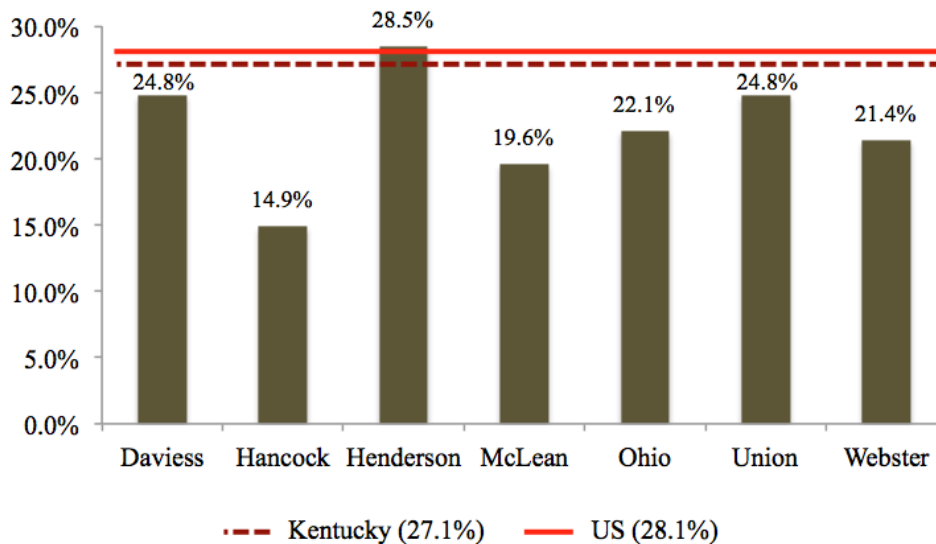
**Figure 10. Percentage households in Kentucky and U.S. that either do not have air conditioning or have it but do not use it (2009).**



**Note:** KY data combines KY, AL, and MS.

**Source:** Energy Information Administration Residential Energy Consumption Survey, <http://www.eia.gov/consumption/residential/data/20>

**Figure 11. Percentage stressed housing in Green River District counties (2007-2011).**



**Note:** Stressed Housing is defined in this report as lacking complete plumbing and/or kitchens, is overcrowded, or is cost burdened.

**Source:** CDC Community Health Status Indicators (CHSI), <http://wwwn.cdc.gov/CommunityHealth/>

## HEALTH EFFECTS IN AGRICULTURE

The health of animals in the agricultural industry is also projected to suffer from increased temperatures. The primary forms of animal agriculture in the Green River District are poultry and beef cattle. Both animals can only tolerate limited temperature ranges.

Performance, production, and fertility suffer when temperatures increase beyond a safe level [3;4, ref 5, p. 47]. For example, in 2011, exposure to prolonged high temperatures led to \$1 billion in cattle production losses [4]. Mortalities can also increase in response to extreme heat exposure [3;4, ref 5, p. 47].

Indirect health impacts to beef and poultry include increasing the cost of water, grain, and energy as more operations convert to confined-production enterprises in order to house animals in air conditioned environments [3;4, ref 5 p.

47]. The increased operational costs associated with cooling livestock housing could be a major financial hit to the industry, as energy is already the second highest expense for poultry producers [71,72]. Water and grain will likely increase in cost as water becomes scarcer and grain suffers from both declining yields and pressure to convert them to biofuels [29, p. 23].

As annual temperatures warm, agricultural workers will be at an increasingly high risk of heat-related illnesses such as heat exhaustion and heat stroke. These conditions will inevitably lead to lower productivity, unless tasks that are currently completed outdoors are brought into conditioned spaces. By 2050, the labor productivity decline across all economic sectors in Kentucky is projected to reach \$770 million per year, or a 0.5% reduction in productivity from 2020-2039 and a 1.1% reduction in productivity from 2040-2059 [3, p. 48].

## Extreme Heat Indicators for Green River District

The following set of indicators was developed to assist the Green River District Health

Department and its partners in protecting the community from existing and future health

concerns associated with exposure to extreme heat events.

The indicators are divided into four categories: environmental exposure, human health outcome, population vulnerability, and environmental vulnerability. This report defines the primary environmental exposure to extreme heat as three or more days with a maximum temperature greater than or equal to 95 °F. The primary human health outcomes associated with heat waves are heat-related morbidity and mortality. From a demographic perspective, the most vulnerable populations in the Green River District are children, the elderly, persons living in poverty, non-Hispanic Blacks, the homeless, and outdoor workers. Chronic conditions that can be exacerbated by exposure to extreme heat include: obesity, diabetes, heart disease, asthma,

and cerebro-vascular disease. All three environmental vulnerability indicators – stressed housing, not owning or using air conditioning, and accidental carbon monoxide poisoning – reference limited access to air conditioning, a primary adaptation strategy for protecting vulnerable populations during extreme heat events.

Each indicator in Table 5 includes a definition explaining how it was calculated and the reasons for its inclusion on the list. Visit the figure(s) listed next to the indicator name to view the indicator for each county in the Green River District, as well as comparison indicators at the Kentucky and national levels. View Appendix A for the complete set of indicators reviewed in this report, including references to data sources.

**Table 5. Extreme heat indicators for Green River District.**

<b>Indicator</b> <i>(Definition)</i>	<b>Reason for Inclusion</b>
<b><i>Environmental Exposure</i></b>	
<b>Exposure to heat waves</b> (Figure 3, Figure 4, Table 3) <i>(Max temperature greater than or equal to 95 °F for a minimum of 3 days)</i>	By 2050, the average annual temperature in the Green River Health District is projected to increase from close to 4 °F (under a low emissions scenario) to 5 °F (under a high emission scenario) [8].
<b><i>Human Health Outcome</i></b>	
<b>Heat-related mortality</b> <i>(Number of heat-related deaths (ICD-10: X30, excluding W92) from May to September)</i>	Primary health outcome from exposure to extreme heat [10,32,35–37,73].
<b>Heat-related morbidity</b> (Figure 5, Figure 6) <i>(Number of heat stress hospitalizations and emergency department visits (ICD-9: 992, E900.0, E900.9, excluding E900.1) from May to September)</i>	Primary health outcome from exposure to extreme heat [10,32,35–37,73].
<b><i>Population Vulnerability</i></b>	
<b>Children</b> (Figure 9) <i>(Percentage population below 18)</i>	Limited capacity to regulate internal temperature [38]. More active than adults and spend more time outdoors [40,42,46,47]. Rely on caregivers to protect them from excessive exposure to heat, particularly in houses and cars [48].
<b>Elderly</b> (Figure 9) <i>(Percentage population aged 65 and above)</i>	Limited capacity to regulate internal temperature [38]. At high risk if live alone or with limited mobility [40–44].



<b>Poverty</b> (Figure 9) (Percentage population living below federal poverty line)	At risk because may not have sufficient access to adaptations such as weatherized buildings and affordable air conditioning [40,42,43,51,57,58].
<b>Non-Hispanic Blacks</b> (Figure 9) (Percentage population Non-Hispanic Black)	At risk because of combination of health status, socioeconomic status, and environmental justice concerns [40,42,43,51,52,74–76].
<b>Homeless</b> (Figure 9) (Percentage population Homeless)	May combine increased exposure to heat and cold with other risk factors such as social isolation, psychiatric illness, and multiple chronic diseases [53].
<b>Outdoor Workers</b> (Figure 9) (Percentage population in outdoor profession - agriculture, industry, construction)	At risk due to increased exposure to elevated temperatures during the heat of the day [44,54,55].
<b>Chronic Conditions – Obesity</b> (Figure 8) (Percentage adult population with BMI 30+)	At risk due to heightened sensitivity to high ambient temperatures [32, p. 34].
<b>Chronic Conditions – Diabetes</b> (Figure 8) (Percentage adult population diagnosed with diabetes)	Exposure to heat and/or poor air quality can exacerbate chronic conditions such as complications related to diabetes [10, p. 46;77].
<b>Chronic Conditions - Heart Disease</b> (Figure 7) (All-Cause Heart Disease Death rate per 100,000)	Exposure to heat can exacerbate chronic conditions such as cardiovascular disease [10, p. 46].
<b>Chronic Conditions – Asthma</b> (Figure 7) (Asthma Hospitalization rate per 10,000)	Exposure to heat can exacerbate chronic conditions such as respiratory disease [10, p. 46].
<b>Chronic Conditions - Cerebro-vascular Disease</b> (Figure 7) (Stroke Death Rate (ICD-10: I60-I69) per 100,000)	Exposure to heat can exacerbate chronic conditions such as cerebro-vascular disease [10, p. 46].
<b>Environmental Vulnerability</b>	
<b>Stressed Housing</b> (Figure 11) (Percentage stressed housing — i.e., lacking complete plumbing and/or kitchens, is overcrowded, or is cost burdened)	Stressed housing can lack adequate weatherization and air conditioning — two important protective strategies during heat-related events [40,42,43,51,57,58].
<b>Air Conditioning - Do Not Have or Have But Do Not Use</b> (Figure 10) (Number of residential units without air conditioning or reporting that they have air conditioning but do not use it)	Air conditioning is an important protective strategy during heat-related events. And, voluntary rationing has been found to be a significant avoidable cause of heat-related negative health outcomes [78].
<b>Carbon Monoxide Poisoning</b> (Figure 23) (Emergency Department visit count for carbon monoxide poisoning - meet the 2013 CSTE case definition for a "Confirmed" or "Probable" case of acute CO poisoning, Unintentional, non-fire related)	Rates of carbon monoxide poisoning often increase during power outages when residents use combustible fuels as an alternative to electricity for daily needs such as heating, air conditioning, and cooking. Heat waves can result in power outages due to unsustainable demand for air conditioning [27].



# Drought

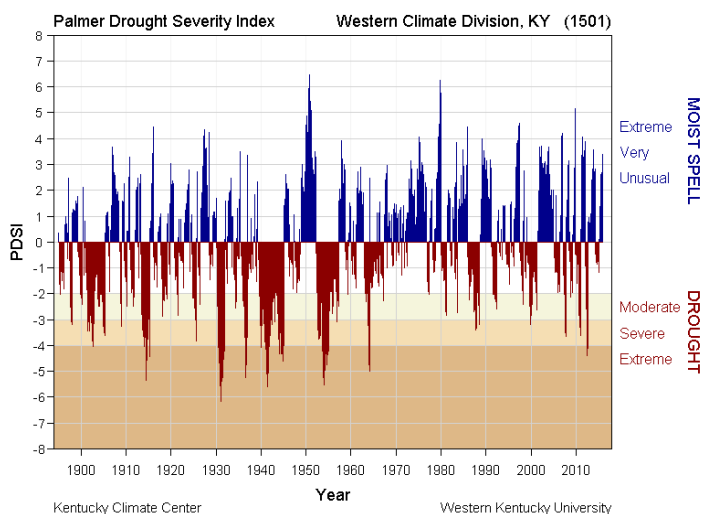
## Background

Droughts are likely to become more common in regions like the Green River District as the climate changes, due to a combination of warmer temperatures and increased variability in precipitation. The previous section presented an overview of historical scientific observations and climatic projections pointing to a significant warming trend in Kentucky (Figures 3 & 4). While climate models are less reliable in predicting annual rainfall than annual average temperatures, projections predict a strong likelihood that the southeastern U.S. will experience increases in both drought and heavy rainfall in the through the end of the century [8, pp.13-14 and Figure 4;79,80]. According to Climate Central, the commonwealth of Kentucky is at below average threat for drought. However, the severity of summertime droughts is expected to double by 2050 [25].

Drought has increased 12-14% in the southeastern U.S. since 1970 [4]. According to the U.S. Environmental Protection Agency, Kentucky experienced a trend of increasing drought conditions from 1958 to 2007 [5].

Droughts tend to become apparent during the summer and last through the dry fall, either ending during the wet winter and spring seasons or persisting into the following year [7]. Another weather pattern, the Bermuda High, can temporarily prolong summer droughts and intensify heat waves by blocking fronts bringing cooler air and precipitation from crossing the commonwealth [7]. Figure 12 displays historical periods of moderate, severe, and extreme drought and moisture in Western Kentucky from 1890 to 2015.

**Figure 12. Palmer drought severity index for the Western Climate Division, KY.**



**Source:** U.S. Drought Monitor,  
<http://droughtmonitor.unl.edu/Home.aspx>

### Primary Impacts of Drought on Green River District

#### Economic Impacts

- Reduced crop and livestock yields.
- Increased water demand for agricultural and power generation uses.
- Increased risk of wildfire.
- Delayed product shipments via waterways.

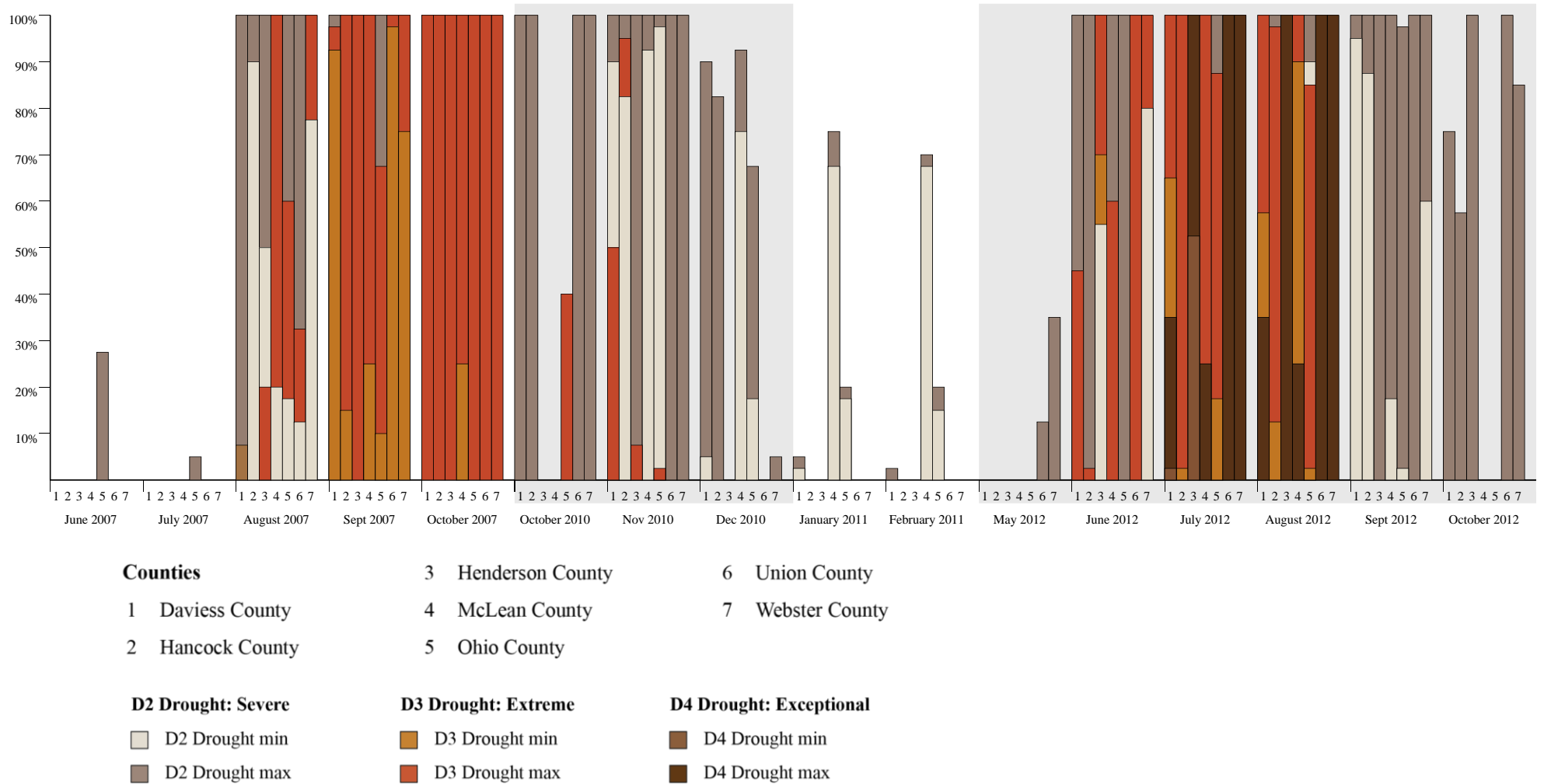
#### Health Impacts

- Reduced access to potable water, compromised water quality, increased risk of waterborne diseases.
- Increased exposure to particulate matter (PM) in the form of airborne dust.
- Increased exposure to vector-borne diseases (e.g., mosquitoes, rodents).
- Exacerbated chronic health conditions such as asthma, hypertension, diabetes, CLRD.
- Mental health concerns.

