# CLIMATE CHANGE REPORT

**HAZARD MITIGATION PLAN ADDITION**
JUNE/AUGUST 2020


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# WHAT IS CLIMATE CHANGE?

Fossil fuels are sources of energy, mainly carbon, that have been buried in the earth for millions of years. These sources can be extracted and used for fuel, the main three types being natural gas, crude oil, and coal. Fossil fuel usage has increased by more than 1300-fold since the year 1800, along with the invention and increased usage of technology that requires such energy sources to function. [1]

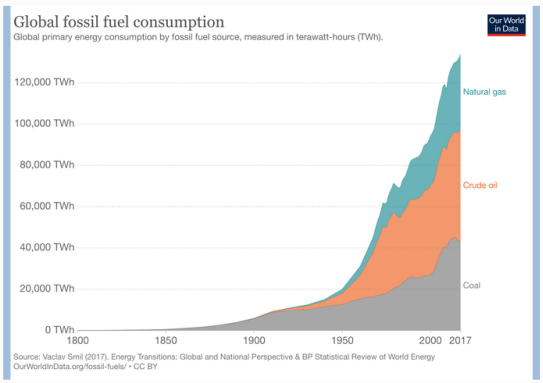


***Figure 1: Global fossil fuel consumption***
*SOURCE: Vaclav Smil (2017). Energy Transitions: Global and National Perspectives. & BP Statistical Review of World Energy [2]*

This increased usage of fossil fuels has meant that the amount of carbon dioxide in the atmosphere has also increased. When fossil fuels are used, they are burned and release carbon dioxide, along with other compounds, into the atmosphere. The greenhouse effect (illustrated above) is usually able to capture some of the Earth's natural release of CO2, while the rest of it is reflected back into space.

Under normal conditions, the Earth is kept reasonably warm by this greenhouse effect. However, with the increased amount of CO2 being released into the atmosphere, there is an inordinate amount of it trapped by the greenhouse gas effect and the Earth is warming at an alarming rate. Carbon dioxide is not the only greenhouse gas that is being released with a higher frequency and thus accelerating the greenhouse gas effect, but it is the most copious. [4]

The scientific consensus is that this increase in greenhouse gas emissions and subsequent warming of the Earth is a result of anthropogenic activities; humans are causing global warming via an increased usage of fossil fuels and other, smaller factors. [5]

This warming of the Earth, in turn, causes numerous other phenomena on Earth. The overall increase in the global temperature changes the climate in every part of the world, although each area is affected differently. Climate change includes change in temperature, precipitation, wind, ocean activity, and natural disasters.

# HOW DOES CLIMATE CHANGE AFFECT HAZARD MITIGATION?

**CHANGES IN TEMPERATURE, PRECIPITATION, AND WIND SPEEDS IMPACT SEVERAL HAZARDS IN A MULTITUDE OF WAYS. THIS MEANS THAT MANY HAZARDS WILL BE IMPACTED BY CLIMATE CHANGE SOMEHOW. IT VARIES FOR EACH HAZARD, BUT THE EFFECTS OF CLIMATE CHANGE CAN CAUSE HAZARDS TO INCREASE IN FREQUENCY, PROLONG THEIR DURATION, INCREASE THEIR SEVERITY, AND SHIFT THEIR SEASONAL OCCURRENCES.**

The standard model for hazard mitigation relies heavily on predicting the likelihood of a hazard occurring and then predicting how severe the impact of that hazard could be. These predictions have historically been formed based on recorded data of hazards occurring, as well as data on different aspects that influence the occurrence of these hazards. This method implies that the chance of hazard occurring is mostly unchanged over time. However, with more recent research on climate change, it is evident that the likelihood of hazards occurring will not remain the same.

Hazards are influenced in the same ways that they were fifty years ago, however, these influencing factors themselves have gone and are undergoing changes due to climate change. Climate change needs to be taken into consideration when discussing hazard mitigation because it is causing the likelihood of hazards occurring to change. This chapter provides a summary and analysis of the most relevant climate change research that applies to the Kentuckiana region, as well as recommendations for what to consider in terms of hazard mitigation.

## SPRINGFIELD CLIMATE ACTION & RESILIENCE PLAN

***What*: The city partnered with the Pioneer Valley Planning Commission to develop a "climate action resilience plan to reduce the city's greenhouse gas emissions by 80% by 2050 and to make the city more resilient. [6]"**

***Who*: The citizens of Springfield who will be impacted by climate change, especially those who will be affected more severely by the compounded effects on public health, economic, and racial injustices.**

***How*: Funded by the US Department of Housing and Urban Development's National Disaster Resilience Competition, Pioneer Valley Planning Commission partnered with the City of Springfield, the Springfield Climate Justice Coalition, University of Massachusetts at Amherst, and Partners for a Healthier Community.**

# CASE STUDY

# GLOBAL CLIMATE CHANGE EFFECTS

Temperature: The most reported on and well known effect of climate change is the increase of the global temperature, however this is actually what causes climate change. [7]

- Increase in extreme heat events in many areas
- Increase in extreme cold in some areas

Precipitation: A warmer atmosphere is an atmosphere that can hold more moisture.

- Atmosphere is holding more water
- Higher amount of precipitation in many areas

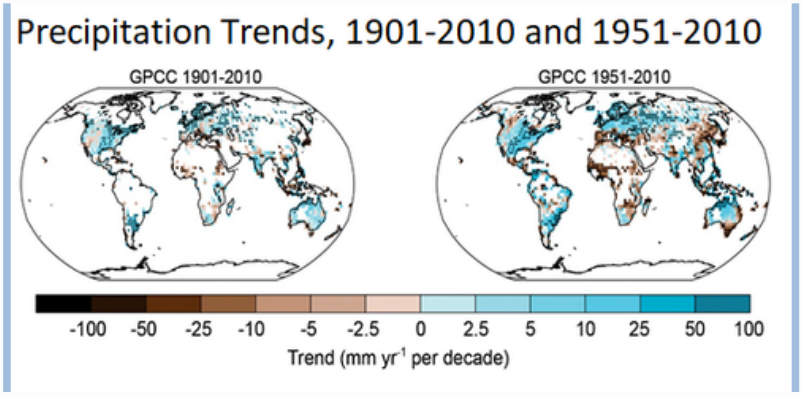


***Figure 2: Precipitation trends (1901-2010 & 1951-2010)***
*SOURCE: Yale University (2019) [9]*

Wind: Wind speeds are affected by climate change because the increase of temperature causes an increase in wind speed.

- Increase in global wind speed from 7 mph to 7.4 mph [10]
- Small increases are quite substantial, especially for the global average [11]

Ocean: Along with the atmosphere, the ocean also absorbs carbon dioxide emissions.

- Absorbs 90% of the heat from global warming, which has increased the temperatures of ocean waters significantly
- Ocean acidification as a result of CO2 in ocean waters [13]

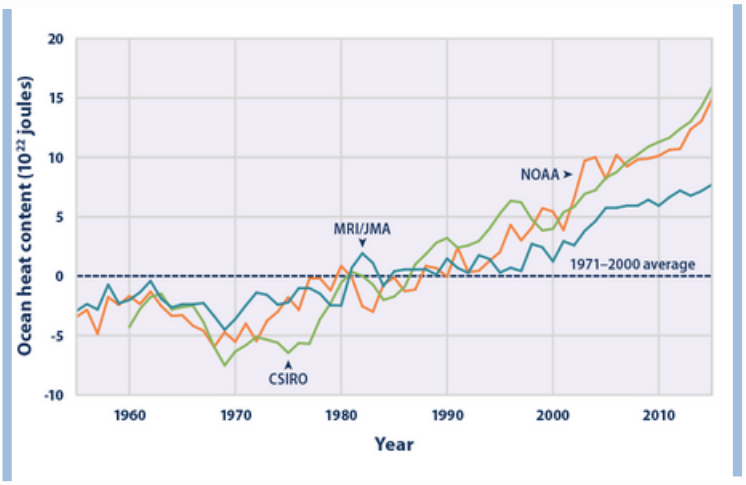


***Figure 3: Ocean heat levels (1950-2010)***
*SOURCE: EPA (2016) [12]*

Natural Disasters: Most natural disasters are at least influenced by temperature, precipitation, or wind. When climate change affects one of these aspects, natural disasters are affected, as well.

- Might increase/decrease in frequency or severity
- Locations of typical occurrence might change
- Different for each disaster and region

# NATIONAL CLIMATE CHANGE EFFECTS

The effects of climate change on the United States are best understood on a regional level, as the country is roughly a squared 3.8 million miles, but there are overall effects that are important to understand before breaking them down to that level.