#### Vulnerable Populations

- Children, Elderly, Women, Non-Hispanic Blacks, Immuno-compromised.
- Residents of Stressed Housing.

**Figure 13. Percent population impacted by drought in Green River District counties (2007-2012).**



**Source:** U.S. Drought Monitor, <http://droughtmonitor.unl.edu/Home.aspx>

Drought events are defined in this report as severe (D2), extreme (D3), and exceptional (D4) droughts as declared by the U.S. Drought Monitor. Historically, the Green River District has experienced droughts on a 10-year cycle [2, p. 88]. From 2010-2015, droughts accounted for 12% of natural hazard events in the District [2, Figure 4-1]. Daviess, McLean, Ohio, and the

eastern half of Webster counties experienced, on average, 15-33 days per year of extreme low flow from 2000-2009 [6]. Furthermore, every county in the District experienced either extreme or exceptional drought conditions in September and October 2007 and July and August 2012 (Figure 13).

## Economic Impacts of Increased Exposure to Drought

Increasing volatility in the drought-flood cycle due to climate change will likely increase harm to the agricultural economy, because agriculture is highly vulnerable to sudden changes in precipitation trends. Corn is particularly susceptible to yield declines due to exposure to too much or too little moisture at the wrong time in the growth cycle [29, p.16]. According to the U.S. Department of Agriculture, the major cause of crop loss from 2000 to 2009 in the counties comprising the Green River District was either excess moisture or drought [29, p. 12, Figure 8]. Reduced grass yields during the 2007 drought led farmers to sell livestock prematurely in order to avoid paying for feed. It also resulted in a sharp increase in the cost of corn feed. And, while livestock prices fell in response to the sell-off, prices rose in the long-term [29, pp. 25-26]. The 2012 drought resulted in over \$1 billion in crop damages in Western Kentucky, \$700 million of which was due to low corn yields [2, p. 89]. Corn yields throughout the commonwealth reached 63% below normal, a low that had not been seen since the 1980's [81].

Rising temperatures will result in higher evapotranspiration rates in vegetated areas, likely leading to increases in the frequency, intensity, and duration of droughts [82, p. 112]. Evaporation may also lead to water scarcity in

Kentucky, because 98% of the commonwealth's water is currently drawn from surface water sources [83], 80% of which is used by thermoelectric plants [84]. Currently, agriculture is not a large water consumer, even though it covers fully half of available acreage, because most cultivated land is not irrigated [85]. However, as temperatures increase, water demand may grow, both from agricultural users adapting to the need for irrigation and from power plants that may need to expand to meet increasing energy demand [86].

The 1999 drought in the Green River District demonstrated additional economic damages caused by drought. The dry conditions resulted in the widespread die-off of area trees and shrubs, generating fuel in a state of already heightened risk of wildfire. Numerous wildfires were reported that season, including one that temporarily closed a major regional thoroughfare. Communities drawing drinking water from the Ohio River experienced deteriorated water quality due to the stagnant conditions. The dry conditions were also blamed for several water main breaks in Owensboro. And, barges on the Ohio River were forced to reduce their loads to compensate for the low water levels [2, p. 89].

## Health Effects of Drought

### OVERVIEW

The major negative health effects of drought stem from its impact on water sources and air quality [11, p. 102]. However, drought can also occur in concert with other extreme weather events, such as wildfires, extreme heat, dust storms, and flash flooding [37]. It can be difficult to quantify the direct health effects of drought, because they tend to result from a complex interplay of socioeconomic variables (such as loss of livelihood); local environmental characteristics (such as land use patterns); and, interactions between the drought and other, related natural events (such as the prevalence of wildfires or the duration of a heat wave) [87,88].

Reduced water quantity can lead to both reduced access to water and compromised water quality, as pollutants in water bodies such as lakes, streams, and aquifers become concentrated [88–93]. Furthermore, as water quantities recede, the temperature of water bodies tends to rise, potentially creating the conditions for microbial growth, such as harmful algal blooms [94–100]. If these water bodies act as the main supply for agricultural or potable water use, compromised quality can increase the risk of food- and water-borne illness. For example, increased concentrations of pathogens and toxic chemicals such as arsenic in water used for irrigation, food processing, or livestock management can lead to a higher risk of transmission into the final food product [101–104]. In particular, drought has been associated with elevated exposure to norovirus and *Cryptosporidium* [105].

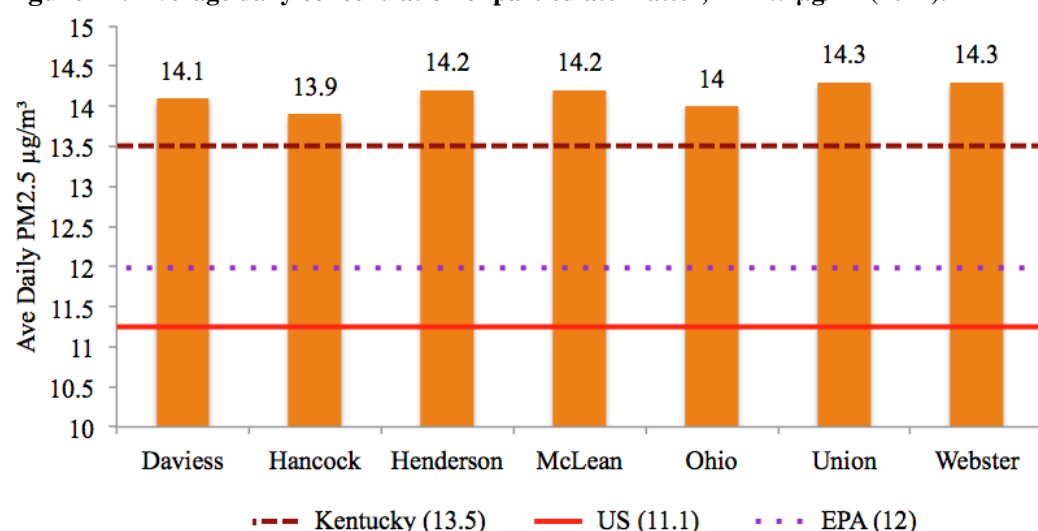
Droughts followed by heavy precipitation events have been associated with outbreaks of waterborne diseases [106]. If the flooding event overwhelms the stormwater infrastructure, large populations can potentially be exposed to contaminated water – either originating in a compromised water body or in another source, such as a concentrated animal farming operation [107–110] or a combined sanitary and storm sewer [111–119].

Populations with underlying vulnerabilities to waterborne diseases such as gastrointestinal illnesses include children, the elderly, pregnant women, and the immunocompromised [75,122–126].

Communities with inconsistency in the current quality of potable drinking water will be at a higher risk of future waterborne disease outbreaks in a changing climate. For example, in the Green River District, the drinking water infrastructure in some public water systems requires upgrade and repair in order to reduce the number of drinking water violations [120]. Similarly, populations living in municipalities with combined sanitary and storm sewer systems are at a higher risk of exposure to raw sewage when those systems overflow. In the Green River District, those populations are Owensboro (Daviess County), Henderson (Henderson County), and Morganfield (Union County) [121]. See the Flooding section for a more detailed review of local environmental health risks associated with contaminated water.

Drought can also result in increased exposure to particulate matter (PM) in the form of airborne dust [127] from wind erosion, loss of vegetation, and wildfires [128,129]. Fine particulate matter (or, PM<sub>2.5</sub> – particulate matter smaller than 2.5 microns in diameter) has been associated with diseases such as lung cancer, chronic obstructive pulmonary disease (COPD), cardiovascular disease, and asthma, [130] particularly in the elderly [131,132]. The health effects of coarse PM found in soil dust are less well established; however, they have been associated with premature mortality, cardiovascular disease, and respiratory disease [130,133,134]. As Figure 14 demonstrates, the average concentration of PM<sub>2.5</sub> in counties in the Green River District (14.1 PM<sub>2.5</sub> µg/m<sup>3</sup>) was slightly higher than the commonwealth average (13.5 PM<sub>2.5</sub> µg/m<sup>3</sup>) and significantly higher than the national average in 2011 (11.1 PM<sub>2.5</sub> µg/m<sup>3</sup> nationally).

**Figure 14. Average daily concentration of particulate matter, PM<sub>2.5</sub>  $\mu\text{g}/\text{m}^3$  (2011).**



**Sources:** P.M. 2.5 (2011): CDC WONDER, <http://wonder.cdc.gov/>

EPA 2012 Annual Standard: <https://www.epa.gov/criteria-air-pollutants/naaqs-table>

While less dust is present in the indoor environment than outdoors, the fact that most Americans spend 90% or more of their time indoors means that their primary exposure occurs inside a building [135–139]. In addition to particles of dirt, dust can contain allergenic and pathogenic biologic material – such as pollen, bacteria, and fungal spores [140,141]. Increased indoor exposure to outdoor dust could therefore increase exposure to these allergens and pathogens. Additionally, droughts followed by heavy rains can force rodent populations indoors, potentially exposing building occupants to rodent-borne diseases [142–148].

The populations most at risk of the negative health effects associated with poor air quality include Non-Hispanic Blacks, women, and the elderly [74]. Pre-existing conditions such as hypertension, diabetes, and COPD can also increase an individual's risk of negative health effects when exposed to air pollution [77]. Populations particularly vulnerable to poor indoor air quality include children, the elderly, asthmatics, the immunocompromised, and people living in substandard housing [149–151].

Drought has also been associated with an increased incidence of West Nile Virus (WNV) in areas of the country where birds and mosquitoes congregate around scarce water sources [152–157]. The key driver of WNV prevalence appears to be the sequence of dry and wet periods that take place prior to the initiation of transmission season [154,155,157,158]. Therefore, a drought could either accelerate or shorten a WNV outbreak, depending on the season it occurs in and its duration. Drought conditions could reduce the prevalence of WNV in rural areas [159], unless appropriately timed precipitation and/or the use of agricultural irrigation create conditions conducive to mosquito breeding [154].

Finally, rural areas in particular have been associated with mental health concerns during droughts, due to increased economic insecurity [87,160–163]. Social networks in rural areas can be disrupted when populations relocate during a drought to seek alternative employment. This vulnerability is compounded by inadequate access to mental health services in many rural communities [1, p. 339]. Primary care physicians often do not have the expertise to treat mental health complaints [15], and wait

times for mental health specialists can be lengthy in rural areas [164]. Furthermore, the intimate nature of small communities can have a chilling effect on seeking services that may carry a social stigma [165].

#### DROUGHT-RELATED VULNERABILITIES IN THE GREEN RIVER DISTRICT

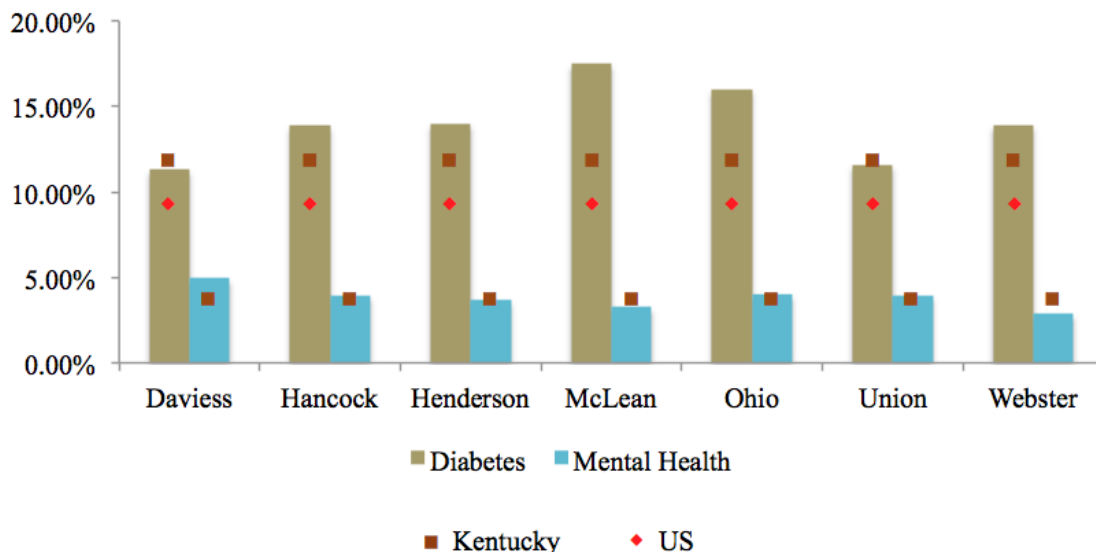
Figures 15 - 17 display the relative vulnerability of populations in Green River District counties to drought. All seven counties exceed the national proportion of the population diagnosed with diabetes (9.3%), and five of the seven exceed the average in Kentucky (12.5%).

On the other hand, the percent of the population receiving services from Community Mental Health Centers in the Green River District is roughly equivalent to the proportion in Kentucky (4.15%), with only Webster County (2.89%) falling below that level. It is important to note that this metric does not take access into account. It is possible that more residents would benefit from receiving mental health services than are represented in the data.

The Chronic Lower Respiratory Death Rate in the District falls in between the Kentucky rate (64.0 per 100,000) and the national rate (44.7 per 100,000), with the exception of Webster County (88.2 per 100,000). Henderson and Webster counties report the highest asthma hospitalization rates in the Green River District at 16.7 and 14.9 per 10,000, respectively. These rates almost double the Healthy People 2020 Goal of 8.7 per 10,000. However, Daviess (10.1 per 10,000), Ohio (10.8 per 10,000), and Union (10.9 per 10,000) counties fall below both the national (11.1 per 10,000) and Kentucky (13.1 per 10,000) rates.