Temperature:

- Recorded as increasing in the past decades
- Expected to continue and to get even warmer
- The occurrence of extreme heat events will also increase
- The breaking down of the polar vortex is causing mid-latitudinal regions to be hit with cold seasonally [15]

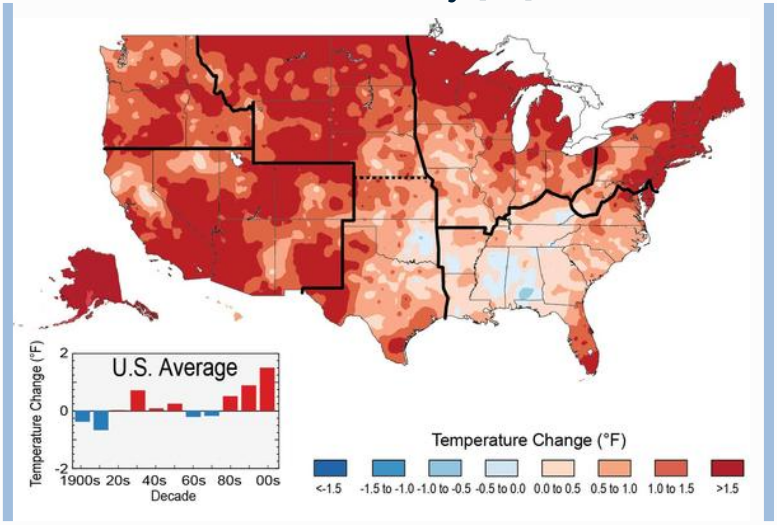


***Figure 4: US average temperature increase***
*SOURCE: National Climate Assessment (2014) [14]*

Precipitation:

- Observed to increase in the US, however this change is much more regional [8]
- Climate change is expected to make wet areas of the United States wetter, and make the dry areas drier
- Could potentially lead to flooding in some areas and droughts and/or wildfires in others

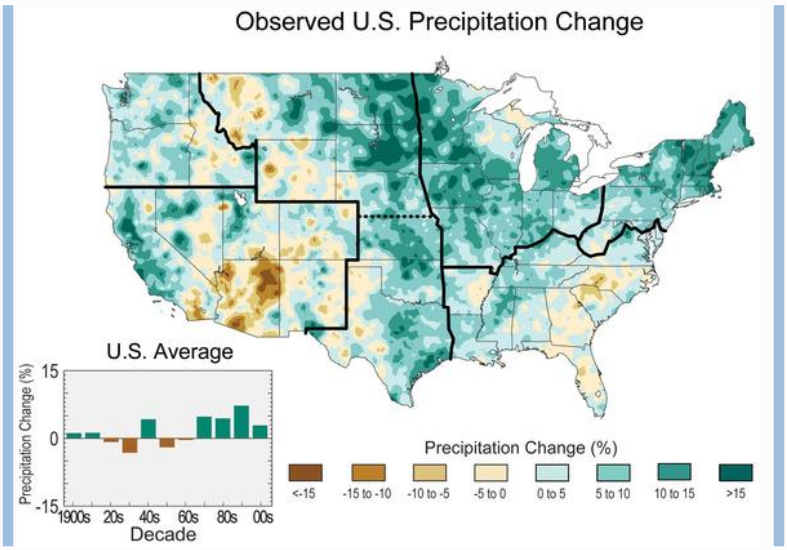


***Figure 5: Observed US precipitation change (1900s-2000s)***
*SOURCE: National Climate Assessment (2014) [8]*

Wind: Wind speeds in the United States are increasing along with the global average.

Ocean: United States' coasts are expected to experience rising sea levels as a result of climate change. [16]

Natural Disasters:

- Might increase/decrease in frequency or severity
- Locations of typical occurrence might change
- Different for each disaster and region

# REGIONAL CLIMATE CHANGE EFFECTS

## Climate Change Impacts

**FOR KENTUCKY AND INDIANA**

A general breakdown of how climate change will impact the Kentuckiana area. Climate change is expected to impact the region in similar ways, but most research is on individual states or on broad regions, such as the Midwest or the Southeast. This comparison shows how the impacts are similar, but that some of the data and research is individual.

| | Kentuckiana |
|---|---|
| Temperature | More recorded extreme heat days since 1970, generally expected to increase in average temperature and number of extreme heat days |
| Polar Vortex | Impacted by the break down of the polar vortex |
| Precipitation | Has increased by 10-15% and expected to increase by over 40% by 2100 |
| Wind | Wind speeds and chills expected to increase |

# EXTREME HEAT

## CLIMATE CHANGE EFFECTS

The steady rising of the global temperature is the most direct effect of climate change. Due to the increase in fossil fuel emissions over the last century, heat-trapping gas levels have increased in the atmosphere, causing the Earth to warm. [17] Even a small increase in the average temperature causes a major shift in the level of heat that is experienced, so there also needs to be a shift in the understanding of what extreme heat is along with the new average. Extreme heat events were rare fifty years ago, but now extreme summer heat occurs about seven percent of the time, as of 2019. [18]

Scientists have linked recent heat waves and occurrences of extreme heat to climate change and the rising global temperature. [19]

Below is a conceptual representation of the shift in the probability distribution for average and extreme temperatures as a result of global warming. The frequency of extreme high temperatures increases non-linearly, while extreme lows show a more muted response. This shift causes a higher frequency of extreme heat, but extreme cold is less affected.

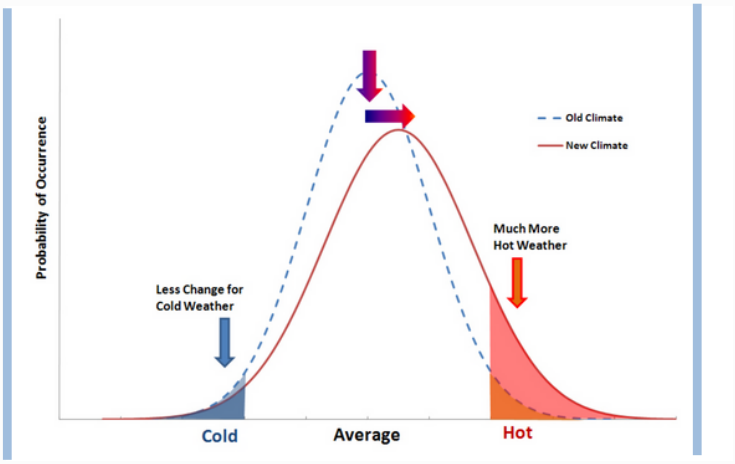


***Figure 6: Shift in the probability distribution of average temperature***

*SOURCE: Adapted from IPCC (2001) [20]*

# EXTREME HEAT

## REGIONAL CLIMATE CHANGE DATA

The Midwest has been shown to have an increased frequency of hot, dry, and humid weather, whereas cold weather has been decreasing in frequency. [21] [22]

Clark County had an average of 42 days with extreme heat events from 1971 and 2000. Under medium emissions scenarios this could become 93 by 2050 and under high emissions it could become 103. Floyd County has an average of 41 days with extreme heat events from 1971 and 2000. Under medium emissions scenarios this could become 92 by 2050 and under high emissions it could become 105. This increase in both the frequency and intensity of extreme heat in the region will also increase the evaporation rate, which will most likely initially offset any increase in precipitation. [23]

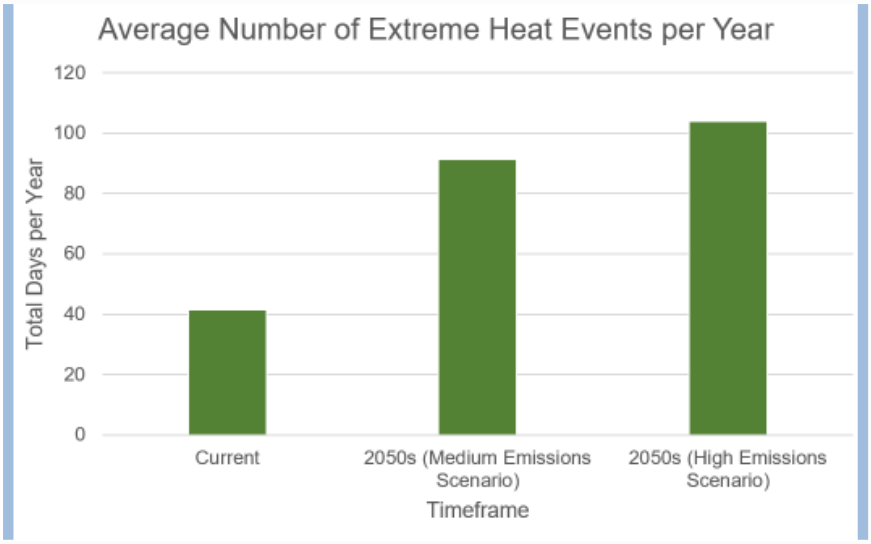


***Figure 7: Average number of extreme heat events per year***

# EXTREME HEAT

## CASCADING EFFECTS

Rising global temperatures will only exacerbate any extreme heat instances in the Kentuckiana region. This general trend in the rise of average temperatures will also leave the area more susceptible to drought, water shortages, poor air quality, and wildfires. [24]

- Drought: the Midwest is not likely to experience traditional droughts, but is susceptible to flash droughts in the summer [25]
- Wildfires: add smoke to the air, which reduces its quality, and provide dangers of their own
- Poor Air Quality: the air is stagnant and emitted pollutants are trapped in it rather than circulated [26]
- Water Shortages: most likely will affect only the more vulnerable of the population

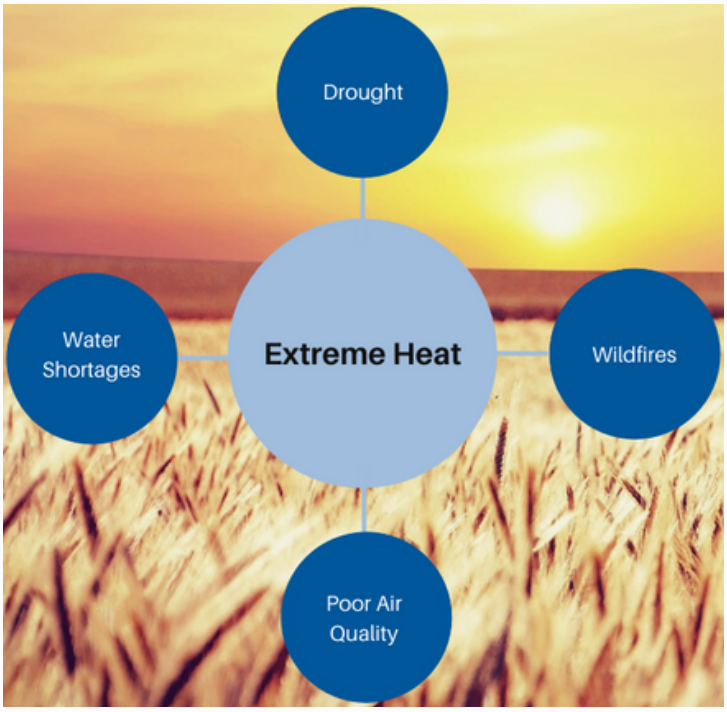


***Figure 8: Cascading effects of extreme heat***

# EXTREME HEAT

## SOCIAL CONSEQUENCES

The effects of extreme heat can be dealt with via coping mechanisms such as air conditioning, evaporative coolers, air-conditioned transportation, and air-conditioned shelters. [27] People that can afford these measures are less at risk to the effects of extreme heat. Due to existing socioeconomic problems and the way they intersect with race, racial and ethnic minorities are also at more of a risk than other groups. [28] In terms of responses to extreme heat physically, the elderly and the very young are more in danger. Extreme heat can lead to heat-related illnesses (e.g. heat stroke, heat exhaustion, heat cramps) and, in some cases, death. [29] There is a linguistic barrier, as well, because the majority of information given out about the effects of extreme heat and the preventative measures one needs to take to avoid these effects are given in English. Non-English speaking citizens are also at more of a risk. Counties need to expect and prepare for hotter summers and the subsequent effects of increased extreme heat occurrences while also taking these disproportionate risk levels into consideration.