Finally, the demographics of three vulnerable groups in the Green River District – children, the elderly, and Non Hispanic Blacks – vary county by county in relation to Kentucky and national population distributions. Notable are the high percentage of elderly populations in McLean County (18.6%) compared with 14.8% in Kentucky and 14.4% in the U.S. and the low percentage of Non Hispanic Black populations throughout the district with the exception of Union County (13.1%), which approximates the national average (13.2%), and Henderson County (7.9%), which approximates the average in Kentucky (8.2%).

**Figure 15. Percentage population with diabetes (2014), requiring mental health services (2013) in Green River District counties.**

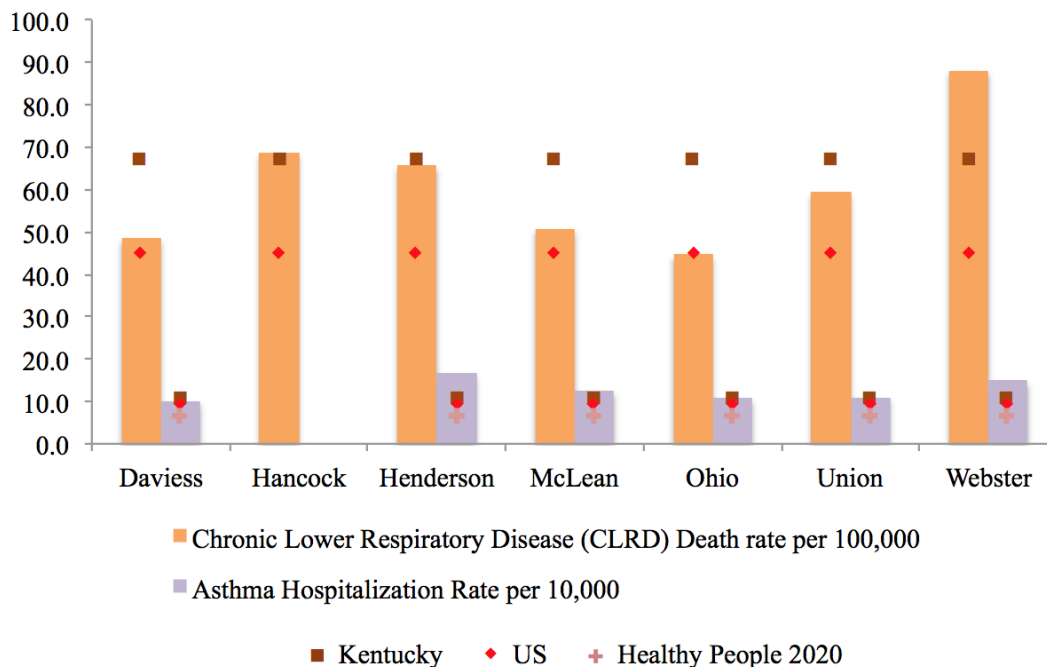


	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
<b>Percentage adult population diagnosed with diabetes</b>	11.3%	13.9%	14.0%	17.5%	16.0%	11.6%	13.9%	12.5%	9.3%
<b>Estimated percent of population receiving services from Community Mental Health Centers statewide for mental or cognitive impairment</b>	4.94%	3.93%	3.67%	3.26%	4.01%	3.95%	2.89%	4.15%	

**Sources:** Diabetes (2014): Kentucky Department of Health, Kentucky BRFSS Data Reports, <http://chfs.ky.gov/dph/info/dpqi/cd/Kentucky+BRFSS+Data+Reports.htm>

Mental Health (2013): Kentucky Safety and Prevention Alignment Network, <http://safekentucky.org/index.php/preparedness>

**Figure 16. Chronic lower respiratory disease death rate (2010), asthma hospitalization rate (2011-2013) in Green River District counties.**



	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.	Healthy People 2020
<b>CLRD disease death rate per 100,000</b>	48.6	68.6	65.6	50.9	44.7	59.3	88.2	64.0	44.7	
<b>Asthma hospitalization rate per 10,000</b>	10.1	not available	16.7	12.6	10.8	10.9	14.9	13.1	11.1	8.7

**Sources:** CLRD (2010): U.S. Centers for Disease Control and Prevention, Community Health Status Indicators (CHSI), <http://wwwn.cdc.gov/CommunityHealth/>

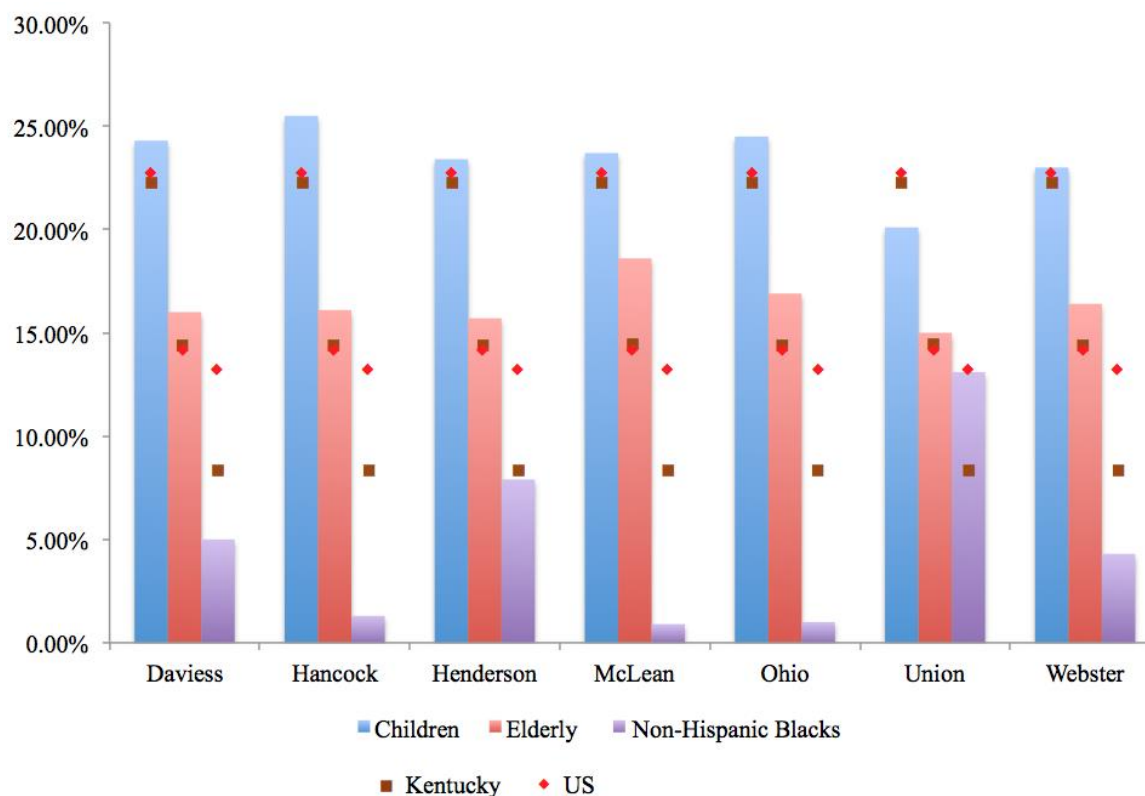
Asthma

KY (2011-2013): U.S. Centers for Disease Control and Prevention, Environmental Public Health Tracking Network, <http://www.cdc.gov/ephtracking>

US (2007): Healthy People 2020, <https://www.healthypeople.gov> (ages 5-64)



**Figure 17. Drought-related socioeconomic and demographic vulnerability (2010-2014) in Green River District counties.**



	Davies	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
Percentage population children (Age < 18)	24.3%	25.5%	23.4%	23.7%	24.5%	20.1%	23.0%	22.9%	23.1%
Percentage population elderly (Age 65+)	16.0%	16.1%	15.7%	18.6%	16.9%	15.0%	16.4%	14.8%	14.5%
Percentage population Non-Hispanic Black	5.0%	1.3%	7.9%	0.9%	1.0%	13.1%	4.3%	8.2%	13.2%

**Sources:** Children (2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Elderly (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Non-Hispanic Blacks (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

## Drought Indicators for Green River District

The following set of indicators was developed to assist the Green River District Health Department and its partners in protecting the community from existing and future health

concerns associated with exposure to drought events.



The indicators are divided into four categories: environmental exposure, human health outcome, population vulnerability, and environmental vulnerability. This report defines the primary environmental exposure to drought as a declaration by the U.S. Drought Monitor of severe (D2), extreme (D3), or exceptional (D4) drought. A secondary indicator for many droughts is exposure to fine particulate matter (PM<sub>2.5</sub>). The demographics most vulnerable to drought in the Green River District are: children, the elderly, and non-Hispanic Blacks. Chronic conditions that can be exacerbated by exposure to extreme heat include: diabetes, chronic lower

respiratory disease (CLRD), asthma, and mental health concerns. Stressed housing is identified as the primary environmental vulnerability.

Each indicator in Table 6 includes a definition explaining how it was calculated and the reasons for its inclusion on the list. Visit the figure(s) listed next to the indicator name to view the indicator for each county in the Green River District, as well as comparison indicators at the Kentucky and national levels. View Appendix A for the complete set of indicators reviewed in this report, including references to data sources.

**Table 6. Drought indicators for Green River District.**

<b>Indicator</b> <i>(Definition)</i>	<b>Reason for Inclusion</b>
<b><i>Environmental Exposure</i></b>	
<b>Exposure to drought</b> (Figure 12, Figure 13) <i>(County declared in D2 (severe), D3 (extreme), or D4 (exceptional) drought by U.S. Drought Monitor)</i>	Kentucky experienced a trend of increasing drought conditions from 1958 to 2007 [5]. Severity of summertime droughts is expected to double by 2050 in Kentucky [25].
<b>Exposure to air pollution</b> (Figure 14) <i>(Ave Daily PM<sub>2.5</sub> µg/m<sup>3</sup>)</i>	Can result in increased exposure to particulate matter (PM) in the form of airborne dust [127] from wind erosion, loss of vegetation, and wildfires [128,129]. Fine particulate matter (or, PM <sub>2.5</sub> — particulate matter smaller than 2.5 microns in diameter) has been associated with diseases such as lung cancer, chronic obstructive pulmonary disease (COPD), cardiovascular disease, and asthma [130], particularly in the elderly [131,132].
<b><i>Human Health Outcome</i></b>	
To be developed.	
<b><i>Population Vulnerability</i></b>	
<b>Children</b> (Figure 17) <i>(Percentage population below 18)</i>	Particularly sensitive to poor indoor air quality [149–151].
<b>Elderly</b> (Figure 17) <i>(Percentage population aged 65 and above)</i>	Particularly sensitive to both poor indoor and outdoor air quality [74,149–151].
<b>Non-Hispanic Blacks</b> (Figure 17) <i>(Percentage population Non-Hispanic Black)</i>	At risk because of combination of health status, socioeconomic status, and environmental justice concerns [40,42,43,51,52,74–76].
<b>Chronic Conditions – Diabetes</b> (Figure 15) <i>(Percentage adult population diagnosed with diabetes)</i>	Exposure to heat and/or poor air quality can exacerbate chronic conditions such as complications related to diabetes [10, p. 46;77].

<b>Chronic Conditions - Chronic Lower Respiratory Disease (CLRD)</b> (Figure 16) <i>(CLRD Death rate per 100,000)</i>	At risk due to heightened sensitivity to poor air quality [77].
<b>Chronic Conditions – Asthma</b> (Figure 16) <i>(Asthma Hospitalization rate per 10,000)</i>	At risk due to heightened sensitivity to poor indoor air quality [149–151].
<b>Mental Health Concerns</b> (Figure 15) <i>(Estimated percent of population receiving services from Community Mental Health Centers Kentucky for mental or cognitive impairment)</i>	Rural areas in particular have been associated with mental health concerns during droughts, due to increased economic insecurity [87,160–163].
<b><i>Environmental Vulnerability</i></b>	
<b>Stressed Housing</b> (Figure 11) <i>(Percentage stressed housing — i.e., lacking complete plumbing and/or kitchens, is overcrowded, or is cost burdened)</i>	Stressed housing can increase indoor exposure to the allergens and pathogens in outdoor dust [149–151].

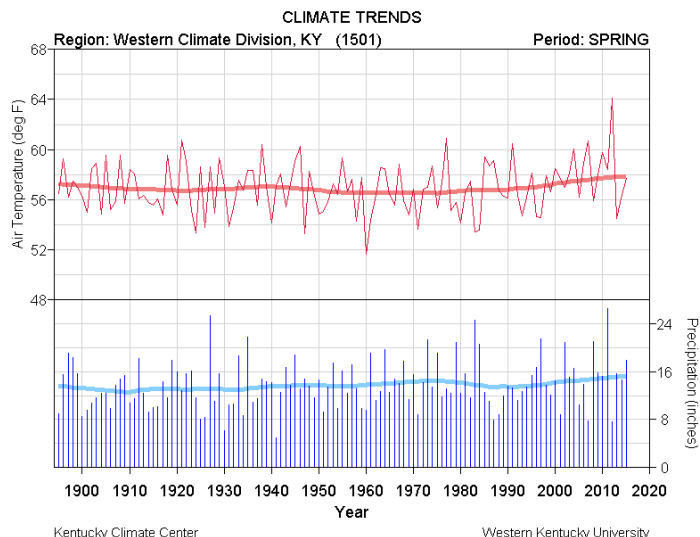
# Flooding

## Background

Large precipitation events often end droughts, leading to one of the paradoxes of climate change: the likelihood of some regions experiencing increases in both halves of the drought-flood cycle. This occurs because precipitation is not spread evenly over the course of a year, even if total annual precipitation may remain constant or even increase. Increasing ambient air temperatures increase the atmosphere's capacity to hold moisture in the air. The results are heavier precipitation events, particularly in the winter and early springtime months, rather than in the summer and fall when rain is needed [166].

Historically, Western Kentucky has experienced an average of 55 thunderstorm days per year. These events can cause flooding, particularly in the winter and spring months [7]. The bottom half of Figure 18 displays annual inches of precipitation during spring months in Western Kentucky from 1900 to 2015. The dark blue line shows that the 30-year average has been trending upwards since 1990.

**Figure 18. Historical climate trends for precipitation and air temperature in Western Kentucky during spring months.**



## Primary Impacts of Flooding on Green River District

### Economic Impacts

- Damage to property and infrastructure.
- Delay in shipments via road, rail, and/or waterways.
- Reduced crop and livestock yields.

### Health Impacts

- Increased risk of drowning-related injury and death.
- Increased risk of gastrointestinal illnesses and infections of the eye, ear, nose, throat, or skin.
- Increased risk of carbon monoxide poisoning during power outages and during flooding cleanup activities.
- Risk of exposure to contaminated water.
- Mental health concerns.