# EXTREME COLD

## CLIMATE CHANGE EFFECTS

Although the idea of climate change is often associated with increasing temperatures, due to the term "global warming" being well-circulated, climate change also includes decreasing temperatures, as well. Scientists believe that the decline of Arctic sea ice is causing mid-latitudinal regions to experience more extreme weather events, including extreme cold. [30] This decrease in the amount of ice, coupled with the increase of atmospheric water vapor in the Arctic during late autumn and early winter, causes there to be more moisture in the air in the Midwestern United States during the winter. [31]

## REGIONAL CLIMATE CHANGE DATA

Extreme cold has been reported in the Midwest both in scientific studies and by Midwesterners themselves. A 2017 study showed that there has been an increase in the amount of several extreme weather events, including extreme cold, in the Midwest and the Southeast in recent years. [32] In a 2013 study done by the Yale Project on Climate Change Communication, 47% of Midwesterners reported extreme cold events, which was an increase by 24 points since the prior year. In addition, 45% reported experiencing an extreme snowstorm, which was an increase by 31 points since the prior year. [33] The winter of 2019 had Midwesterners experiencing a cold front, which is theorized to be caused by the weakening and fragmentation of the polar vortex. The warmer temperatures in the Arctic may be causing a distortion of the polar jet stream, which might be bringing more cold air to the midlatitudes to the globe. [34] [35] These changes are not expected to be as severe as the changes to the occurrences of extreme heat events, but they still are significant.

# EXTREME COLD

## CASCADING EFFECTS

Extreme cold leads to extreme cold events, which include snowstorms and wind chills. Wind chills are how cold it actually feels once wind speed is factored in. [36] Climate change is also thought to be increasing wind speeds and an increase in global winds speeds since 2010 has been reported. [11] This means that climate change is already making the winter colder in Kentucky, and the faster winds will make it even colder.

## SOCIAL CONSEQUENCES

An increase in the occurrences of extreme cold events means that the health consequences that come with them are also going to become more frequent. High winds speeds paired with cold temperature can cause frostbite and hypothermia. [37]  To prepare for extreme cold events, it is recommended to have ways to warm oneself on hand and basic supplies for staying indoors for an extended period of time. [36] Citizens should be informed on how to properly check for and deal with frozen pipes and walkways should be salted. More vulnerable demographics are similar to those more vulnerable to extreme cold, mainly the elderly or very young and those living in rural communities. Due to existing socioeconomic problems and the way they intersect with race, racial and ethnic minorities are also at more of a risk than other groups. Non-English speaking citizens will need accommodations for any disseminated information. Counties need to expect and prepare for colder winters and the subsequent effects of increased extreme cold occurrences while also taking these disproportionate risk levels into consideration.

# DAM FAILURE

## CLIMATE CHANGE EFFECTS

In some regions, climate change is causing an increase in precipitation in the form of rainfall. [38] These changes in hydrological conditions are creating stress on dams that were not built to withstand such amounts of water. Increased rainfall and increased streamflow into reservoirs also creates an influx of sedimentation, which limits the functionality of the dam and degrades its performance. [39] In 2017, the American Society of Civil Engineers gave US dams a D in their last infrastructure report card. [40] As a whole, dams in the US are not engineered to withstand the effects of climate change.

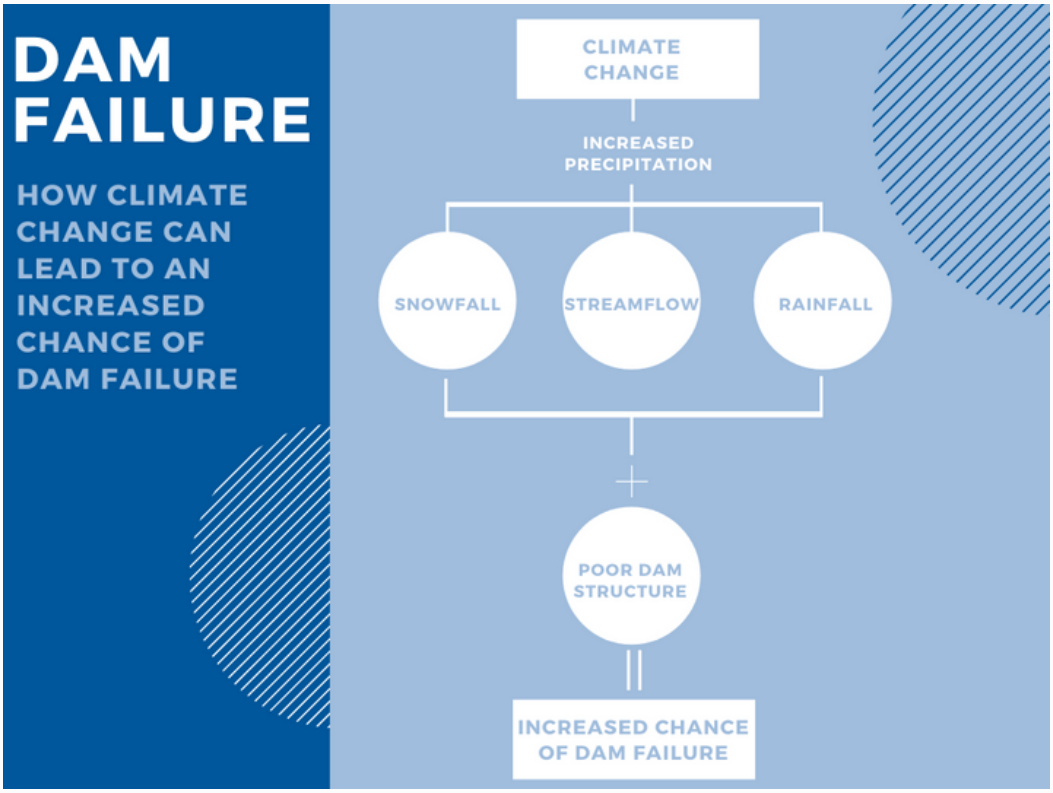


***Figure 9: How climate change can lead to an increased chance of dam failure***

# DAM FAILURE

## REGIONAL CLIMATE CHANGE DATA

*Precipitation:*

Combined data from the National Climate Assessment and the Army Corps of Engineers predicts that regions northeast, east and south of the Ohio River will experience an increase in precipitation in the form of rainfall by 40-50% by the year 2100. [41-43] The Hoosier Resilience Index also predicts an increase in the number of extreme precipitation events per decade, ranging from 6-8 more. [23]

*Dam Infrastructure:*

The American Society of Civil Engineers reported that Indiana as a total of 266 dams that classified as high hazards. The average US dam is 60 years old, meaning that most of these 266 dams are not built to withstand the effects of climate change. 50% of the state regulated dams have emergency action plans. [44]

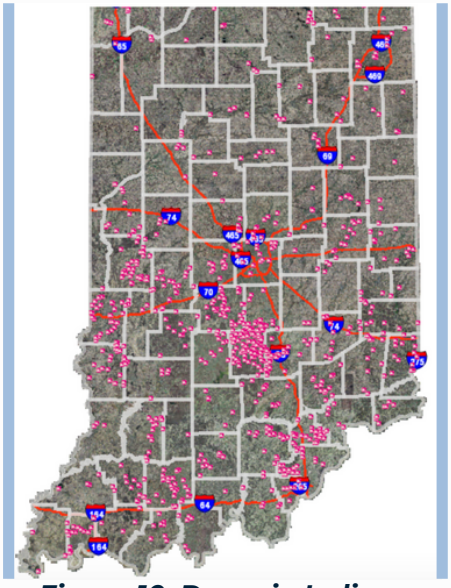

***Figure 10: Dams in Indiana***

*SOURCE: Adapted from Dams - IDNR (2020) [45]*

# DAM FAILURE

## CASCADING EFFECTS

Increased precipitation is only adding to the stress on already high hazard dams in Indiana. [44] Should these dams fail, the resulting onslaught of water could be catastrophic. The effect of each individual dam failure is specific to its location, but the populations at risk are generally those that live downstream of the dam, in areas that were developed after the dam was built. These floods can damage infrastructure, buildings, and anything else in their path.

## SOCIAL CONSEQUENCES

No specific group of people is necessarily more vulnerable to dam failure based on demographics. The more vulnerable groups are those that live in areas downstream of dams, especially those of lower income who might not have any preventative measures in place. [44] It is important that each dam have an emergency action plan on file with local officials and that the information in it is properly shared with the citizens at risk. Given that the majority of the dams in Kentucky are over fifty years old and are not prepared to withstand the effects of climate change, it is also important that they be as updated as possible. The American Society of Civil Engineers reports that 4 dams in Indiana could qualify for funding through the Water Infrastructure Improvements for the Nation Act of 2016. [46] This money would go towards repairing, removing, or rehabilitating non-federal, high-hazard potential dams in the state. Counties need to expect and prepare for potential dam failures and the subsequent effects of them while also taking these risk levels and potential funding opportunities into consideration.

# DROUGHT

## CLIMATE CHANGE EFFECTS

Scientists are uncertain on how exactly climate change will affect droughts due to inconsistencies in study methods. [47] The general consensus is that climate change may not actually cause droughts to occur more frequently, but when they do occur they will commence sooner and be more intense. [48] The changes to droughts are likely to be locational, as well.