### Vulnerable Populations

- Populations living in floodplains and/or stressed housing.
- Children, Elderly, Women, Non-Hispanic Blacks, Hispanics, Disabled, Populations with Chronic Diseases (e.g., diabetes), Populations Requiring Regular Medical Treatment, Immuno-compromised, Medical Patients and Long-term Care Residents, Low Socioeconomic Status, Limited English Proficiency.

### Source:

Kentucky Climate Center, Department of Geography and Geology, Western Kentucky University. Accessed May 3, 2016.

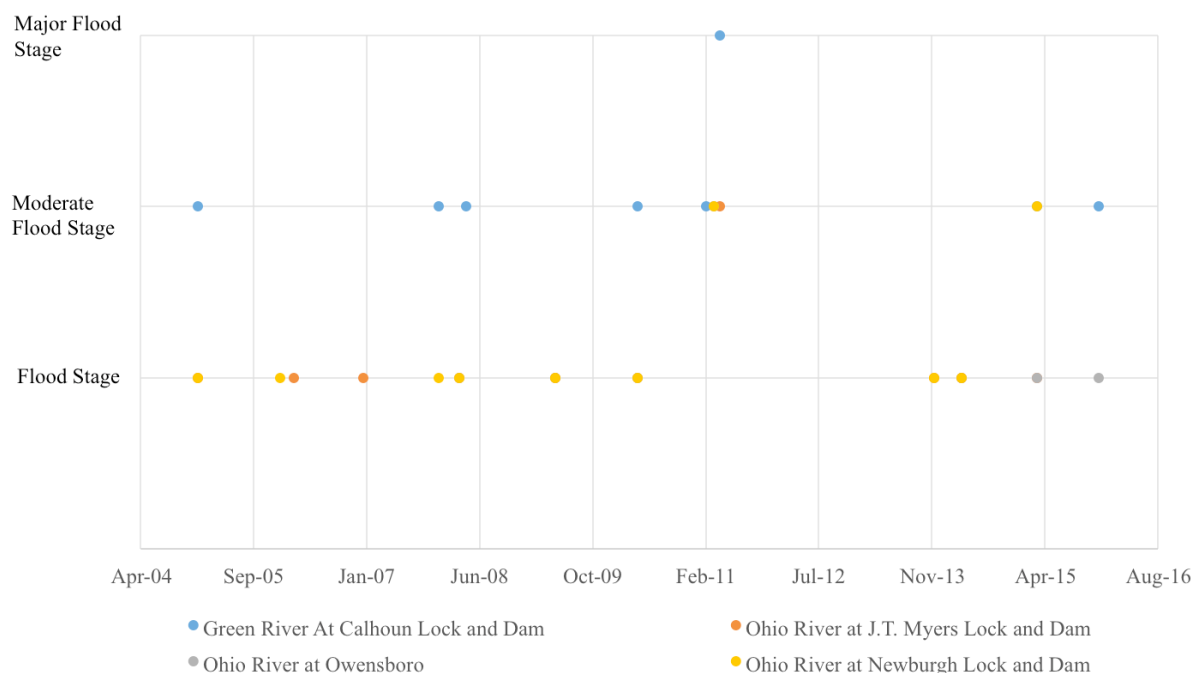
Two of the three major tributaries responsible for draining the Commonwealth of Kentucky pass through the Green River District: the Ohio River and the Green River. The Ohio River is a particularly significant potential flood risk, because it receives the majority of Kentucky's stormwater runoff via 13 river basins [167–169]. Flooding in the Green River District, therefore, may not always be caused by local precipitation. Heavy precipitation in other parts of Kentucky could cause flooding in the Ohio River and/or in tributaries passing through the District to reach the Ohio.

Flooding exposure in this report is defined as the number of days annually with precipitation over 2 inches, as reported by weather stations. Flooding and severe thunderstorms accounted for 42% of natural hazard events and 92% of related property damage in the Green River District from 2010-2015 [2, Figures 4-1 & 4-2]. Serious floods occur in the area, on average, every two years [2, p. 109]. All of the counties in the District experienced at least 15 days of extreme high water flow, on average, from 2000-2009. Areas next to the Ohio River and

Henderson, Hancock, Union, the western half of Webster, and the northeastern quadrant of Daviess counties experienced more than 23 days of high flow, on average, during the same time period [6]. Figure 19 gives a ten-year snapshot of four river gauges adjacent to or inside the Green River District. From 2005-2015, one gauge (Green River at Calhoun Lock and Dam) reported that the river had reached a Major Flood Stage. Moderate Flood Stage was reported 11 times across the four river gauges. And, Flood Stage (the lowest designation on the chart) was reported 23 times.

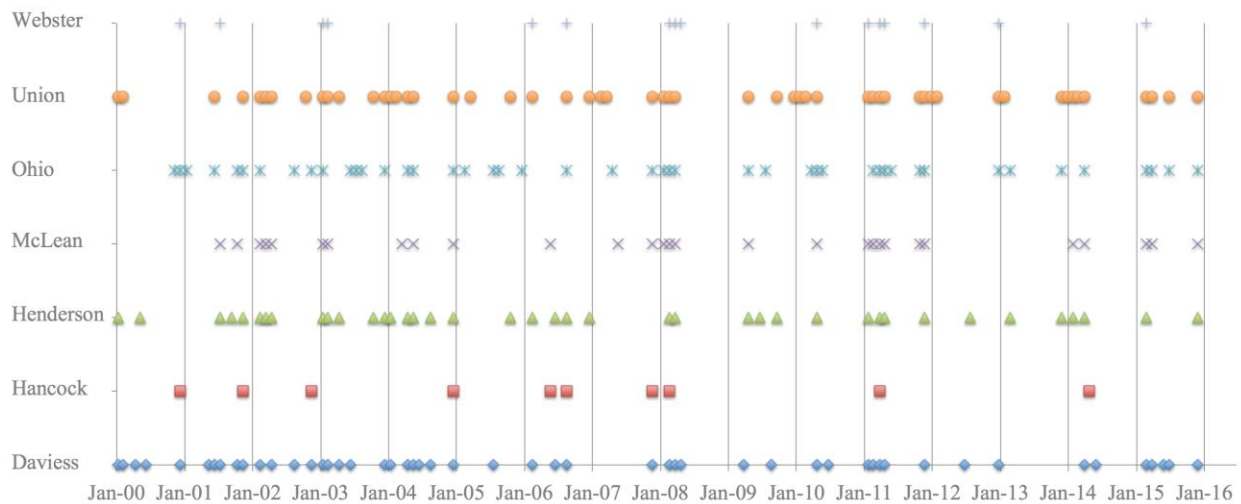
Figure 20 displays flood and flash flood storms in the Green River District from 2000 through 2015, as reported to the NOAA Storm Events Database. Appendix B displays the date and affected counties associated with each flooding event. While all of the counties in the District experienced flooding during this period, Hancock and Webster counties were the least flood-prone, reporting 10 and 17 flooding events, respectively; and, Davis and Union were the most flood-prone, at 52 and 55 events each.

**Figure 19. Historic river crests in Green River District counties (2005-2015).**



**Source:** National Weather Service Advanced Hydrologic Prediction Service. Available at: <http://water.weather.gov/ahps2/>.

**Figure 20. Flooding events in Green River District by year and county (2000-2015).**

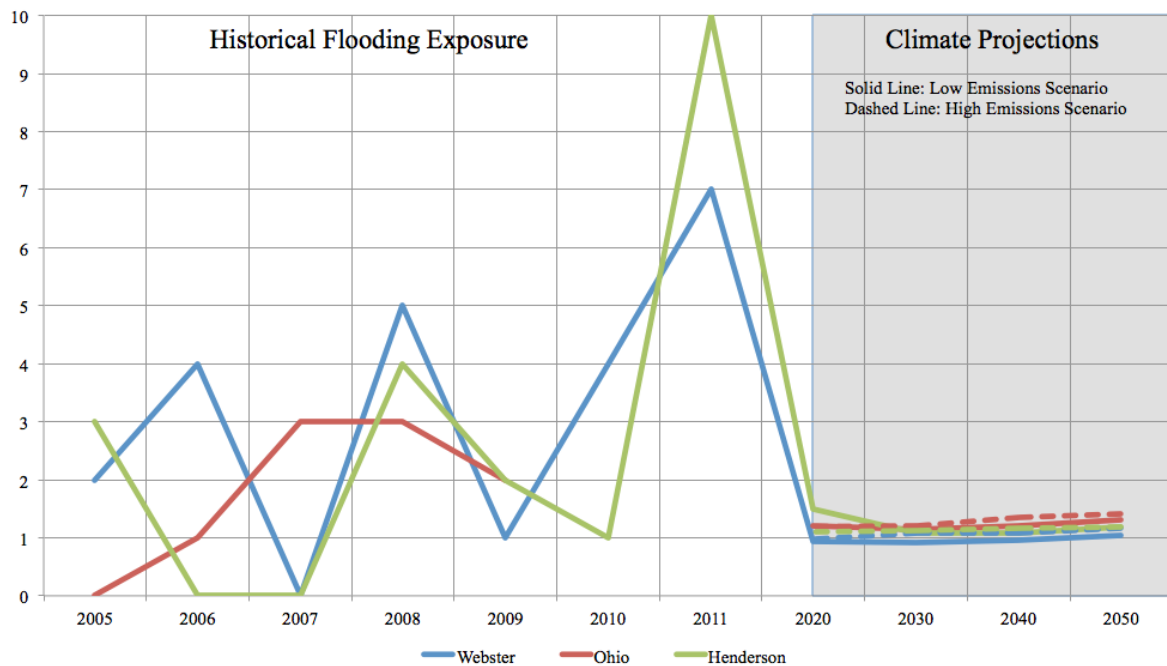


**Source:** NOAA National Climatic Data Center Storm Events Database, <http://www.ncdc.noaa.gov/stormevents>

Climate projections for three counties in the Green River District – Webster, Ohio, and Henderson – generally support the historical trend of gradually increasing exposure to flooding under both low and high emission scenarios (Figure 21). Average annual precipitation in the District is projected to

increase close to 2% under a low emissions scenario and up to 6% under a high emissions scenario [8, p. 16]. Meanwhile, the historical data in Figure 21 (2005-2010) reminds us that precipitation rates will vary significantly year-over-year, even as the longer-term trend increases.

**Figure 21. Current and future flooding exposure in three Green River District counties. Defined by number of days with precipitation over 2 inches reported by weather stations annually.**



	Historical Data						Low Emissions Projection				High Emissions Projection			
	2005	2006	2007	2008	2009	2010	2020	2030	2040	2050	2020	2030	2040	2050
Webster	2	4	0	5	1	4	7	0.93	0.91	0.96	0.97	1.08	1.08	1.17
Ohio	0	1	3	3	2	No data	No data	1.21	1.15	1.21	1.19	1.21	1.34	1.42
Henderson	3	0	0	4	2	1	10	1.5	1.09	1.09	1.1	1.12	1.17	1.19

**Source:** Kentucky Climate Center, Department of Geography and Geology, Western Kentucky University. Accessed June 2016.

## Economic Impacts of Increased Exposure to Flooding

Major disasters due to flooding and/or severe storms were declared in Kentucky 29 times from 2000 - 2015, almost equivalent to the total number of declarations over the previous 40 years combined. These events damaged more than 6,000 homes, a disproportionate number of which belonged to low-income families. Total private assistance from the federal government exceeded \$140 million during this period, and total public assistance exceeded \$577 million [170]. The direct economic effects of flooding in the Green River District during the same period included close to \$40 million in property damage, and almost \$6 million in crop damage [171].

Most of the public assistance was dedicated to repairing infrastructure, such as roads, bridges, and power lines [170]. Rural areas such as the Green River District have fewer infrastructure redundancies than their urban counterparts. And, power and communication outages often last longer. Furthermore, rural areas rely on a combination of roads, rail, and rivers to ship products to market. Any disruption to infrastructure can therefore have serious economic implications, in addition to the risk posed to vulnerable populations such as the elderly and infirm [1, p. 339]. For example, the April 2011 flood resulted in the multi-week closure of several state and federal highways

passing through the Green River District [2, p. 112].

Changes in precipitation patterns and flooding events linked to climate change will also likely result in economic losses in the agriculture sector. Severe winds during thunderstorms can cause both property damage and crop damage. For example, a single thunderstorm in July 2013 resulted in \$210,000 in crop and property damage in Henderson and Union counties [2, p. 174]. Changes in temperature and precipitation patterns may lead to a shift in the location and prevalence of diseases affecting livestock such

as anthrax, blackleg, and hemorrhagic septicemia [172,173].

Another concern is the risk of erosion and water logged soil from extreme precipitation events. The increasing number of days with heavy rainfall has prompted some farmers to install costly subsurface drainage systems to protect against these threats and allow springtime activities to proceed in spite of changing weather patterns [174, p. 159]. Finally, severe storms leading to power loss can result in catastrophic loss of livestock, particularly confined poultry and cattle [175].

## Health Effects of Flooding

### OVERVIEW

The health effects of flooding range from drowning-related injury and death to gastrointestinal illnesses and mental health concerns.

Most flooding-related injuries and deaths occur when individuals attempt to drive or walk near or through floodwaters [177–180]. Other flooding-related traumas include coming into contact with falling debris or objects in moving water, electrocution, falls, motor vehicle accidents on wet roads, hypothermia, and animal bites [75,181,182].

Western Kentucky is at high risk of flooding-related injuries and mortalities due to its low elevation in relation to the Ohio River and associated tributaries and due to its rural character. Rural roads are more likely than their urban counterparts to intersect water bodies using low water crossings rather than bridges. They also tend to have fewer response units to close roads and rescue stranded vehicles. And,

their response rate is often slower than in metropolitan areas [180].

### FLOODING-RELATED HEALTH OUTCOMES AND VULNERABILITIES IN THE GREEN RIVER DISTRICT

Seven people died of unintentional drowning-related injuries in the Green River District from 2008-2015. Thirteen individuals were admitted to hospital with flooding-related injuries from 2001-2013. And, 29 emergency department visits were recorded from 2008-2013. The majority of injuries were located in Daviess County, the most urban county in the District (Table 7).

In spite of the low numbers of flooding-related morbidities and mortalities in the District, residents are at high risk of exposure. Roughly 170,000 Kentuckians (5.4%, Figure 22) live in the 100-year floodplain, as defined by FEMA [25], placing them at enhanced risk of exposure to flooding due to climate change [37,76,176]. Every county in the Green River District except

for Webster County (2.8%) exceeds the Kentucky percentage of populations living in the 100-year floodplain, in three cases – Daviess, Hancock, and McLean – more than doubling exposure (Figure 22). From a geographic perspective, every county in the District except for Webster also greatly exceeds the 9.8% of

Kentucky land located in a floodplain, with close to one half of the land in Henderson and McLean counties located in vulnerable areas. In spite of the relatively high percentage of Green River District residents living in a floodplain, only a small fraction of them hold current flood insurance policies (Table 8).

**Table 7. Flooding-related morbidity and mortality in the Green River District (2001-2015).**

Health Outcome	Counts	Affected Counties
Unintentional drowning-related mortalities (2008-2015)	7	Not released
Flooding-related hospital inpatient admissions (2001-2013)	13	Daviess (8 counts), Henderson, Ohio
Flooding-related emergency department visits (2008-2013)	29	Daviess (17 counts), Ohio (6 counts), Henderson, Union, Webster

**Sources:** Morbidity Data: Kentucky Inpatient Hospitalization and Outpatient Services Claims Files at the Kentucky Cabinet for Health and Family Services, Office of Health Policy.

Mortality Data: Kentucky Death Certificates Files at the Kentucky Department for Public Health, Cabinet for Health and Family Services.

Data sets retrieved by the Kentucky Injury Prevention and Research Center at the University of Kentucky.

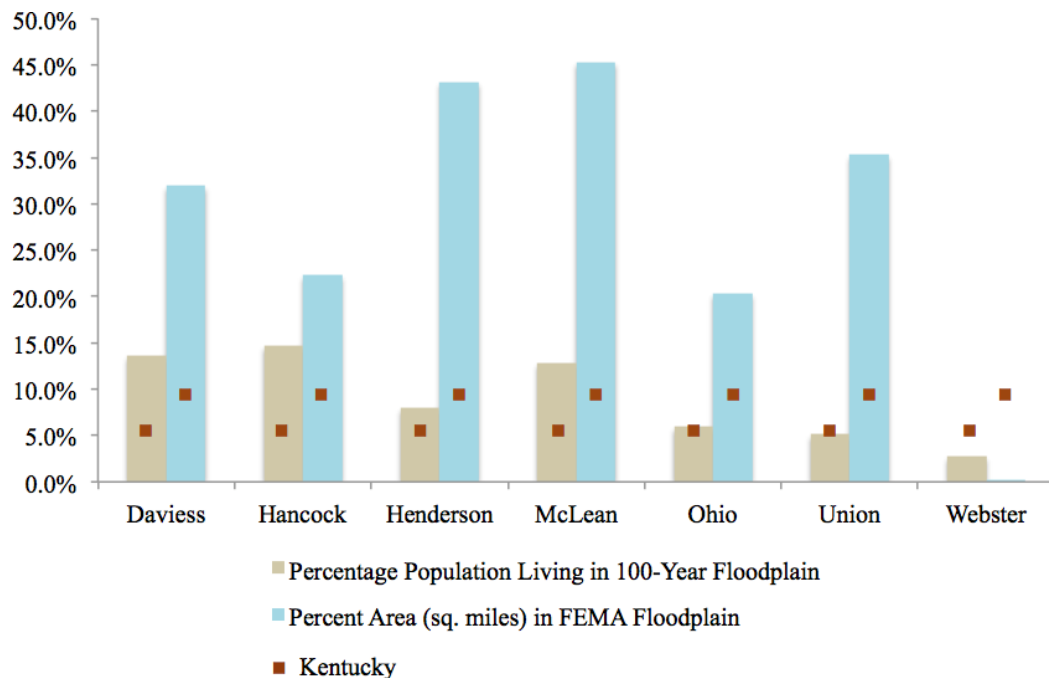
**Table 8. Total flood insurance policies in force (2016) by percentage population (2014).**

	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
Total flood insurance policies in force, as a percentage of 2014 population	1.71%	1.15%	0.83%	0.85%	0.15%	0.18%	0.42%	0.49%	1.51%

**Source:** Federal Emergency Management Agency (FEMA) National Flood Insurance Program, Policy Statistics Country-Wide as of 04/30/2016, <http://bsa.nfipstat.fema.gov/reports/1011.htm#KYT>

**Figure 22. Percentage population and percent area in Green River District counties located in 100-year FEMA floodplain (2011).**





	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky
Percentage population living in 100-Year Floodplain	13.6%	14.7%	8.0%	12.8%	5.9%	5.1%	2.8%	5.4%
Percent area (square miles) in FEMA Floodplain	32.0%	22.3%	43.2%	45.3%	20.3%	35.3%	0.2%	9.8%

**Source:** National Environmental Public Health Tracking, <http://ephrtracking.cdc.gov>

**Reference:** Federal Emergency Management Agency (FEMA) 2011 National Flood Hazard Layer

## POPULATIONS WITH HIGH VULNERABILITY TO FLOODING

Populations vulnerable to flooding-related injuries and illnesses include the elderly, the immunocompromised, individuals dependent on routine medical treatment or prescriptions, populations with limited English proficiency (who may experience a delay before being informed of an impending flood), and populations with low socioeconomic status [75,76]. Non-Hispanic Black and Hispanic populations have also been associated with an elevated rate of flood-related injuries and death [75,76].

Heavy precipitation can lead to exposure to contaminated water, either due to combined sewer overflows or polluted runoff from agriculture, mining installations, manufacturing

facilities, and urban roadways [169;174, p. 160]. Combined sewer overflows are a health risk for nearly 20 communities in Kentucky, including Owensboro (Daviess County), Henderson (Henderson County), and Morganfield (Union County) [111].

Environmental health concerns associated with stormwater runoff include exposure to fertilizers, herbicides, fungicides, insecticides heavy metals, persistent bioaccumulative toxins, harmful algal blooms (caused by a combination of increased water temperature and increased nutrient load), and increased siltation and turbidity in waterways putting pressure on municipal water treatment facilities. Furthermore, warmer waterways foster the persistence of waterborne pathogens [26, p. 113].

Exposure to contaminated water can lead to gastrointestinal illnesses and infections of the eye, ear, nose, throat, or skin [75,181]. These types of injuries are particularly prevalent in rural areas [180] and in occupational settings [203]. Eight pathogens account for 97% [204] of the 12-19 million cases of waterborne gastrointestinal disease reported each year in the U.S. [122,205,206]: norovirus, rotavirus, adenovirus, *Campylobacter jejuni*, *E. coli* O157:H7, *Salmonella enterica*, *Cryptosporidium*, and *Giardia*. [204] All of these pathogens are influenced by climatic factors [207, p. 160].

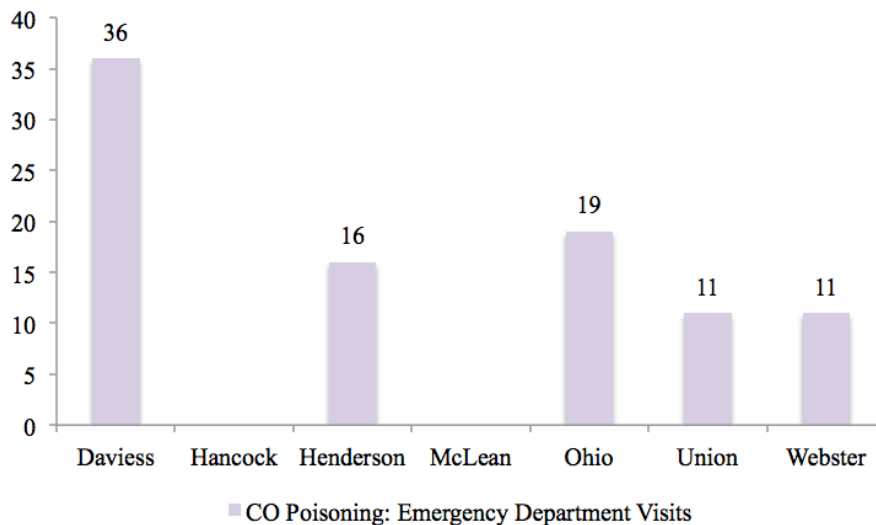
Severe flooding may require evacuation, which can pose particular dangers to the disabled; to patients residing in hospitals, nursing homes, and assisted living facilities; and, to populations with limited English proficiency [75,199–202]. Displaced populations in shelters are at a heightened risk of gastrointestinal disease, particularly infants and young children whose immune systems are still developing [75,181].

Flood exposure can lead to adverse birth outcomes, such as preterm birth or low birth rates [208,209]. And, children are at an elevated risk of injury or death during floods if they become separated from their caregivers [210–212].

Flooding events can cause moisture infiltration in buildings, increasing dampness and humidity indoors [183]. These conditions are exacerbated if the flood disables the air conditioning system [184, p. 81] – either through a power outage or by flooding the unit itself. If not immediately and properly treated, dampness and loss of climate control can compromise indoor air quality by facilitating mold growth, dust mites, bio-contaminants such as bacteria, and building materials’ off-gassing volatile organic compounds (VOCs) such as formaldehyde [146,185–190]. Poor indoor air quality arising from dampness and mold in the home is currently associated with 8%-20% of respiratory infections in the U.S. (such as acute bronchitis) and with exacerbating 4.6 million cases of asthma [191,192].

Loss of power has also been associated with increases in hospital visits from carbon monoxide (CO) poisoning stemming from the use of backup generators and other combustion appliances indoors [193,194]. Figure 23 displays recent counts of emergency department (2008-2013) visits related to unintentional carbon monoxide poisoning in the Green River District counties.

**Figure 23. Unintentional carbon monoxide (CO) poisoning: emergency department visits (2008-2013).**



**Note:** Data suppressed for Hancock and McLean counties due to low counts.

**Source:** Emergency Department Visits (2008-2013): Office of Health Policy, Kentucky Cabinet for Health and Family Services. (2015). via EnviroHealthLink, June 2016.

The populations most vulnerable to power outages include children, the elderly, the disabled, and individuals reliant on electrically powered medical equipment (such as ventilators and oxygen) [75,195,196]. These populations are particularly vulnerable in rural communities, because it can take longer to restore service in sparsely populated areas [1]. If flooding damages the transportation infrastructure, it can lead to disruptions in medical treatment – whether in terms of access to hospitals for the injured or for regularly scheduled treatment among the chronically ill [75,197,198].

Finally, flooding can lead to mental health effects related to the loss of loved ones, the loss of property, stress, and economic hardship [75,181,182]. The populations who are particularly vulnerable to these impacts include women, children, the elderly, populations with low socioeconomic status, individuals with pre-existing mental or physical health conditions, and individuals with weak social networks [11, p. 108].

The Green River District displays a mixture of heightened and lower than average vulnerability to several flooding-related indicators (Figures

24-26). Every county except for Daviess (11.3%) and Union (11.6%) reports a higher percentage population diagnosed with diabetes than either the commonwealth of Kentucky (12.5%) or the nation as a whole (9.3%). However, the percentage population receiving services from Community Mental Health Centers is roughly on par with Kentucky (4.2%). As noted above, this metric may not capture challenges associated with accessing mental health services.

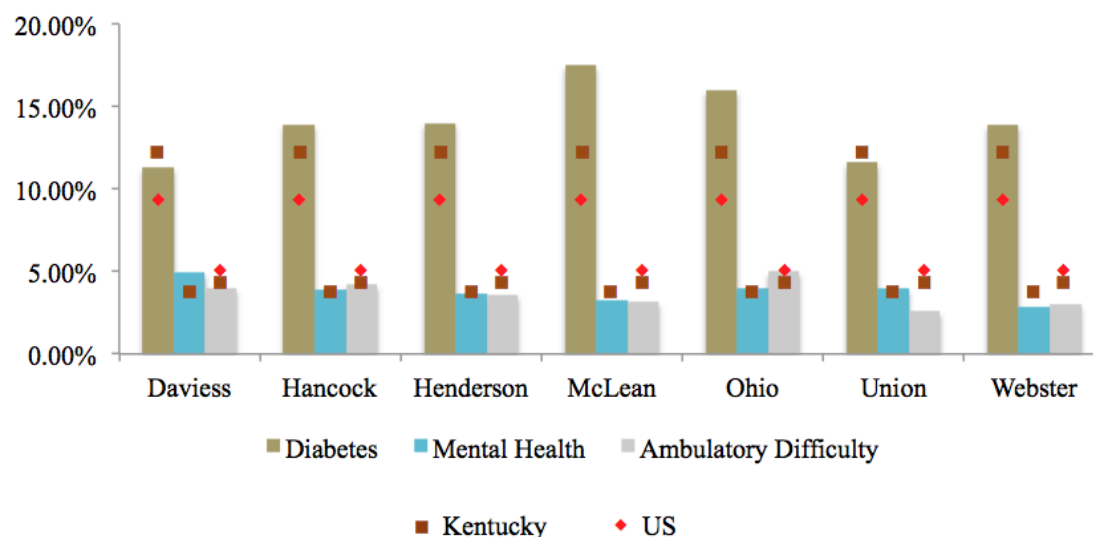
Green River District counties also report a lower percentage of population with ambulatory difficulty in comparison with both the Kentucky average (4.8%) and the national average (5%). Every county except for Union County (55.39 per 10,000) exceeds the number of long-term care beds per 10,000 in Kentucky (76.76 per 10,000), indicating possible heightened risk to vulnerable populations during precipitation events that either close roads or disrupt utilities.

Five counties – Daviess (24.3%), Hancock (25.5%), Henderson (23.4%), McLean (23.7%), and Ohio (24.5%) – have a slightly higher percentage population of children than the commonwealth of Kentucky (22.9%) and the

U.S. as a whole (23.1%). Also, every county exceeds the percentage population of elderly in Kentucky (14.8%) and the U.S. (14.5%) – most notably McLean County (18.6%) and Ohio County (16.9%). Only Ohio County (19.7%) exceeds the Kentucky average of populations living below the poverty line (19.1%). However, every county except Hancock (13.8%) exceeds the national percentage of populations living in

poverty (14.8%). Finally, every county reports a lower percentage population with limited English proficiency than either Kentucky (1.1%) or the U.S. (4.5%). However, it is possible that this statistic is undercounted in the Green River District, due to the presence of foreign migrant workers who may not respond to the U.S. Census.