## REGIONAL CLIMATE CHANGE DATA

The results of a 2010 study on drought were uncertain for the Kentuckiana region; depending on the level of emissions released in the future, drought could either decrease or increase in frequency in the region. [47] Another 2010 study, focused on the Midwest, found much of the same. It appears as though the increased precipitation in the region will offset the possibility of drought. [48] The effect of climate change on the intensity and duration of droughts in the region is still relatively unknown. Illinois' state climatologist, Jim Angel, thinks that the Midwest should be more worried about short flash droughts in the summer than the traditionally thought of long-term drought. [49]

Regardless of the environmental predictions, Indiana has been experiencing drought conditions more frequently in the past few years. In July and August of 2019, it was reported that there were near-drought like conditions in the state. [50] Later, in October of the same year, the US Drought Monitor recorded the Kentuckiana region as experiencing moderate-severe drought. [51]

# DROUGHT

## CASCADING EFFECTS

The main concern for how drought will affect the Kentuckiana region is the effect on water availability and agricultural practices.

- Water availability: droughts can cause water shortages, specifically to communities that rely on small lakes, small headwater streams and wells located in drought-vulnerable aquifers [52]
- Agricultural practices: crop yields suffer due to the lack of water availability farmers should expect extreme weather conditions all year-round [53] [54]
- Wildfire: droughts dry out vegetation and decrease soil moisture, leaving the perfect conditions for a wildfire, experts say that Kentucky is long overdue for a forest fire that would be notable in size and destruction [53] [55]

## SOCIAL CONSEQUENCES

People who are more vulnerable to drought are those who have less access to water, which includes those of a lower income and those living in areas that are more susceptible to droughts and their effects. People who rely on small lakes, small headwater streams, or drought-vulnerable aquifers are more at risk to drought conditions. [52] In addition to this, anyone whose income relies on agricultural practices or who relies on locally-grown food is also more vulnerable to the economic and health risks that droughts present. Due to existing socioeconomic problems and the way they intersect with race, racial and ethnic minorities are also at more of a risk than other groups. Counties need to expect and prepare for the increased frequency of droughts in the late summer and early fall and the subsequent effects of droughts while also taking these disproportionate risk levels into consideration.

# EARTHQUAKE

## CLIMATE CHANGE EFFECTS

The link between climate change and earthquakes is uncertain. They can be triggered by increased pressure on a fault line, which can be caused by increased precipitation in the form of snow or rain. Drought can also cause stress on fault lines, although this depends on the length of the drought and the alternation of drought and heavy precipitation. [54]

## REGIONAL CLIMATE CHANGE DATA

Climate change impacts on the New Madrid Seismic Zone are dependent on the level of precipitation and the occurrence of drought in the region. [54] A study conducted in 2017 also posits that "seismicity variations [of the New Madrid Seismic Zone] are the direct result of elastic stresses induced by the water load. [55]" This supports the idea that increased precipitation will add stress on the fault line, potentially increasing the frequency of earthquakes in the region.

## SOCIAL CONSEQUENCES

Earthquakes cause damage to infrastructure and are unpredictable in their occurrence. Climate change will not change this unpredictably and might even increase it. All of the region is at the same risk to earthquakes due to the unpredictability of earthquakes. Due to the fact that the occurrences of earthquakes may increase, counties should prepare for this and the subsequent effects of earthquakes.

# FLOODING

## CLIMATE CHANGE EFFECTS

Flooding is a result of more precipitation and the possibility of dam failure. Climate change is, in general, causing an increase in precipitation. The warming of the atmosphere means that it can hold more water and thus precipitation increases. This varies by location and scientists predict that the wetter areas of the world will get wetter while the dry areas will get drier. [8]

## REGIONAL CLIMATE CHANGE DATA

The National Climate Assessment reported that the Kentuckiana area had experienced a 10-15% increase in precipitation when comparing the 1991-2012 average to the 1901-1960 average and reported an expected increase of heavy precipitation of over 40% by 2100:

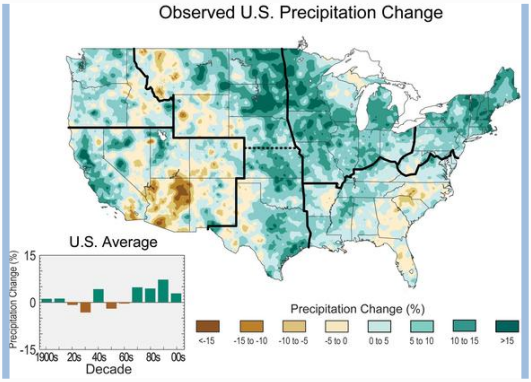


***Figure 5: Observed US precipitation change (1900s-2000s)***
*SOURCE: Adapted from NCA (2014) [8]*

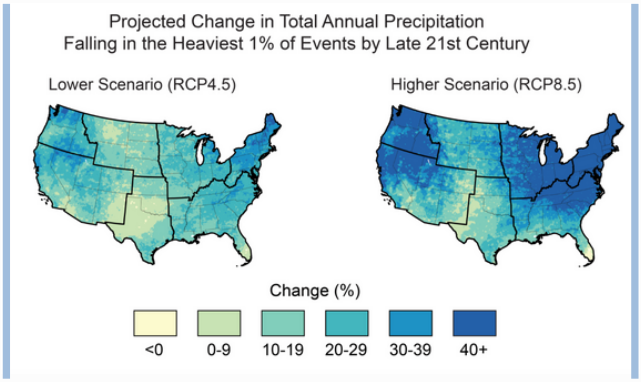


***Figure 11: Projected change in total annual precipitation falling in the heaviest 1% of events by late 21st century***
*SOURCE: Adapted from NCA (2018) [41]*

# FLOODING

These predictions are further supported by the US Army Corp's 2017 report where they said that flooding, drought and power failures are likely to become more common in both Indiana and Kentucky, along with the entire Ohio River Basin. [42] The Courier Journal spoke on the Army Corp's report, saying that "...areas northeast, east and south of the Ohio River are expected to see as much as 50 percent more precipitation, with resulting higher tributary stream flows. [43]" This increased precipitation is expected to occur in the spring. In the fall, drought is expected to cause a lowering of the water level by as much as 35%.

The Hoosier Resilience Index recorded Clark County having an average of 17 extreme precipitation events per decade between 1971 and 2000. Under medium emissions scenarios this could become 23 by 2050 and under high emissions it could become 24. Floyd County had an average of 18 extreme precipitation events per decade. Under medium emissions scenarios this could become 23 by 2050 and under high emissions it could become 25. [23]

This increase in precipitation, coupled with the number of high hazard dams in Indiana, also raises the risk of dam failure. The chance of floods occurring in the region are only increased by climate change, both floods caused by dam failure, and floods from undammed bodies of water. Studies show that the occurrence of heavy precipitation is moving more towards the spring, including snowmelt. [56] [57] This will put a strain on agricultural drainage as well as increase the chance of flooding. Some simulations predict that streamflow will increase significantly in most Midwestern rivers by the 2080s, all but guaranteeing a flood. [58] The area has already been experiencing floods most likely caused by climate change, with floods occurring in Goshen, Indiana; Hudson, Iowa; and Varney, West Virginia being a few examples from 2019.

# FLOODING

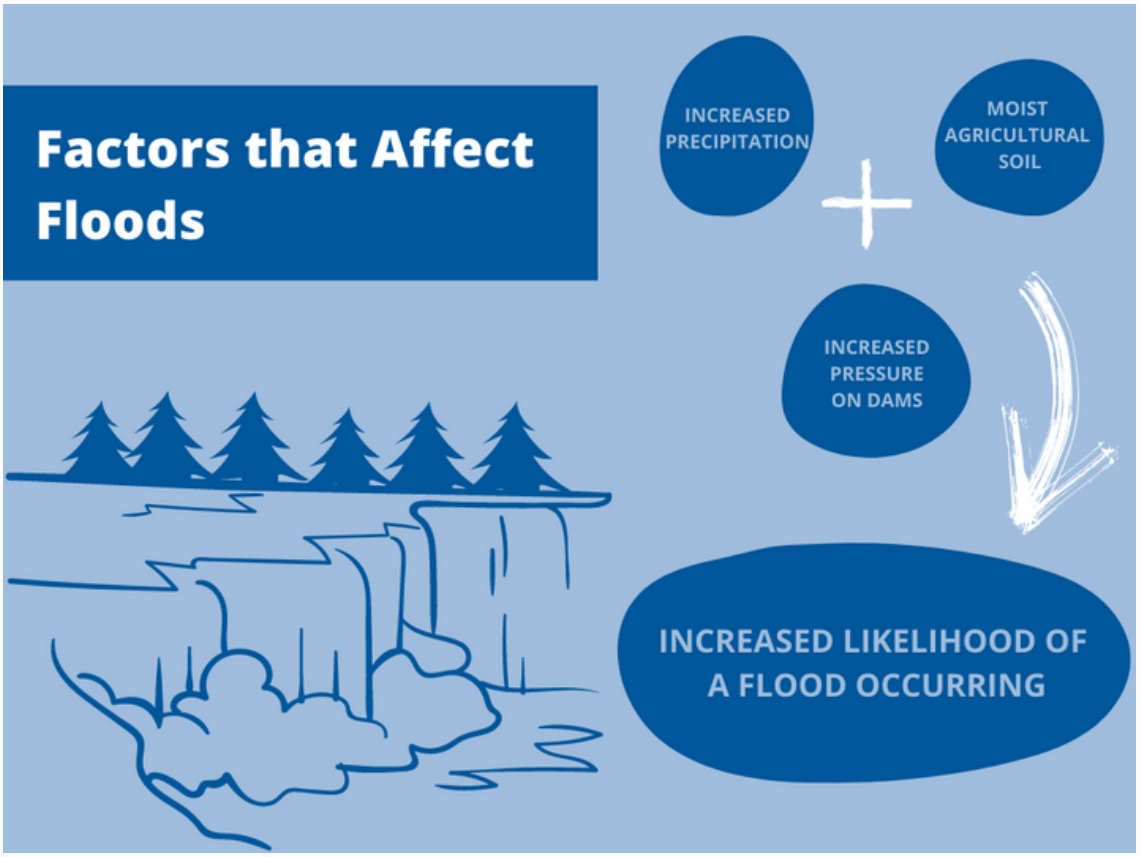


***Figure 12: Factors that affect floods***

## SOCIAL CONSEQUENCES

Individuals at the most risk are those living in flood plains and near flood sources. Those of lower income who do not have flood prevention measures in place are more vulnerable than others. In addition to this, those that depend on agricultural practices for their livelihood are also more vulnerable due to the possible destruction to farmland. Counties need to expect and prepare for the increased frequency of floods in the spring and the subsequent effects of floods.