**Figure 24. Percentage population with diabetes (2014), requiring mental health services (2013), or suffering from ambulatory difficulty (2010-2014) in Green River District counties.**



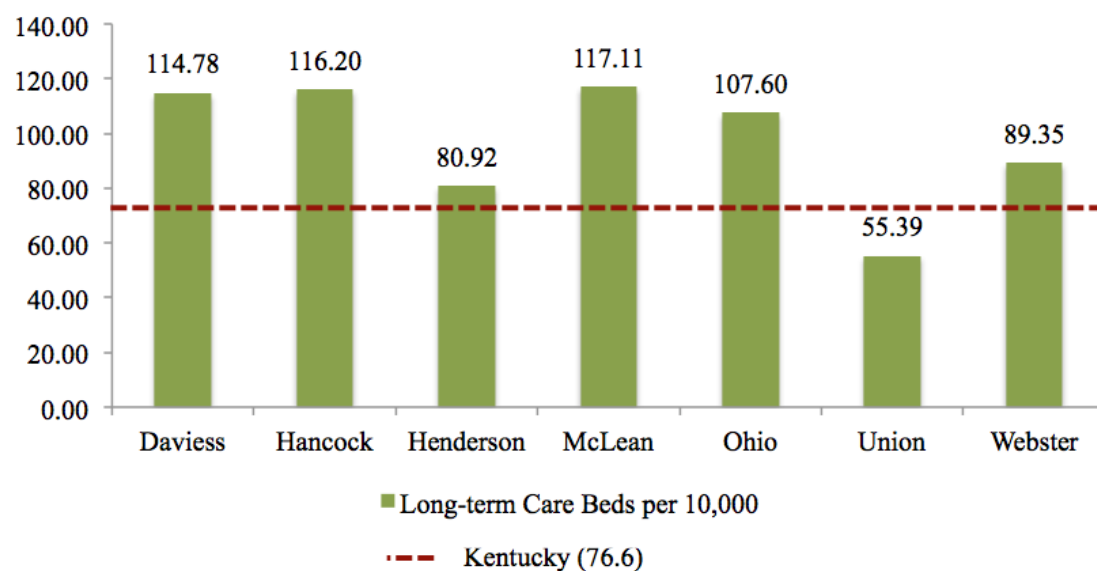
	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
Percentage adult population diagnosed with diabetes	11.3%	13.9%	14.0%	17.5%	16.0%	11.6%	13.9%	12.5%	9.3%
Estimated percent of population receiving services from Community Mental Health Centers statewide for mental or cognitive impairment	4.9%	3.9%	3.7%	3.3%	4.0%	4.0%	2.9%	4.2%	No data
Percentage population aged 5+ with ambulatory difficulty	4.0%	4.2%	3.6%	3.2%	5.0%	2.6%	3.0%	4.8%	5.0%

**Sources:** Diabetes (2014): Kentucky Department of Health, Kentucky BRFSS Data Reports, <http://chfs.ky.gov/dph/info/dpqi/cd/Kentucky+BRFSS+Data+Reports.htm>

Mental Health (2013): Kentucky Safety and Prevention Alignment Network, <http://safekentucky.org/index.php/preparedness>

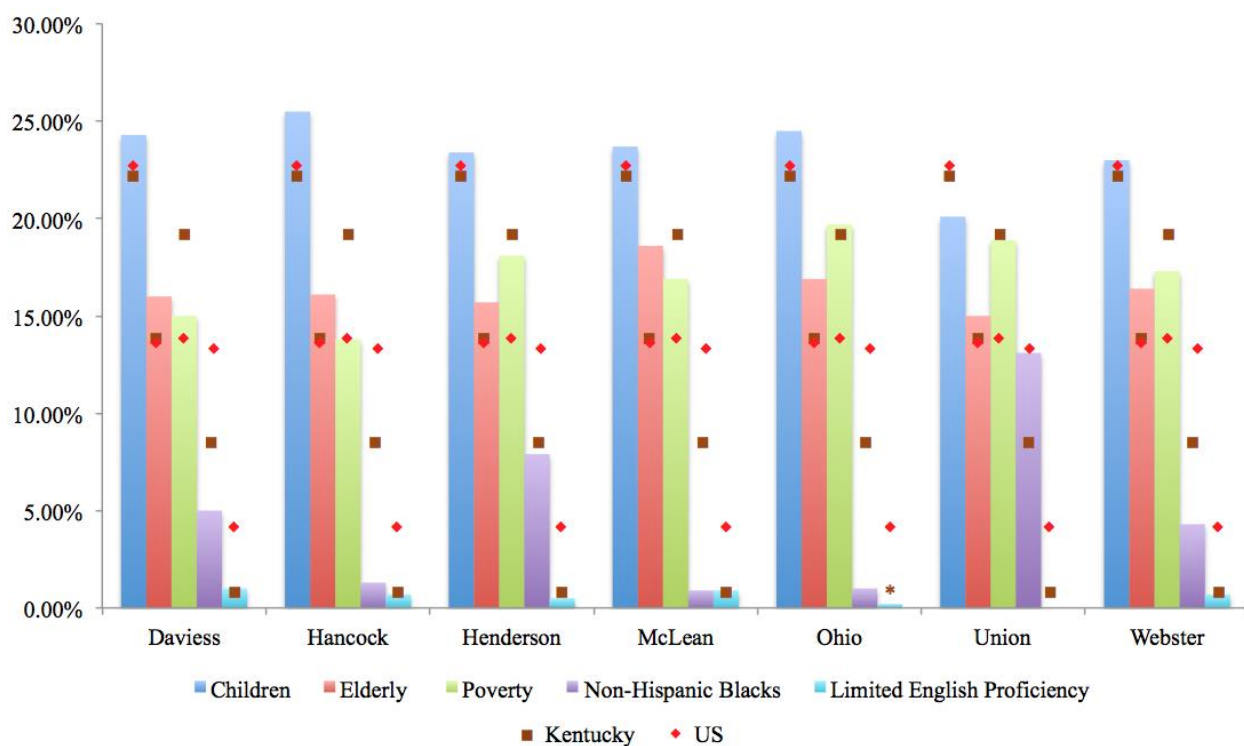
Ambulatory Difficulty (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

**Figure 25. Long-term care beds per 10,000 in Green River District counties (2014).**



**Source:** Long-term Care: Kentucky Cabinet for Health and Family Services Office of Health Policy. 2014 Kentucky Annual Long-Term Care Report, <http://chfs.ky.gov/NR/rdonlyres/10BB473B-4AAE-40CE-B36E-882C68D8370F/0/2014KYAnnualLongTermCareReport.pdf>

**Figure 26. Flood-related socioeconomic and demographic vulnerability (2010-2014) in Green River District counties.**



	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster	Kentucky	U.S.
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<b>Percentage population children (Age &lt; 18)</b>	24.3%	25.5%	23.4%	23.7%	24.5%	20.1%	23.0%	22.9%	23.1%
<b>Percentage population elderly (Age 65+)</b>	16.0%	16.1%	15.7%	18.6%	16.9%	15.0%	16.4%	14.8%	14.5%
<b>Percentage population living below federal poverty line</b>	15.0%	13.8%	18.1%	16.9%	19.7%	18.9%	17.3%	19.1%	14.8%
<b>Percentage population with limited English proficiency</b>	1.0%	0.7%	0.5%	0.9%	0.2%	0.0%	0.7%	1.1%	4.5%

**Sources:** Children (2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Elderly (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Poverty (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Limited English Proficiency (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

Homeless:

KY (2014): Kentucky Housing Corporation K-Count, <http://www.kyhousing.org/Resources/Data-Library/Pages/K-Count-Results.aspx>

US (2014): HUD, Point-in-Time Estimates of Homelessness, <https://www.hudexchange.info/resource/3031/pit-and-hic-data-since-2007/>

Outdoor Workers (2010-2014): U.S. Census Bureau, Population Division, <http://www.census.gov>

## Flooding Indicators for Green River District

The following set of indicators was developed to assist the Green River District Health Department and its partners in protecting the community from existing and future health concerns associated with exposure to flooding events.

The indicators are divided into four categories: environmental exposure, human health outcome, population vulnerability, and environmental vulnerability. This report defines the primary environmental exposure to flooding as the number of days annually with precipitation over 2 inches, as reported by weather stations. The health outcomes associated with this exposure are unintentional flooding-related morbidity and mortality. The demographics most vulnerable to flooding in the Green River District are: children, the elderly, families living in poverty, non-Hispanic Blacks, and individuals with

limited English proficiency. Chronic conditions that can be exacerbated by exposure to extreme heat include: diabetes, mental health concerns, individuals with ambulatory difficulty, and patients living in long-term care facilities. The primary indicators for environmental vulnerability are residences located in the FEMA 100-year floodplain, families living in stressed housing, and unintentional carbon monoxide poisoning.

Each indicator in Table 9 includes a definition explaining how it was calculated and the reasons for its inclusion on the list. Visit the figure(s) listed next to the indicator name to view the indicator for each county in the Green River District, as well as comparison indicators at the Kentucky and national levels. View Appendix A for the complete set of indicators reviewed in this report, including references to data sources.

**Table 9. Flooding indicators for Green River District.**

**Indicator**  
(Definition)

**Reason for Inclusion**

***Environmental Exposure***

**Exposure to heavy precipitation events**  
(Figure 18, Figure 19, Figure 20, Figure 21, Appendix B)  
(Number of days with precipitation over 2 inches reported by weather stations annually)

All of the counties in the Green River Health District experienced at least 15-23 days of extreme high water flow, on average, from 2000-2009. Major disasters related to heavy precipitation have been declared in the commonwealth nearly 19 times since 2000 [6]. Average annual precipitation in the district is projected to increase due to climate change from close to 2% under a low emission scenario to 6% under a high emission scenario [8, p. 16].

***Human Health Outcome***

**Unintentional flooding-related mortality**  
(Table 7)  
(Number of unintentional drowning-related deaths under ICD-10 codes: W69, W70, X38)

Primary health outcome from exposure to extreme precipitation [171,213].

**Unintentional flooding-related injury**  
(Table 7)  
(Number of flooding-related hospitalizations and emergency department visits under ICD-9 codes: E908.2, E908.9, E910.8, E910.9)

Primary health outcome from exposure to extreme precipitation [171,213].

***Population Vulnerability***

**Children** (Figure 26)  
(Percentage population below 18)

Increased vulnerability if separated from caregivers [210–212]. Particularly vulnerable to the negative mental health effects of flooding [11, p. 108], as well as negative health effects associated with power outages [75,195,196].

**Elderly** (Figure 26)  
(Percentage population aged 65 and above)

At heightened vulnerability to flooding-related injuries and illnesses [75,76], as well as negative health effects associated with power outages [75,195,196]. Particularly vulnerable to the negative mental health effects of flooding [11, p. 108].

**Poverty** (Figure 26)  
(Percentage population living below federal poverty line)

At heightened risk of flooding-related injuries and illnesses [75,76], due to their location in more flood-prone areas and reduced access to transportation options during evacuations. Particularly vulnerable to the negative mental health effects of flooding [11, p. 108].

**Non-Hispanic Blacks** (Figure 26)  
(Percentage population Non-Hispanic Black)

At risk because of combination of health status, socioeconomic status, and environmental justice concerns [40,42,43,51,52,74–76].

**Limited English Proficiency** (Figure 26)  
(Percentage persons age 14+ in whose household no one speaks English only or speaks English "very well")

At risk due to potential delay in receiving emergency messages, such as evacuation notices [75,76,199–202].

**Chronic Conditions – Diabetes** (Figure 24)  
(Percentage adult population diagnosed with diabetes)

Flooding can cause medical disruption, exacerbating chronic conditions such as diabetes [214,215].

**Mental Health Concerns** (Figure 24)  
(Estimated percent of population receiving services from Community Mental Health Centers Kentucky for mental or cognitive impairment)

Flooding can lead to mental health effects related to loss of loved ones, loss of property, stress, and economic hardship [75,181,182].

<b>Ambulatory Difficulty</b> (Figure 24) (Percentage population aged 5+ with ambulatory difficulty)	At heightened risk of negative health effects associated with power outages and mandatory evacuation [75,195–202].
<b>Long-term Care</b> (Figure 25) (Crude Rate Long-Term Care Beds per 10,000 population)	At heightened risk when required to evacuate or when medical care and/or medical transportation are disrupted [75,195–202].
<b>Environmental Vulnerability</b>	
<b>100-Year Floodplain</b> (Figure 21, Table 7) (Percentage population living in 100-Year Floodplain) (Percent Area (square miles) FEMA Floodplain) (Total flood insurance policies in force)	Structures located in floodplains are more likely to be exposed to flooding than structures on higher ground [216].
<b>Stressed Housing</b> (Figure 11) (Percentage stressed housing — i.e., lacking complete plumbing and/or kitchens, is overcrowded, or is cost burdened)	Stressed housing may not be equipped with the structural barriers to moisture infiltration and rodent intrusion after heavy precipitation events, both of which can lead to negative health outcomes [142–148,183,185–192].
<b>Carbon Monoxide Poisoning</b> (Figure 23) (Emergency Department visit count for carbon monoxide poisoning - meet the 2013 CSTE case definition for a "Confirmed" or "Probable" case of acute CO poisoning, Unintentional, non-fire related)	Rates of carbon monoxide poisoning often increase during power outages when residents use combustible fuels as an alternative to electricity for daily needs such as heating, air conditioning, and cooking. Flooding events can lead to both widespread power outages and compromised air conditioning systems in individual buildings [184, p. 81;146;185–190;193;194].



# Green River District Health Department Policy Recommendations

## Existing Green River District Health Department Policies

The Green River District Health Department (GRDHD) provides services, supports activities, and promotes policies that address the health impacts from natural disasters, chronic diseases, and social economic vulnerability. However, no formal agency policies or program activities currently focus specifically on climate change or its potential negative health outcomes. Existing programmatic activities attempt to address many of the hazards and needs outlined in this report, but they do not explicitly associate these actions with climate change.

This report fills that gap by identifying opportunities to strengthen policies and expand existing programs to better recognize potential hazards, monitor the impact on community health, and develop recommendations to mitigate the climate-related risks facing the community.

Three areas of local health have been identified as having the potential to address the needs and focus of this report.

- **Epidemiology program:** Green River District Health Department's epidemiology program monitors the health status of the community and investigates disease clusters and outbreaks. Health department staff manage a passive surveillance system, tracking and investigating infectious diseases that are reported by health care providers and other community members. This surveillance system reports into the National Notifiable Disease Surveillance System (NNDS) operated by the U.S. Centers for Disease Control and Prevention (CDC). The GRDHD system is currently primarily focused on infectious diseases. Timely investigation and follow-up on individual cases is considered necessary for controlling the spread of a disease outbreak within the community. The list of diseases required by state law to be reported is revised regularly to include emerging diseases. Reporting criteria may be modified based on declining incidents of a particular disease or changes in diagnostic capabilities such as laboratory testing methods. The list of reportable diseases includes a number that may be affected by extreme heat, drought, and/or flooding events. These include waterborne diseases such as campylobacteriosis and cryptosporidiosis and vector-borne diseases like West Nile Virus, Encephalitis, Dengue, and Zika Virus. Health department policies are in place to provide morbidity and mortality surveillance and to support state health department requests during community events and disasters.
- **Public health preparedness program:** The department's public health preparedness program works in conjunction with community partners and the Kentucky Department for Public Health to develop plans and policies for responding to and recovering from public health emergencies. Specifically, GRDHD coordinates a coalition of health care, emergency medical services, and county emergency management agencies. The focus of the coalition is to evaluate emergency plans against federal and state benchmarks and to ensure regular exercising of plans with partners within the region. The health department's role during emergency responses varies depending on the type of event. For flooding events, GRDHD's primary responsibilities have included the dissemination of public information related to health hazards associated with flooding; conducting surveillance for morbidity and mortality associated with the event; supporting county emergency shelters with clients that may have limited special medical needs; and, implementing core public health programs, such as protecting the public food supply and providing immunizations to affected populations. Program

activities are aligned with the CDC Public Health Emergency Preparedness Capabilities, the Assistant Secretary for Preparedness and Response's Hospital Preparedness Program, and the National Health Security Strategy.