*What*: The creation of a new floodplain that will protect nearby neighborhoods and also provide local recreational benefits. [59]

*Who*: Those who live in the neighborhoods south of Big Creek who would be affected should it flood.

BIG CREEK WETLAND AND RESTORATION AREA

*How*: A floodway will be created between the existing levee in the north and the highway in the south. This floodway will create and area for floodwaters to bypass the community. The trees removed for the floodplain will be offset by a tree canopy plan. The floodplain will also "...create sustainable wildlife areas with native vegetation, wetlands, and other natural features [59]" and provide community opportunities.

# CASE STUDY

# HAIL

## CLIMATE CHANGE EFFECTS

The effect of climate change on the occurrence of hailstorms is a combination of the effects that it will have on cold temperatures and precipitation. A weakening of the polar vortex has caused cold air to be blown toward the mid-latitudinal regions of the globe, making winters colder. [35] A decrease in the amount of ice in the Arctic, coupled with the increase of atmospheric water vapor in the area, causes there to be more moisture in the air in the Midwestern United States during the winter. [33] [34] The increased amount of moisture results in more precipitation. This evidence indicates that there will be a greater occurrence of hailstorms in some areas of the United States, but the severity of those possible storms and the size of the hail is specific to each location.

## REGIONAL CLIMATE CHANGE DATA

The midwestern United States is in the region where winter precipitation is expected to increase. [60] The climate predictions given from a 2017 study, however, predict a decrease in the amount of hailstorms in the Kentuckiana region. [61] The study specifically cited Kentucky as a state where hail is expected to melt before reaching the surface in the spring. Atmospheric scientist Robert Trapp thinks that the size of hail will increase, regardless of the increase or decrease in the frequency of hailstorms. [62] A 2019 study conducted by the University of Albany also supports this claim, showing that parts of the Midwest had a 10 to 15 day uptick in the number of days with favorable conditions for large hail between 1979 and 2017. [63] The data on the next page shows that the Kentuckiana region is one of the parts of the US with the most significant increase in large hail parameter days.

# HAIL

There is a general consensus that the size of hail will increase. The impact of climate change on the frequency of the occurrence of hailstorms is uncertain. There is not enough current research done on the matter to arrive at a sure conclusion.

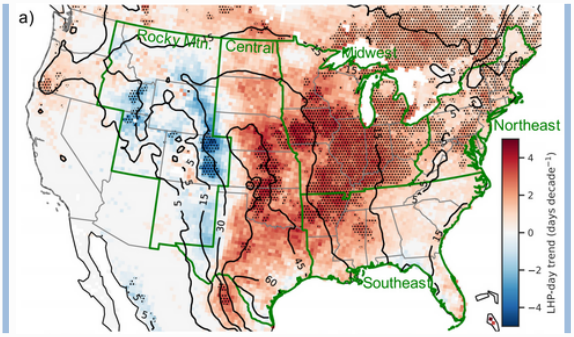


***Figure 13: Increase in favorable hail conditions in the US***
*SOURCE: Adapted from Trends in United States large hail environments and observations (2019) [63]*

## SOCIAL CONSEQUENCES

Hailstorms result in property and crop damage, resulting in substantial economic losses. Large enough hail also poses a danger to people if they are directly hit. There is no particular group or demographic that is at more risk to hail, as the occurrence of hailstorms is evenly distributed across the Kentuckiana region. Those of a lower income are more vulnerable to hail because they might lack the proper protection from hailstorms. Counties need to expect and prepare for the increased size of hail and the possible effect that climate change might have on the frequency of hailstorms in the winter and the subsequent effects of hailstorms.

# KARST/ SINKHOLE

## CLIMATE CHANGE EFFECTS

The research conducted on the relationship between climate change and karsts/sinkholes is still relatively small. The current available research indicates that climate change is increasing the occurrences of sinkholes. A 2017 study that collected evidence from the Fluvia Valley in Spain posited that sinkhole activity is enhanced during droughts. When the water table drops, there is less buoyant support and the weight on cavity roofs is increased, causing them to collapse. [64] The increase of drought as a result of climate change would thus increase the occurrence of sinkholes. A different case study, in Florida, conducted in 2018 yielded similar results. [65] Another aspect is the variability of the weather. As climate change increases the variability of rainfall and alters the hydrological process, the earth is bound to become more volatile. [66]

## REGIONAL CLIMATE CHANGE DATA

Indiana has experienced more drought and drought like conditions in the past few years. [51] Scientists expect the Midwest to experience more flash droughts. [50] This increase in the occurrence of drought will most likely then lead to an increase in the occurrence of sinkholes.

# KARST/ SINKHOLE

## SOCIAL CONSEQUENCES

There is no particular group or demographic that is at more risk to sinkholes, as the occurrence of sinkholes is dependent on which parts of the region exist karst-prone substrate. Those that live in areas where there is karst-prone substrate are more vulnerable than others. Both Clark and Floyd County have the Knobstone escarpment that run through them, which is an area full of karsts.

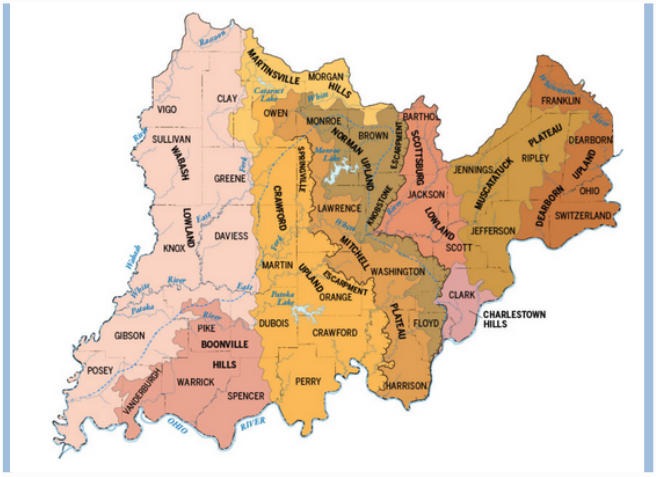


***Figure 14: Karst areas in Southern Indiana***

*SOURCE: Adapted from the Indiana Department of Transportation (2017) [67]*

The collapse of karst-prone substrate causes sinkholes, which lead to potential dam or radon leakage. In addition to the possible leakage, there is also the obvious damage done to property and land. Low income individuals are also more vulnerable to the economic losses that can result from sinkholes. Counties need to expect and prepare for the increased frequency of the occurrence of sinkholes and the subsequent effects of sinkholes, while taking into consideration where these events are most likely to occur.

# LANDSLIDE

## CLIMATE CHANGE EFFECTS

Most landslides are caused by rainfall and snowmelt disturbing slope evolution, which in turn causes fractured rock masses to become unstable. Any way in which precipitation is increased will increase the likelihood of a landslide occurring. The way that climate change is affecting the hydrological processes of the Earth will result in an increase of landslide events in some regions.

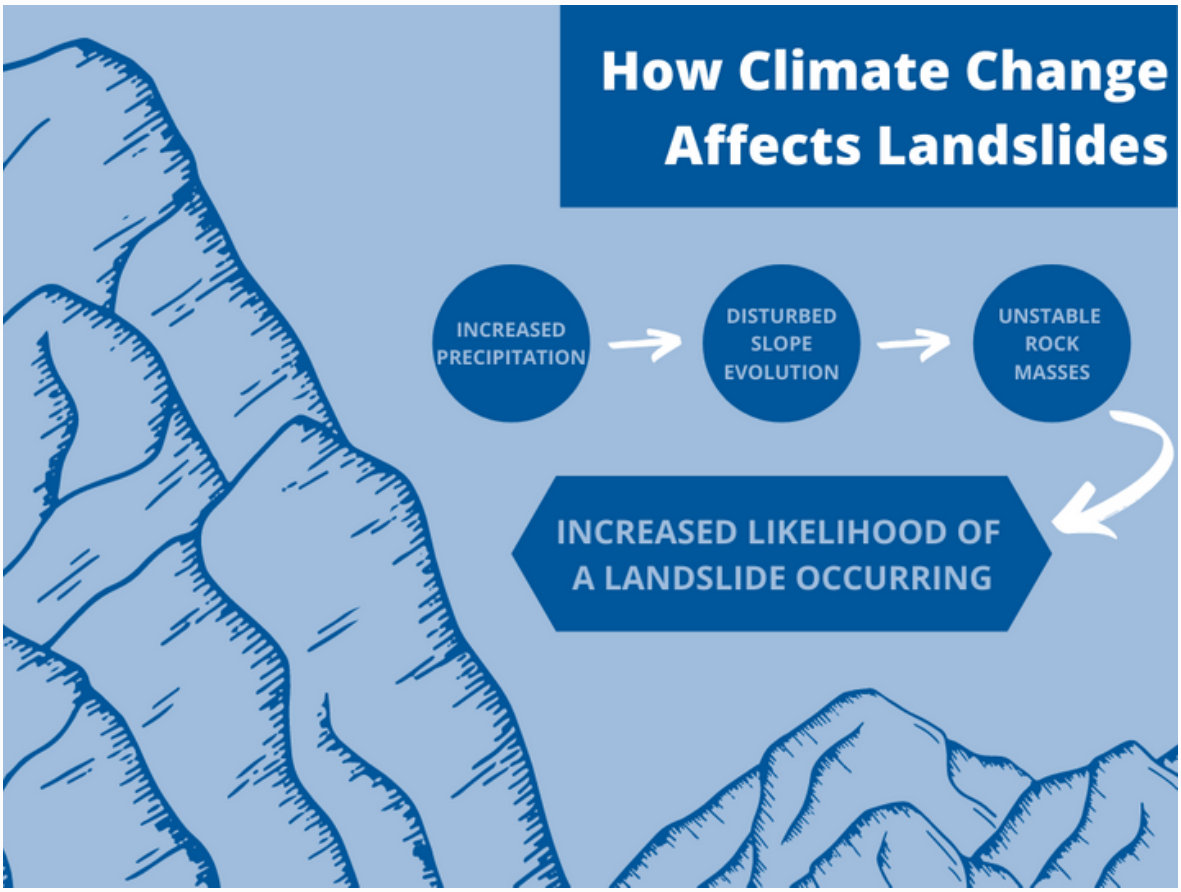


***Figure 15: How climate change affects landslides***

# LANDSLIDE

## REGIONAL CLIMATE CHANGE DATA

Combined data from the National Climate Assessment and the Army Corps of Engineers predicts that regions northeast, east and south of the Ohio River will experience an increase in precipitation in the form of rainfall by 40-50% by the year 2100. Increased rainfall in Indiana means that the likelihood of a landslide event occurring is increased.