- **Community health assessment and health improvement planning:** Using a process based on the Mobilization for Action through Planning and Partnerships (MAPP) framework, the health department leads and maintains an ongoing comprehensive community health assessment. A community health improvement plan is sustained with the cooperation of a large number of community partners. The planning process and assessment includes a focus on vulnerable populations and eliminating health disparities. The community health assessment and the community health improvement plan are updated annually and fully revised and redeveloped on a three-year cycle. Local communities utilize the health assessment to establish priorities and develop strategic planning efforts to improve the health and resiliency of their community. Since GRDHD implemented the community health assessment and improvement planning process in 2012, county level coalitions with support from regional groups have implemented strategic initiatives related to the focus areas of: reducing substance abuse, reducing obesity, reducing teen pregnancy, and improving access to health care and mental health services.

## Policy Recommendations

The communities served by the Green River District Health Department could benefit from the development of new policies addressing climate change risk. Tracking environmental exposure, select health outcomes, and environmental health indicators identified in this report can clarify the risk of climate change associated with extreme heat, flooding, and drought in the region. By addressing potential future risks to the community's health and economy, the health department will play a key role in mitigating potential public health disasters and increasing the resiliency of the region.

The proposed policy recommendations will strengthen the department's existing efforts in supporting five of the ten essential public health services (EPHS) [217].

- EPHS 1: Monitor Health Status to identify and solve community health problems.
- EPHS 2: Diagnose and investigate health problems and health hazards in the community.
- EPHS 3: Inform educate, and empower people about health issues.
- EPHS 4: Mobilize community partnerships and action to identify and solve health problems.
- EPHS 5: Develop policies and plans that support individual and community health efforts.

Policies will focus on expanding and reinforcing the aims of the epidemiology and public health preparedness planning program that align with the CDC's Public Health Emergency Preparedness Capabilities, the Assistant Secretary for Preparedness and Response's Hospital Preparedness Program, and the National Health Security Strategy. The policy recommendations listed below address the following objectives and aims [218]:

- Build and sustain resilient communities.
- Ensure situational awareness to support decision-making.

- Develop and maintain plans to ensure response and recovery to public health emergencies.

Recommendations have been organized into three categories:

1. opportunities for GRDHD to expand upon current agency activities,
2. opportunities for GRDHD to strengthen public health preparedness and response for polices and interventions led by community partners; and,
3. opportunities to expand and add value to the outcomes of this project.

### **Opportunities for GRDHD to expand upon current agency activities**

1. Routinely monitor, track, update and report new data for the environmental public health indicators identified in this report.
  - GRDHD should annually update data related to environmental public health indicators and health outcomes described in this report.
  - GRDHD should annually update data projections for environmental public health indicators described in this report, as available.
  - This information should be published and shared with community partners, policy makers, and the public in multiple avenues.
  - GRDHD should seek assistance from the Kentucky Department for Public Health EnviroHealthLink program to access data sets and to publish District data on the Kentucky Environmental Public Health Tracking website.
2. Integrate the tracking and reporting of climate risks and environmental public health indicators into future annual updates and revisions of the Community Health Assessment.
  - GRDHD should include data gathered for this project as well as annual updates in its ongoing revisions to the Community Health Assessment.
  - The information should be distributed and presented to community partners for consideration when prioritizing the community's top health issues.
3. Establish new policies and practices related to surveillance of negative health outcomes associated with extreme heat events, flooding, and drought.
  - GRDHD should identify appropriate "trigger points" to initiate enhanced surveillance activities, and a notification system.
  - GRDHD should establish procedures to solicit and remind area health care providers to report notifiable diseases and other event-related morbidities and mortalities to the health department. The health department will contact health care providers in the community using a variety of methods (fax, email, and phone) to request surveillance reports when the National Weather Service issues a Heat Advisory or a Flood Warning for any area in the District's jurisdiction.
  - GRDHD should also develop an active surveillance program for health concerns among clients of emergency shelters and cooling centers. GRDHD will maintain daily contact with agencies operating shelters and/or cooling centers to collect data on clients reporting issues from the following syndrome categories: Injuries, Dermatologic, Gastrointestinal Illness,

- Pregnancy, Respiratory Illness, Pain, Dehydration, Fever, Exacerbation of Chronic Disease, and Mental Health. GRDHD should develop additional relevant categories and sub categories.
4. Establish public education message toolkits to be utilized during extreme heat, drought, and flooding events.

#### **Opportunities for GRDHD to strengthen public health preparedness and response for policies and interventions led by community partners**

1. In coordination with regional healthcare preparedness and emergency preparedness partners, use the environmental public health indicators to inform the development and revision of response recovery plans to events related to extreme heat, drought, and flooding.
  - GRDHD should incorporate identified hazards and risks into the existing Green River Community Health Improvement Plan under the guidance of the Regional Healthcare Preparedness Coalition. Focus on ensuring that agencies in the coalition develop and maintain revised response plans to meet the needs of vulnerable populations under climate change conditions.
  - GRDHD should continue to work with these partners to ensure their plans account for populations at higher risk to the adverse health effects of extreme heat and flooding.
2. Incorporate the health and hazard indicators into the 2021 revision of the Green River Area Development Districts (GRADD) Hazard Mitigation Plan
  - GRDHD should work with GRADD staff and the district Hazard Mitigation Council to ensure that the vulnerable populations identified in this report are addressed in the Hazard Mitigation Plan.
  - GRDHD should work with the council to identify county and city mitigation projects that address the hazards of extreme heat, drought, and flooding.
  - GRDHD should ensure that the revised hazard analysis includes data on hazards that are impacted by climate change.
3. Partner with local community and outreach organizations to customize preparedness educational materials to be shared throughout the region. These partners may include county coalitions, the Medical Reserve Corps, Voluntary Organizations Active in Disaster (VOAD), and Citizen Corp agencies.
4. Coordinate with businesses and services that work with vulnerable populations to ensure that environmental hazard awareness is included in outreach to their clients. This goal includes the development of specialized materials to account for differently abled and language barriers.

#### **Opportunities to expand and add value to the outcomes of this project**

1. Perform more robust analysis of the data compiled during this project to specifically examine the links between historical extreme heat and flooding events in the Green River District and expected health outcomes. Use this information to refine thresholds for action (such as when to open cooling centers). Conduct additional geocoded analysis to identify locations where multiple vulnerabilities are clustered.

2. Identify indirect environmental health risks and indirect health outcomes not addressed specifically or fully in this report. Indirect effects to be researched may include: mental health, respiratory and cardiovascular conditions related to air quality, economic impact, and behavioral health.
3. Coordinate at the state or regional level to create a broader policy or plan to address climate change hazards and outcomes. Possible partners include: other local health departments in Kentucky, as well the Kentucky Department for Public Health.

Many of the policy recommendations listed above related to existing programs and cooperative practices with community partners may be largely achievable utilizing existing resources. However, limited additional funding and resources may be needed to fully implement them. The new policy recommendations that are aimed at expanding and adding validity to the outcomes of this report will require GRDHD to identify and acquire funding and resources that are currently beyond its capacity.

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# Appendix A

## Climate and Health Indicators for Green River District Health Department

Hazard	Indicator (Definition)	Reason for Inclusion	Sources
<b>Environmental Exposure</b>			
<b>HEAT</b>	Exposure to heat waves (Figure 3, Figure 4, Table 3) (Max temperature greater than or equal to 95 °F for a minimum of 3 days)	<u>Heat</u> : By 2050, the average annual temperature in the Green River Health District is projected to increase from close to 4 °F (under a low emissions scenario) to 5 °F (under a high emission scenario) [8].	Kentucky Climate Center, Department of Geography and Geology, Western Kentucky University. Accessed May and June, 2016.  CDC National Environmental Public Health Tracking, <a href="http://ephtracking.cdc.gov">http://ephtracking.cdc.gov</a>
<b>DROUGHT</b>	Exposure to drought (Figure 12, Figure 13) (County declared in D2 (severe), D3 (extreme), or D4 (exceptional) drought by U.S. Drought Monitor)	<u>Drought</u> : Kentucky experienced a trend of increasing drought conditions from 1958 to 2007 [5]. Severity of summertime droughts is expected to double by 2050 in Kentucky [25].	U.S. Drought Monitor, <a href="http://droughtmonitor.unl.edu/Home.aspx">http://droughtmonitor.unl.edu/Home.aspx</a>
<b>DROUGHT</b>	Exposure to air pollution (Figure 14) (Ave Daily PM2.5 µg/m³)	<u>Drought</u> : Can result in increased exposure to particulate matter (PM) in the form of airborne dust [127] from wind erosion, loss of vegetation, and wildfires [128,129]. Fine particulate matter (or, PM2.5 — particulate matter smaller than 2.5 microns in diameter) has been associated with diseases such as lung cancer, chronic obstructive pulmonary disease (COPD), cardiovascular disease, and asthma [130], particularly in the elderly [131,132].	CDC WONDER, <a href="http://wonder.cdc.gov/">http://wonder.cdc.gov/</a>  CDC National Environmental Public Health Tracking, <a href="http://ephtracking.cdc.gov">http://ephtracking.cdc.gov</a>
<b>FLOODING</b>	Exposure to heavy precipitation events (Figure 18, Figure 19, Figure 20, Figure 21, Appendix B) (Number of days with precipitation over 2 inches reported by weather stations annually)	<u>Flooding</u> : All of the counties in the Green River Health District experienced at least 15-23 days of extreme high water flow, on average, from 2000-2009. Major disasters related to heavy precipitation have been declared in the commonwealth nearly 19 times since 2000 [6]. Average annual precipitation in the district is projected to increase due to climate change from close to 2% under a low emission scenario to 6% under a high emission scenario [8, p. 16].	Kentucky Climate Center, Department of Geography and Geology, Western Kentucky University. Accessed May and June, 2016.  CDC National Environmental Public Health Tracking, <a href="http://ephtracking.cdc.gov">http://ephtracking.cdc.gov</a>  National Weather Service Advanced Hydrologic Prediction Service. Available at: <a href="http://water.weather.gov/ahps2/">http://water.weather.gov/ahps2/</a>

<i>Human Health Outcome</i>			
<b>HEAT</b>	Heat-related mortality (Number of heat-related deaths (ICD-10: X30, excluding W92) from May to September)	<u>Heat</u> : Primary health outcome from exposure to extreme heat [10,32,35–37,73].	Kentucky Death Certificates Files, Frankfort, KY 2001-2014. Kentucky Department for Public Health, Cabinet for Health and Family Services. Retrieved by Kentucky Injury Prevention and Research Center. (CHFS-IRB-DPH-FY17-02).
<b>HEAT</b>	Heat-related morbidity (Figure 5, Figure 6) (Number of heat stress hospitalizations and emergency department visits (ICD-9: 992, E900.0, E900.9, excluding E900.1) from May to September)	<u>Heat</u> : Primary health outcome from exposure to extreme heat [10,32,35–37,73].	Kentucky Inpatient & Outpatient Hospitalization Claims Files, Frankfort, KY, 2008-2012; Cabinet for Health and Family Services, Office of Health Policy. Retrieved by Kentucky Injury Prevention and Research Center. (CHFS-IRB-DPH-FY17-02).
<b>FLOODING</b>	Unintentional flooding-related mortality (Table 7) (Number of unintentional drowning-related deaths under ICD-10 codes: W69, W70, X38)	<u>Flooding</u> : Primary health outcome from exposure to extreme precipitation [171,213].	<u>KY</u> : Kentucky Death Certificates Files, Frankfort, KY 2008-2015. Kentucky Department for Public Health, Cabinet for Health and Family Services. Retrieved by Kentucky Injury Prevention and Research Center. (CHFS-IRB-DPH-FY17-02). <u>US</u> : CDC WONDER, <a href="http://wonder.cdc.gov/">http://wonder.cdc.gov/</a>
<b>FLOODING</b>	Unintentional flooding-related injury (Table 7) (Number of flooding-related hospitalizations and emergency department visits under ICD-9 codes: E908.2, E908.9, E910.8, E910.9)	<u>Flooding</u> : Primary health outcome from exposure to extreme precipitation [171,213].	Kentucky Inpatient & Outpatient Hospitalization Claims Files, Frankfort, KY, 2008-2012; Cabinet for Health and Family Services, Office of Health Policy. Retrieved by Kentucky Injury Prevention and Research Center. (CHFS-IRB-DPH-FY17-02).
<i>Population Vulnerability</i>			
<b>HEAT</b>	Children (Figure 9, Figure 17, Figure 26) (Percentage population below 18)	<u>Heat</u> : Limited capacity to regulate internal temperature [38]. More active than adults and spend more time outdoors [40,42,46,47]. Rely on caregivers to protect them from excessive exposure to heat, particularly in houses and cars [48]. <u>Drought</u> : Particularly sensitive to poor indoor air quality [149–151]. <u>Flooding</u> : Increased vulnerability if separated from caregivers [210–212]. Particularly vulnerable to the negative mental health effects of flooding [11, p. 108], as well as negative health effects associated with power outages [75,195,196].	U.S. Census Bureau, Population Division, <a href="http://www.census.gov">http://www.census.gov</a>
<b>DROUGHT</b>			

<b>FLOODING</b>			
<b>HEAT</b>	Elderly (Figure 9, Figure 17, Figure 26) (Percentage population aged 65 and above)	<u>Heat</u> : Limited capacity to regulate internal temperature [38]. At high risk if live alone or with limited mobility [40–44]. <u>Drought</u> : Particularly sensitive to both poor indoor and outdoor air quality [74,149–151]. <u>Flooding</u> : At heightened vulnerability to flooding-related injuries and illnesses [75,76], as well as negative health effects associated with power outages [75,195,196]. Particularly vulnerable to the negative mental health effects of flooding [11, p. 108].	U.S. Census Bureau, Population Division, <a href="http://www.census.gov">http://www.census.gov</a>
<b>DROUGHT</b>			
<b>FLOODING</b>			
<b>HEAT</b>	Poverty (Figure 9, Figure 26) (Percentage population living below federal poverty line)	<u>Heat</u> : At risk because may not have sufficient access to adaptations such as weatherized buildings and affordable air conditioning [40,42,43,51,57,58]. <u>Flooding</u> : At heightened risk of flooding-related injuries and illnesses [75,76], due to their location in more flood-prone areas and reduced access to transportation options during evacuations. Particularly vulnerable to the negative mental health effects of flooding [11, p. 108].	U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates, <a href="http://www.census.gov">http://www.census.gov</a>
<b>FLOODING</b>			
<b>HEAT</b>	Non-Hispanic Blacks (Figure 9, Figure 17, Figure 26) (Percentage population Non-Hispanic Black)	<u>Heat, Drought, Flooding</u> : At risk because of combination of health status, socioeconomic status, and environmental justice concerns [40,42,43,51,52,74–76].	U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates, <a href="http://www.census.gov">http://www.census.gov</a>
<b>DROUGHT</b>			
<b>FLOODING</b>			
<b>HEAT</b>	Homeless (Figure 9) (Percentage population Homeless)	<u>Heat</u> : May combine increased exposure to heat and cold with other risk factors such as social isolation, psychiatric illness, and multiple chronic diseases [53].	<u>KY</u> : Kentucky Housing Corporation K-Count, <a href="http://www.kyhousing.org/Resources/Data-Library/Pages/K-Count-Results.aspx">http://www.kyhousing.org/Resources/Data-Library/Pages/K-Count-Results.aspx</a> <u>US</u> : HUD, Point-in-Time Estimates of Homelessness, <a href="https://www.hudexchange.info/resource/3031/pit-and-hic-data-since-2007/">https://www.hudexchange.info/resource/3031/pit-and-hic-data-since-2007/</a>
<b>HEAT</b>	Outdoor Workers (Figure 9) (Percentage population in outdoor profession - agriculture, industry, construction)	<u>Heat</u> : At risk due to increased exposure to elevated temperatures during the heat of the day [44,54,55].	U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates, <a href="http://www.census.gov">http://www.census.gov</a>
<b>FLOODING</b>	Limited English Proficiency (Figure 26)	<u>Flooding</u> : At risk due to potential delay in receiving emergency messages, such as evacuation notices [75,76,199–202].	U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates, <a href="http://www.census.gov">http://www.census.gov</a>