## SOCIAL CONSEQUENCES

There is no particular group or demographic that is at more risk to landslides, as the occurrence of sinkholes is dependent on which parts of the region contain fractured rock masses.  Landslides are not common in Indiana, but they occur more frequently along the border between Indiana and Kentucky, meaning that the Kentuckiana area as a whole is more prone to landslides that other regions.

Low income individuals are also more vulnerable to the economic losses that can result from landslides. Counties need to expect and prepare for the increased occurrence of landslides and the subsequent effects of landslides, while taking into consideration where these events are most likely to occur.

# SEVERE STORM

## CLIMATE CHANGE EFFECTS

Severe storms are a combination of many different factors, such as precipitation, wind speed, and hail, which are all individually affected by climate change. Due to the higher atmospheric temperature, the air can hold more moisture and precipitation is likely to be increased in some regions. The occurrence and speed of wind is likely to rise, as well, according to a 2013 study that predicts that non-tornadic wind events will increase in frequency due to climate change. [68] The effect on hail and hailstorms is more regional specific, but the general consensus is that the size of hail will increase. The amount of research done on the effect of climate change on severe storms is limited, however, so it is uncertain exactly how that will be affected. [69]

# SEVERE STORM

## REGIONAL CLIMATE CHANGE DATA

For the Midwest, scientists expect rising precipitation to be the most concerning factor of increased severe storms, as they are mostly expected to occur in the spring. Violent winds appear to have increased for a time and now are decreasing again, but they could possible speed up again in the future as a result of climate change. [70]

The Kentuckiana region is specifically expected to have more winter and spring precipitation, so severe storms are also predicted to increase during those seasons. The effect of climate change on summer and fall events is more uncertain. Evidence on how climate change will affect the type of severe storms that produce tornadoes is also limited. [71]

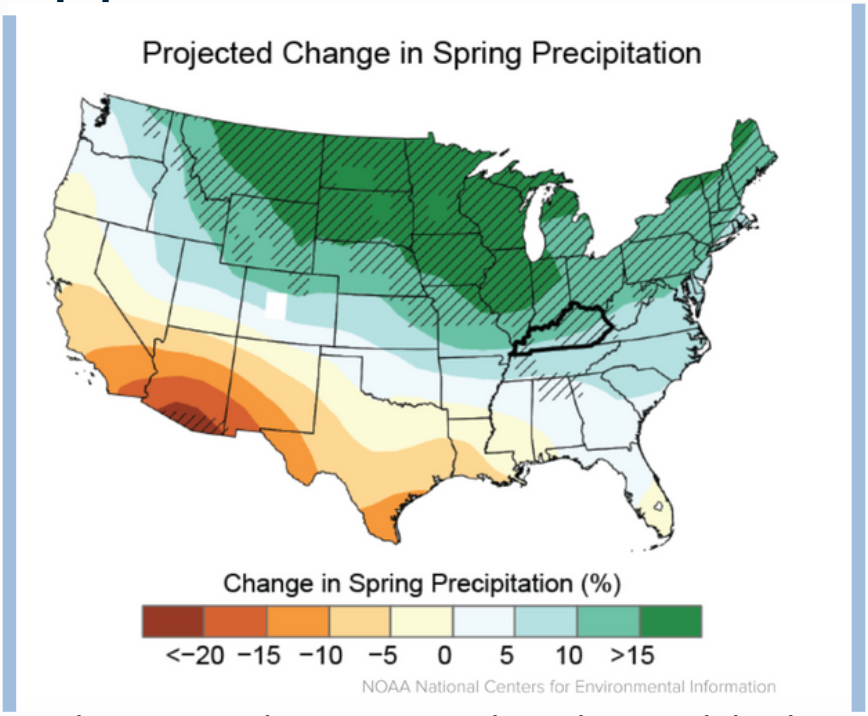


***Figure 16: Projected change in spring precipitation***

*SOURCE: Adapted from the National Center for Environmental Information (2019) [78]*

# SEVERE STORM

## CASCADING EFFECTS

The rise in the occurrence of severe storms indicate that the chance of flooding in the Kentuckiana region is also increasing.

## SOCIAL CONSEQUENCES

There is no particular group or demographic that is at more risk to severe storms, as the occurrence of these weather events is evenly distributed across the Kentuckiana region. Those of a lower income are more vulnerable to hail because they might lack the proper protection from severe storms. Floods, depending on where they occur, damage most everything in their paths. They can destroy buildings, infrastructure, and land. Hail can result in property and crop damage, as well as health risks to people directly hit. Increase wind speeds also pose a danger to citizens and property. Counties need to expect and prepare for the increased frequency of severe storms and the possible effect that climate change might have on the seasonal distribution of these storms.

## BEE BRANCH HEALTHY HOMES RESILIENCY PROJECT

***What*: Forgivable loans are being given to improve 275 housing units of different sizes. [72]**

***Who*: Low to moderate income individuals who reside on properties in the Bee Branch Watershed that have been affected by flash-flooding events in the past, leaving them with "...residual structural issues, electrical hazards, and chronic mold and mildew problems. [72]"**

***How*: The money will go toward repairs and onsite stormwater management principles, such as: foundation repairs and modification, furnace replacement, water heater replacement, basement window repairs, mold and mildew remediation, lead paint and asbestos remediation, sidewalk improvements, sump pump repair/installation, and property drainage improvements**

# CASE STUDY

# SEVERE WINTER STORM

## CLIMATE CHANGE EFFECTS

The overall increase in global atmospheric temperature means that the air is increasingly able to hold moisture. This moisture will fall in some form of precipitation, most commonly as rain or snow, depending on the season. [73] Although some regions may get colder or experience a higher frequency of extreme cold events, they will not experience an increase in precipitation as snow. This depends on the region and its specific characteristics.

## REGIONAL CLIMATE CHANGE DATA

The lower Midwest and the South have experienced a decrease in the amount of snowfall during the last century. The temperatures in the Midwest have increased on average during the winter, but the occurrence of extreme cold events might increase. The 2019 cold front that swept through the region shows that the fragmentation of the polar vortex might also cause colder weather, although this may not occur every year. This leaves the effect of climate change on severe winter storms in Indiana uncertain. There is an expected increase in precipitation in the winter, but this is likely to be in the form of rain, not snow. The expected and observed increase in wind chills is also a factor, as increased wind speeds would lead to more storms. [74]

# TORNADO

## CLIMATE CHANGE EFFECTS

The relationship between tornadoes and climate change is under-researched and, thus, fairly uncertain. A 2016 study found that the annual number of days on which tornadoes may occur has been increasing, along with an increase in the annual mean and variance of the number of tornadoes per outbreak. [75]

These observed changes could not, however, be linked to climate change. It has also been recorded that Tornado Alley, the region where tornadoes occur most frequently in the US, is shifting eastward. By 2019, scientists had acknowledged a correlation between this shift and the warming of the Earth, but there has been no clear science that establishes causation. [76] It has hard for scientists to study tornadoes due to their relatively small size in comparison to other extreme weather events and the shortness of their duration. The formation of tornadoes is impacted by the amount of moisture in the air, and climate change is increasing that, but right now there is not enough research done to speak definitively on the topic. [77]

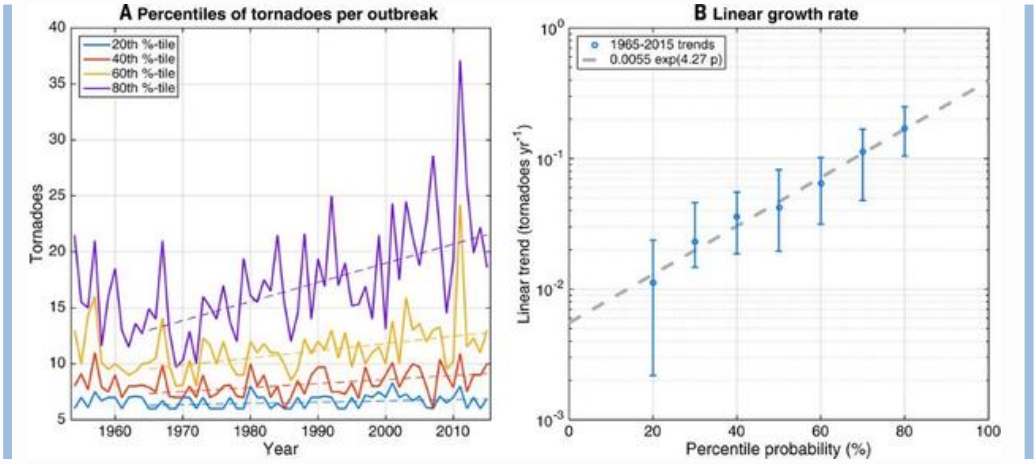


***Figure 17: Tornadoes per outbreak (1950s-2010s)***

*SOURCE: Adapted from More tornadoes in the most extreme U.S. tornado outbreaks (2016) [75]*

# TORNADO

## REGIONAL CLIMATE CHANGE DATA

Due to the uncertainty of how climate change is affecting tornadoes it is impossible to know how this will or will not impact the Midwest and Indiana specifically. It is known that tornadoes and tornado outbreaks are occurring more frequently in the region, as Tornado Alley shifts east, but there is no way to know at the present if this is as a result of climate change. [78]

## SOCIAL CONSEQUENCES

There is no particular group or demographic that is at more risk to tornadoes, as the occurrence of tornadoes is evenly distributed across the Kentuckiana region. Those of a lower income are more vulnerable to the effects of tornadoes because they might lack the proper protection from tornadoes. Due to the uncertainty of the science on the relationship between climate change and tornadoes, there is no specific recommendation on how to deal with this for each county other than to keep in mind the shift of Tornado Alley eastward.

# WILDFIRE/ FOREST FIRE

## CLIMATE CHANGE EFFECTS

The occurrence and frequency of wildfires is influenced by the occurrence and frequency of both extreme heat and drought. The rising of the average global temperature is increasing the intensity and duration at which droughts occur, meaning that there are longer periods of time where the conditions for wildfires are optimal. [48] Dry vegetation, caused by heat and lack of precipitation, fuels wildfires and forest fires, prolonging their duration and impact. [79]

## REGIONAL CLIMATE CHANGE EFFECTS

Indiana has experienced more drought and drought like conditions in the past few years. Scientists expect the Midwest to experience more flash droughts. The probability of a forest fire occurring is increasing, as well.

# WILDFIRE/ FOREST FIRE

## SOCIAL CONSEQUENCES

Wildfires pose a threat to land and property, although they typically occur in non-residential areas and can be contained before they spread to residential areas. Agricultural land and forests are likely to be more affected, causing economic loss to those who depend on local agriculture for income. [49] Fires also add smoke to the air and this reduces the air quality having negative impacts on public health. There is no particular group or demographic that is at more risk to wildfires or forest fires, as the occurrence of these fires is dependent on vegetation in the Kentuckiana region. Those that depend on agricultural land for their income are more vulnerable to the impacts of wildfires, as are those of low income who are less likely to be prepared for such an event. Counties need to expect and prepare for the increased frequency of the occurrence of wildfires and forest fires and the subsequent effects of these firs, while taking into consideration where these events are most likely to occur.

# References


1. Ritchie, H., & Roser, M. (2017, October 02). Fossil Fuels. Retrieved July 23, 2020, from https://ourworldindata.org/fossil-fuels
2. Smil, V. (2017). Energy transitions: Global and national perspectives. Santa Barbara, CA: Praeger, an imprint of ABC-CLIO, LLC.
3. Sources of Greenhouse Gas Emissions. (2020, April 11). Retrieved July 23, 2020, from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
4. What is the greenhouse effect? – Climate Change: Vital Signs of the Planet. (n.d.). Retrieved July 23, 2020, from https://climate.nasa.gov/faq/19/what-is-the-greenhouse-effect/
5. Climate Change Indicators: Atmospheric Concentrations of Greenhouse Gases. (2020, June 29). Retrieved July 23, 2020, from https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases
6. Strong, Healthy & Just: Springfield Climate Action & Resilience Plan. (n.d.). Retrieved July 28, 2020, from http://www.pvpc.org/projects/strong-healthy-just-springfield-climate-action-resilience-plan
7. Explainer: What climate models tell us about future rainfall. (2018, January 18). Retrieved July 23, 2020, from https://www.carbonbrief.org/explainer-what-climate-models-tell-us-about-future-rainfall
8. Walsh, J., & Wuebbles, D. (2014). Precipitation Change. Retrieved July 23, 2020, from https://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change
9. Wibig, Joanna. (2016). Symptoms and Driving Factors of Contemporary Earth Warming and Projections for the Future. Papers on Global Change IGBP. 23. 10.1515/igbp-2016-0004.
10. Harvey, C. (2019, November 19). The World's Winds Are Speeding Up. Retrieved July 23, 2020, from https://www.scientificamerican.com/article/the-worlds-winds-are-speeding-up/
11. Zeng, Z., Ziegler, A. D., Searchinger, T., Yang, L., Chen, A., Ju, K., . . . Wood, E. F. (2019). A reversal in global terrestrial stilling and its implications for wind energy production. *Nature Climate Change, 9*(12), 979-985. doi:10.1038/s41558-019-0622-6
12. Climate Change Indicators: Ocean Heat. (2016, December 17). Retrieved July 23, 2020, from https://www.epa.gov/climate-indicators/climate-change-indicators-ocean-heat
13. Ocean acidification. (n.d.). Retrieved July 23, 2020, from https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification
14. Observed U.S. Temperature Change. (2014). Retrieved July 28, 2020, from https://nca2014.globalchange.gov/highlights/report-findings/our-changing-climate/graphics/observed-us-temperature-change
15. Rowlatt, J. (2019, January 31). Polar vortex: What role does climate change play? Retrieved July 23, 2020, from https://www.bbc.com/news/world-us-canada-47078054
16. Climate Change: Global Sea Level: NOAA Climate. (2019, November 19). Retrieved July 23, 2020, from https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level
17. Overview: Weather, Global Warming and Climate Change. (2019, August 28). Retrieved July 23, 2020, from https://climate.nasa.gov/resources/global-warming-vs-climate-change/
18. Yes, climate change is making heat waves more common. (2020, April 04). Retrieved July 23, 2020, from https://www.yaleclimateconnections.org/2019/06/heat-waves-and-climate-change-is-there-a-connection/
19. CLIMATE CHANGE and EXTREME HEAT What You Can Do to Prepare. (2016, October). Retrieved July 23, 2020, from http://www.epa.gov/climatechange/extreme-heat-guidebook
20. Extreme Weather and Climate Change: Understanding the Link and Managing the Risk. (2019, August 13). Retrieved July 23, 2020, from https://www.c2es.org/document/extreme-weather-and-climate-change-understanding-the-link-and-managing-the-risk/
21. Angel, J. R., Swanson, C., Boustead, B. M., Conlon, K., Hall, K. R., Jorns, J. L., . . . Todey, D. (2018). Chapter 21 : Midwest. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II. doi:10.7930/nca4.2018.ch21
22. United States, Environmental Protection Agency. (2016). *What Climate Change Means for Indiana* (pp. 1-2).
23. Hoosier Resilience Index. (n.d.). Retrieved July 24, 2020, from https://hri.eri.iu.edu/
24. Pryor, S. C., Scavia, D., Downer, C., Gaden, M., Iverson, L., Nordstrom, R., . . . Robertson, G. P. (2014). Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment. doi:10.7930/j0j1012n
25. Ouhamdouch, S., Bahir, M., Souhel, A., & Paula, C. (2016). Vulnerability and Impact of Climate Change Processes on Water Resource in Semi-Arid Areas: In Essaouira Basin (Morocco). *Energy, Transportation and Global Warming Green Energy and Technology,* 719-736. doi:10.1007/978-3-319-30127-3_53
26. The Impact of Weather and Climate Extremes on Air and Water Quality. (n.d.). Retrieved July 24, 2020, from https://www.ncdc.noaa.gov/news/impact-weather-and-climate-extremes-air-and-water-quality
27. Wilhelmi, O. V., & Hayden, M. H. (2010). Connecting people and place: A new framework for reducing urban vulnerability to extreme heat. *Environmental Research Letters, 5*(1), 014021. doi:10.1088/1748-9326/5/1/014021
28. Hansen, A., Bi, L., Saniotis, A., & Nitschke, M. (2013). Vulnerability to extreme heat and climate change: Is ethnicity a factor? *Global Health Action, 6*(1), 21364. doi:10.3402/gha.v6i0.21364
29. Warning Signs and Symptoms of Heat-Related Illness. (2017, September 01). Retrieved July 24, 2020, from https://www.cdc.gov/disasters/extremeheat/warning.html
30. Correction for Liu et al., Impact of declining Arctic sea ice on winter snowfall. (2012). *Proceedings of the National Academy of Sciences, 109*(17), 6781-6783. doi:10.1073/pnas.1204582109
31. Xie, Z., Black, R. X., & Deng, Y. (2017). The structure and large-scale organization of extreme cold waves over the conterminous United States. *Climate Dynamics, 49*(11-12), 4075-4088. doi:10.1007/s00382-017-3564-6
32. Leiserowitz, A., Maibach, E. W., Roser-Renouf, C., Feinberg, G., & Howe, P. (2013). Extreme Weather and Climate Change in the American Mind, April 2013. *SSRN Electronic Journal*. doi:10.2139/ssrn.2292599
33. Yoksoulian, L. (2019, February 12). Are global warming, recent Midwest cold snap related? Retrieved July 24, 2020, from https://news.illinois.edu/view/6367/750060
34. Rainey, J. (2019, January 30). Extreme cold gripping Midwest does not debunk global warming, experts say. Retrieved July 24, 2020, from https://www.nbcnews.com/science/environment/extreme-cold-gripping-midwest-does-not-debunk-global-warming-experts-n964366
35. Novelly, T. (2019, January 29). Will the polar vortex affect Louisville? Here's what to know. Retrieved July 24, 2020, from https://www.courier-journal.com/story/weather/local/winter/2019/01/28/polar-vortex-2019-affect-louisville-kentucky/2702488002/
36. Neighmond, P. (2019, January 31). Medical Effects Of Extreme Cold: Why It Hurts And How To Stay Safe. Retrieved July 24, 2020, from https://www.npr.org/sections/health-shots/2019/01/30/690170470/medical-effects-of-extreme-cold-why-it-hurts-and-how-to-stay-safe
37. Conlon, K. C., Rajkovich, N. B., White-Newsome, J., Larsen, L., & O'Neill, M. S. (2011). Preventing Cold-Related Morbidity And Mortality In A Changing Climate. *ISEE Conference Abstracts, 2011*(1). doi:10.1289/isee.2011.01641
38. Lee, B., & You, G. (2013, March 20). An assessment of long-term overtopping risk and optimal termination time of dam under climate change. Retrieved July 24, 2020, from https://www.sciencedirect.com/science/article/pii/S0301479713001138?casa_token=PLqZxb118WcAAAAA%3ASgoAODu4COtOLpz40MMJuWCZWcd3l1bKbFiqvs-5GeC2cEdc40BUM5mHnExGE6Wp4s2THmnWeg
39. Fountain, H. (2020, May 21). 'Expect More': Climate Change Raises Risk of Dam Failures. Retrieved July 24, 2020, from https://www.nytimes.com/2020/05/21/climate/dam-failure-michigan-climate-change.html
40. Ironcore. (2017). Dams. Retrieved July 24, 2020, from https://www.infrastructurereportcard.org/cat-item/dams/
41. Hayhoe, K., Wuebbles, D. J., Easterling, D. R., Fahey, D. W., Doherty, S., Kossin, J. P., . . . Wehner, M. F. (2018). Chapter 2 : Our Changing Climate. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II. doi:10.7930/nca4.2018.ch2
42. United States, US Army Corps of Engineers, Institute for Water Resources. (2017). *Ohio River Basin: Formulating climate change mitigation/adaptation strategies through regional collaboration with the ORB Alliance*. US Army Corps of Engineers. Retrieved July 24, 2020, from https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/5108/.
43. Bruggers, J. (2017, December 01). Army engineers warn of brutal future for Ohio River region from climate change. Retrieved July 24, 2020, from https://www.courier-journal.com/story/tech/science/environment/2017/11/30/ohio-river-valley-climate-change-report/831135001/
44. Ironcore. (2020, July 24). Indiana. Retrieved August 07, 2020, from https://www.infrastructurereportcard.org/state-item/indiana/
45. Dams - IDNR (2020). (2020). Retrieved August 07, 2020, from https://maps.indiana.edu/previewMaps/Infrastructure/Dams_IDNR.html
46. Ironcore. (n.d.). Funding & Future Need. Retrieved July 24, 2020, from https://www.infrastructurereportcard.org/dams/funding-future-need/
47. Strzepek, K., Yohe, G., Neumann, J., & Boehlert, B. (2010). Characterizing changes in drought risk for the United States from climate change. *Environmental Research Letters, 5*(4), 044012. doi:10.1088/1748-9326/5/4/044012