	(Percentage persons age 14+ in whose household no one speaks English only or speaks English "very well")		
HEAT	Chronic Conditions – Obesity (Figure 8) (Percentage adult population with BMI 30+)	<u>Heat</u> : At risk due to heightened sensitivity to high ambient temperatures [32, p. 34].	U.S. Centers for Disease Control and Prevention, Behavioral Risk Factor Surveillance System (BRFSS), <a href="http://www.cdc.gov/brfss/">http://www.cdc.gov/brfss/</a>
HEAT	Chronic Conditions – Diabetes (Figure 8, Figure 15, Figure 24) (Percentage adult population diagnosed with diabetes)	<u>Heat, Drought</u> : Exposure to heat and/or poor air quality can exacerbate chronic conditions such as complications related to diabetes [10, p. 46;77]. <u>Flooding</u> : Flooding can cause medical disruption, exacerbating chronic conditions such as diabetes [214,215].	Kentucky Department of Health, Kentucky BRFSS Data Reports, <a href="http://chfs.ky.gov/dph/info/dpqi/cd/Kentucky+BRFSS+Data+Reports.htm">http://chfs.ky.gov/dph/info/dpqi/cd/Kentucky+BRFSS+Data+Reports.htm</a>  CDC National Environmental Public Health Tracking, <a href="http://ephtracking.cdc.gov">http://ephtracking.cdc.gov</a>
DROUGHT			
FLOODING			
HEAT	Chronic Conditions - Heart Disease (Figure 7) (All-Cause Heart Disease Death rate per 100,000)	<u>Heat</u> : Exposure to heat can exacerbate chronic conditions such as cardiovascular disease [10, p. 46].	CDC Interactive Atlas of Heart Disease and Stroke, <a href="http://nccd.cdc.gov/dhdspatlas/">http://nccd.cdc.gov/dhdspatlas/</a>
DROUGHT	Chronic Conditions - Chronic Lower Respiratory Disease (CLRD) (Figure 16) (CLRD Death rate per 100,000)	<u>Drought</u> : At risk due to heightened sensitivity to poor air quality [77].	CDC Community Health Status Indicators (CHSI), <a href="http://www.cdc.gov/CommunityHealth/">http://www.cdc.gov/CommunityHealth/</a> (Data Reference: [219])
HEAT	Chronic Conditions – Asthma (Figure 7, Figure 16) (Asthma Hospitalization rate per 10,000)	<u>Heat</u> : Exposure to heat can exacerbate chronic conditions such as respiratory disease [10, p. 46]. <u>Drought</u> : At risk due to heightened sensitivity to poor indoor air quality [149–151].	<u>KY</u> : CDC National Environmental Public Health Tracking, <a href="http://ephtracking.cdc.gov">http://ephtracking.cdc.gov</a> <u>US</u> : Healthy People 2020, <a href="https://www.healthypeople.gov">https://www.healthypeople.gov</a> (Note: Specific to ages 5-64.)
DROUGHT			
HEAT	Chronic Conditions - Cerebro-vascular Disease (Figure 7) (Stroke Death Rate(ICD-10: I60-I69) per 100,000)	<u>Heat</u> : Exposure to heat can exacerbate chronic conditions such as cerebro-vascular disease [10, p. 46].	CDC Interactive Atlas of Heart Disease and Stroke, <a href="http://nccd.cdc.gov/dhdspatlas/">http://nccd.cdc.gov/dhdspatlas/</a>

<b>DROUGHT</b>	Mental Health Concerns (Figure 15, Figure 24) ( <i>Estimated percent of population receiving services from Community Mental Health Centers Kentucky for mental or cognitive impairment</i> )	<u>Drought</u> : Rural areas in particular have been associated with mental health concerns during droughts, due to increased economic insecurity [87,160–163]. <u>Flooding</u> : Flooding can lead to mental health effects related to loss of loved ones, loss of property, stress, and economic hardship [75,181,182].	Kentucky Safety and Prevention Alignment Network, <a href="http://safekentucky.org/index.php/preparedness">http://safekentucky.org/index.php/preparedness</a> Data Reference: Kentucky Department for Behavioral Health & Intellectual Disabilities
<b>FLOODING</b>			
<b>FLOODING</b>	Ambulatory Difficulty (Figure 24) ( <i>Percentage population aged 5+ with ambulatory difficulty</i> )	<u>Flooding</u> : At heightened risk of negative health effects associated with power outages and mandatory evacuation [75,195–202].	U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates, <a href="http://www.census.gov">http://www.census.gov</a>
<b>FLOODING</b>	Long-term Care (Figure 25) ( <i>Crude Rate Long-Term Care Beds per 10,000 population</i> )	<u>Flooding</u> : At heightened risk when required to evacuate or when medical care and/or medical transportation are disrupted [75,195–202].	Kentucky Cabinet for Health and Family Services Office of Health Policy. 2014 Kentucky Annual Long-Term Care Report, <a href="http://chfs.ky.gov/NR/rdonlyres/10BB473B-4AAE-40CE-B36E-882C68D8370F/0/2014KYAnnualLongTermCareReport.pdf">http://chfs.ky.gov/NR/rdonlyres/10BB473B-4AAE-40CE-B36E-882C68D8370F/0/2014KYAnnualLongTermCareReport.pdf</a>
<b>Environmental Vulnerability</b>			
<b>FLOODING</b>	100-Year Floodplain (Figure 21, Table 7) ( <i>Percentage population living in 100-Year Floodplain</i> ) ( <i>Percent Area (square miles) FEMA Floodplain</i> ) ( <i>Total flood insurance policies in force</i> )	<u>Flooding</u> : Structures located in floodplains are more likely to be exposed to flooding than structures on higher ground [216].	CDC National Environmental Public Health Tracking, <a href="http://ephrtracking.cdc.gov">http://ephrtracking.cdc.gov</a> Reference: Federal Emergency Management Agency (FEMA) 2011 National Flood Hazard Layer Federal Emergency Management Agency (FEMA) National Flood Insurance Program, Policy Statistics Country-Wide as of 04/30/2016, <a href="http://bsa.nfipstat.fema.gov/reports/1011.htm#KYT">http://bsa.nfipstat.fema.gov/reports/1011.htm#KYT</a>
<b>HEAT</b>	Stressed Housing (Figure 11) ( <i>Percentage stressed housing — i.e., lacking complete plumbing and/or kitchens, is overcrowded, or is cost burdened</i> )	<u>Heat</u> : Stressed housing can lack adequate weatherization and air conditioning — two important protective strategies during heat-related events. [40,42,43,51,57,58]. <u>Drought</u> : Stressed housing can increase indoor exposure to the allergens and pathogens in outdoor dust [149–151]. <u>Flooding</u> : Stressed housing may not be equipped with the structural barriers to moisture infiltration and rodent intrusion after heavy precipitation events, both of which can lead to negative health outcomes [142–148,183,185–192].	CDC Community Health Status Indicators (CHSI), <a href="http://wwwn.cdc.gov/CommunityHealth/">http://wwwn.cdc.gov/CommunityHealth/</a>
<b>DROUGHT</b>			
<b>FLOODING</b>			
<b>HEAT</b>	Air Conditioning - Do Not Have or Have But Do Not Use (Figure 10) ( <i>Number of residential units without air conditioning or reporting that they have air</i> )	<u>Heat</u> : Air conditioning is an important protective strategy during heat-related events. And, voluntary rationing has been found to be a significant avoidable cause of heat-related negative health outcomes [78].	Energy Information Administration Residential Energy Consumption Survey, <a href="http://www.eia.gov/consumption/residential/data/2009/#ac">http://www.eia.gov/consumption/residential/data/2009/#ac</a> Note: KY data combines KY, AL, and MS

	conditioning but do not use it)		
<b>HEAT</b>	Carbon Monoxide Poisoning (Figure 23) (Emergency Department visit count for carbon monoxide poisoning - meet the 2013 CSTE case definition for a "Confirmed" or "Probable" case of acute CO poisoning, Unintentional, non-fire related)	Rates of carbon monoxide poisoning often increase during power outages when residents use combustible fuels as an alternative to electricity for daily needs such as heating, air conditioning, and cooking. <u>Heat</u> : Heat waves can result in power outages due to unsustainable demand for air conditioning [27]. <u>Flooding</u> : Flooding events can lead to both widespread power outages and compromised air conditioning systems in individual buildings [184, p. 81;146;185–190;193;194].	Office of Health Policy, Kentucky Cabinet for Health and Family Services. (2015). Unintentional Carbon Monoxide Poisoning Emergency Department Data, 2008-2013. via EnviroHealthLink, June 2016.
<b>FLOODING</b>			



## Appendix B

### Flooding events in Green River District Counties (2000-2015)

Flooding Event	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
1/3/00	✓		✓	✓		✓	✓
2/21/00	✓		✓			✓	
3/1/00						✓	
5/3/00	✓						
6/17/00			✓				
7/31/00	✓						
12/17/00					✓		
2/16/01					✓		
6/7/01	✓						
7/25/01-7/26/01	✓				✓	✓	
7/29/01	✓						
8/11/01	✓		✓	✓			✓
10/24/01			✓				
11/29/01	✓			✓	✓		
12/16/01-12/17/01	✓	✓	✓		✓	✓	
1/23/02-1/24/02	✓	✓			✓		✓
3/20/02				✓	✓		
3/22/02	✓		✓			✓	
3/26/02					✓		
4/1/02			✓	✓		✓	
4/24/02			✓				
4/26/02						✓	
5/1/02	✓		✓			✓	
5/18/02				✓			
9/15/02	✓						
9/26/02					✓		
11/10/02						✓	
12/18/02-12/20/02	✓	✓			✓		
2/15/03	✓		✓	✓	✓		✓
2/19/03			✓			✓	
2/22/03					✓		
3/1/03	✓		✓	✓		✓	✓
5/7/03						✓	
5/8/03	✓		✓			✓	
7/21/03	✓				✓		
8/22/03					✓		
9/3/03					✓		
11/26/03			✓			✓	
Flooding Event	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
1/2/04					✓		
1/6/04	✓		✓			✓	
2/10/04	✓		✓			✓	
3/11/04						✓	
4/30/04				✓			
5/27/04					✓		
5/30/04	✓		✓			✓	

6/1/04-6/2/04	✓		✓	✓	✓	✓	
7/5/04	✓						
9/22/04	✓		✓				
1/3/05				✓			
1/7/05-1/8/05	✓	✓	✓		✓	✓	
3/28/05					✓		
4/4/05						✓	
8/28/05	✓						
8/31/05					✓		
9/1/05					✓		
11/14/05-11/15/05			✓			✓	
1/23/06					✓		
3/9/06	✓						✓
3/15/06			✓			✓	
6/7/06				✓			
6/20/06		✓					
7/21/06	✓		✓				
9/12/06			✓				
9/22/06-9/23/06	✓	✓	✓		✓	✓	✓
1/13/07			✓			✓	
3/6/07						✓	
4/22/07						✓	
5/11/07					✓		
6/28/07				✓			
12/10/07					✓		
12/13/07				✓			
12/15/07	✓	✓			✓		
12/17/07						✓	
2/6/08					✓		
2/8/08-2/9/08				✓		✓	
2/12/08					✓		
2/22/08					✓		
3/4/08					✓		
3/6/08				✓			
3/18/08-3/20/08	✓	✓	✓	✓	✓	✓	✓
4/1/08						✓	
4/3/08-4/4/08	✓		✓	✓	✓	✓	✓
<b>Flooding Event</b>	<b>Daviess</b>	<b>Hancock</b>	<b>Henderson</b>	<b>McLean</b>	<b>Ohio</b>	<b>Union</b>	<b>Webster</b>
4/10/08			✓				
5/2/08	✓						✓
4/2/09	✓						
5/8/09-5/11/09			✓	✓		✓	
5/27/09					✓		
7/30/09			✓				
8/4/09					✓		
9/20/09	✓						
10/9/09			✓			✓	
1/30/10						✓	
2/1/10						✓	
3/20/10						✓	
4/24/10					✓		
5/1/10-5/3/10	✓		✓	✓	✓		✓
5/6/10-5/7/10	✓					✓	
6/2/10					✓		

7/15/10	✓						
2/24/11	✓		✓				✓
2/28/11				✓		✓	
3/1/11-3/2/11				✓		✓	
3/4/11	✓		✓				
3/9/11					✓		
4/12/11-4/14/11	✓	✓	✓	✓	✓		
4/17/11						✓	
4/20/11					✓		
4/23/11-4/24/11	✓		✓	✓	✓	✓	✓
5/1/11-5/2/11	✓		✓	✓	✓	✓	✓
6/28/11					✓		
11/29/11- 12/2/11				✓	✓	✓	
12/4/11-12/5/11	✓		✓	✓	✓	✓	✓
1/28/12						✓	
2/1/12						✓	
7/2/12	✓						
7/14/12	✓						
8/2/12			✓				
1/13/13-1/14/13	✓				✓		✓
1/19/13						✓	
2/6/13						✓	
3/19/13					✓		
3/22/13			✓				
12/21/13- 12/22/13			✓		✓		
12/25/13						✓	
1/1/14						✓	

Flooding Event	Daviess	Hancock	Henderson	McLean	Ohio	Union	Webster
2/8/14			✓	✓			
2/25/14						✓	
3/1/14						✓	
4/3/14-4/5/14	✓		✓		✓	✓	
4/7/14				✓			
5/14/14		✓					
6/4/14	✓						
3/4/15					✓		✓
3/6/15-3/10/15	✓		✓	✓	✓	✓	
3/13/15-3/14/15					✓		✓
4/3/15					✓		
4/5/15-4/6/15					✓	✓	
4/10/15				✓			
4/15/15	✓						
6/21/15	✓						
7/3/15	✓				✓		
7/15/15						✓	
12/27/15- 12/28/15				✓	✓	✓	
12/30/15	✓		✓				

**Source:** NOAA National Climatic Data Center Storm Events Database, <http://www.ncdc.noaa.gov/stormevents>