48.Mishra, V., Cherkauer, K. A., & Shukla, S. (2010). Assessment of Drought due to Historic Climate Variability and Projected Future Climate Change in the Midwestern United States. *Journal of Hydrometeorology, 11*(1), 46-68. doi: 10.1175/2009jhm1156.1
49.Wbur. (2018, November 28). Midwest Farmers Will Bear The Brunt Of Climate Change, Federal Report Says. Retrieved July 24, 2020, from https://www.wbur.org/hereandnow/2018/11/28/climate-change-midwest-farmers
50.By:. (2019, August 13). Near-drought conditions continue in parts of central Indiana - WISH-TV: Indianapolis News: Indiana Weather: Indiana Traffic. Retrieved August 07, 2020, from https://www.wishtv.com/news/near-drought-conditions-continue-in-parts-of-central-indiana/
51.Maps. (n.d.). Retrieved August 07, 2020, from https://droughtmonitor.unl.edu/Maps/MapArchive.aspx
52.Lobell, D. B., Roberts, M. J., Schlenker, W., Braun, N., Little, B. B., Rejesus, R. M., & Hammer, G. L. (2014). Greater Sensitivity to Drought Accompanies Maize Yield Increase in the U.S. Midwest. *Science, 344*(6183), 516-519. doi:10.1126/science.1251423
53.As climate change bites in America's midwest, farmers are desperate to ring the alarm. (2018, December 12). Retrieved July 24, 2020, from https://www.theguardian.com/us-news/2018/dec/12/as-climate-change-bites-in-americas-midwest-farmers-are-desperate-to-ring-the-alarm
54.Can Climate Affect Earthquakes, Or Are the Connections Shaky? – Climate Change: Vital Signs of the Planet. (2019, October 29). Retrieved July 24, 2020, from https://climate.nasa.gov/news/2926/can-climate-affect-earthquakes-or-are-the-connections-shaky/
55.Craig, T. J., Chanard, K., & Calais, E. (2017). Hydrologically-driven crustal stresses and seismicity in the New Madrid Seismic Zone. *Nature Communications, 8*(1). doi:10.1038/s41467-017-01696-w
56.Edwards, B. (2019, November 11). Galvanized by disaster. Retrieved July 24, 2020, from https://www.indianaenvironmentalreporter.org/posts/galvanized-by-disaster
57.Did climate change cause the flooding in the Midwest and Plains? (2019, April 02). Retrieved July 24, 2020, from https://www.yaleclimateconnections.org/2019/04/did-climate-change-cause-midwest-flooding/
58.Bruggers, J. (2019, November 27). Climate Change In Kentucky: 'One Home Came Floating Down The River'. Retrieved July 24, 2020, from https://www.leoweekly.com/2019/11/climate-change-kentucky-one-home-came-floating-river/
59.Big Creek Millington. (n.d.). Retrieved July 28, 2020, from https://resilientshelby.com/overview/resilience-activities/big-creek-millington/
60.Hayhoe, K., VanDorn, J., Naik, V., & Wuebbles, D. (2019). Climate Change in the Midwest Projections of Future Temperature and Precipitation. *Climate Change in the Midwest Projections of Future Temperature and Precipitation*. Retrieved July 24, 2020, from https://www.ucsusa.org/sites/default/files/2019-09/midwest-climate-impacts.pdf
61.Brimelow, J. C., Burrows, W. R., & Hanesiak, J. M. (2017). The changing hail threat over North America in response to anthropogenic climate change. *Nature Climate Change, 7*(7), 516-522. doi:10.1038/nclimate3321
62.Biello, D. (2007, December 05). Thunder, Hail, Fire: What Does Climate Change Mean for the U.S.? Retrieved July 24, 2020, from https://www.scientificamerican.com/article/thunder-hail-fire-what-does-climate-change-mean-for-us/
63.Tang, B. H., Gensini, V. A., & Homeyer, C. R. (2019). Trends in United States large hail environments and observations. *Npj Climate and Atmospheric Science, 2*(1). doi:10.1038/s41612-019-0103-7
64.Linares, R., Roqué, C., Gutiérrez, F., Zarroca, M., Carbonel, D., Bach, J., & Fabregat, I. (2017). The impact of droughts and climate change on sinkhole occurrence. A case study from the evaporite karst of the Fluvia Valley, NE Spain. *Science of The Total Environment, 579*, 345-358. doi:10.1016/j.scitotenv.2016.11.091
65.Meng, Y., & Jia, L. (2018). Global warming causes sinkhole collapse – Case study in Florida, USA. doi:10.5194/nhess-2018-18
66.Mathiesen, K. (2014, February 20). Are humans causing more sinkholes? Retrieved July 24, 2020, from https://www.theguardian.com/environment/2014/feb/20/are-humans-causing-more-sinkholes Allen, J. T. (2018). Climate Change and Severe Thunderstorms. *Oxford Research Encyclopedia of Climate Science*. doi:10.1093/acrefore/9780190228620.013.62
67.*Karst Geological Resources and INDOT Construction* [PDF]. (2017, November 21). Indiana Department of Transportation.
68.Allen, J. T. (2018). Climate Change and Severe Thunderstorms. *Oxford Research Encyclopedia of Climate Science*. doi:10.1093/acrefore/9780190228620.013.62
69.Wuebbles, D. J., Kunkel, K., Wehner, M., & Zobel, Z. (2014). Severe Weather in United States Under a Changing Climate. *Eos, Transactions American Geophysical Union, 95*(18), 149-150. doi:10.1002/2014eo180001
70.Molteni, M. (n.d.). Climate Change Is Bringing Epic Flooding to the Midwest. Retrieved July 24, 2020, from https://www.wired.com/story/for-the-midwest-epic-flooding-is-the-face-of-climate-change/
71.Velzer, R. (2019, February 07). Ky. Won't Escape Human-Driven Climate Change, Federal Report Warns. Retrieved July 24, 2020, from https://wfpl.org/kentucky-wont-escape-human-driven-climate-change-federal-report-warns/
72.Bee Branch Healthy Homes Resiliency Program . (n.d.). Retrieved July 28, 2020, from https://www.cityofdubuque.org/2339/Bee-Branch-Healthy-Homes-Resiliency-Prog
73.Winter Storms. (n.d.). Retrieved July 24, 2020, from https://www.climatecommunication.org/new/features/extreme-weather/winter-storms/
74.'How is climate change affecting winter in my region?' " Yale Climate Connections. (2020, March 03). Retrieved July 24, 2020, from https://www.yaleclimateconnections.org/2020/02/how-is-climate-change-affecting-winter-in-my-region/
75.Tippett, M. K., Lepore, C., & Cohen, J. E. (2016). More tornadoes in the most extreme U.S. tornado outbreaks. *Science, 354*(6318), 1419-1423. doi:10.1126/science.aah7393
76.Akpan, N. (2019, March 05). Is climate change making U.S. tornadoes worse? Retrieved July 24, 2020, from https://www.pbs.org/newshour/science/is-climate-change-making-u-s-tornadoes-worse
77.National Geographic Society. (2019, September 17). Tornadoes and Climate Change. Retrieved July 24, 2020, from https://www.nationalgeographic.org/article/tornadoes-and-climate-change/
78.Strader, S. M., Ashley, W. S., Pingel, T. J., & Krmenec, A. J. (2017). Observed and Projected Changes in United States Tornado Exposure. *Weather, Climate, and Society, 9*(2), 109-123. doi:10.1175/wcas-d-16-0041.1
79.The Connection Between Climate Change and Wildfires. (n.d.). Retrieved July 24, 2020, from https://www.ucsusa.org/resources/climate-change-and-wildfires