

Shelter from the Storm

How Wetlands Protect Our Communities from Flooding

Spring 2015



Acknowledgments

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America's Wetlands: Nature's Flood Control

In the summer of 1993, residents of the American Midwest experienced the most costly flood in the history of the United States.¹ By the end of that summer, the Mississippi River in St. Louis was 20 feet above flood stage, and levee breaks in Illinois led to the inundation of thousands of acres of land.² The flood claimed 48 lives and caused nearly \$20 billion in damage.³

In the aftermath of the flood, numerous studies were conducted to examine what had gone wrong and what could be done to prevent another flood of this scale. The conclusion: the decades spent building levees and dams to control the Mississippi River had debilitated our first line of defense against flooding – wetlands.⁴

Scientists now know that wetlands are critical to the global water cycle.⁵ They are the kidneys of our national water system, cleaning out sediment and water pollution. They are home to numerous plant and animal species, supporting our nation's biodiversity. They are also able to store vast amounts of water and are thus an important tool to protect America's cities and towns from flooding.

Wetlands Reduce the Risk of Flooding and Mitigate Its Worst Impacts

Wetlands can be found throughout the United States.⁶ While there are many types of wetlands, and they differ by geographic location, by soil permeability and by the amount of water they contain at any given point in time, most share one common characteristic: they occur in low-lying areas near higher ground. The ability of wetlands to hold large amounts of water enables them to serve as a key protection against

flooding.⁷ During times of heavy precipitation, wetlands act as a sponge – slowing the velocity of runoff and retaining excess water, thereby reducing the danger of flooding.⁸ Once captured by a wetland, excess water evaporates, settles into the soil to replenish groundwater, or is slowly released over time.⁹

During the 1993 Mississippi River Flood, the volume of water that brought the river above its normal levels at St. Louis could have been held by 13 million acres of wetlands – half of the wetlands acreage that has been destroyed in the Upper Mississippi Basin since 1780.¹⁰

The flood protection that wetlands provide is valuable. According to one study, inland wetlands in the United States provide over \$237 billion in water flow regulation services annually.¹¹

Flooding Is a Massive Problem that May Get Worse with Global Warming

Floods are the most common natural disaster in the United States, according to the Federal Emergency Management Agency (FEMA).¹² Over the past 30 years, floods have caused an average of \$8.2 billion of damage and 89 fatalities per year.¹³ Scientists predict that the damage caused by floods will only increase in the years to come, to over \$1 trillion per year by 2050.¹⁴

As global warming continues to progress, the extreme rain events that often trigger flooding are likely to become more common. Warmer air is able to hold more water vapor, leading to higher levels of precipitation during rain and snow storms.¹⁵

Indeed, extreme rain and snow events have already become more than 30 percent more common since the first part of the 20th

century, with the greatest changes in the Northeast and the Midwest.¹⁶ Greater changes are in store for the decades ahead.



The 1993 Mississippi River Flood devastated numerous communities along the river's route, including St. Charles, MO, pictured here. (Credit: USGS)

America's Wetlands Are in Danger

The U.S. is left with only 53 percent of the more than 221 million acres of wetlands that dotted colonial America.¹⁷ For many years, wetlands were seen as obstacles to development, leading to decades of policies encouraging the building of wetlands-destroying levees, the filling of wetlands in order to build cities and shopping malls, and the draining of wetlands for agricultural purposes.¹⁸

Passage of the federal Clean Water Act in 1972 was an important step in stemming the loss of wetlands. The law established the goal of making all of the country's waterways safe for fishing, swimming and

supplying drinking water, with wetlands protection a key strategy in achieving that goal.¹⁹

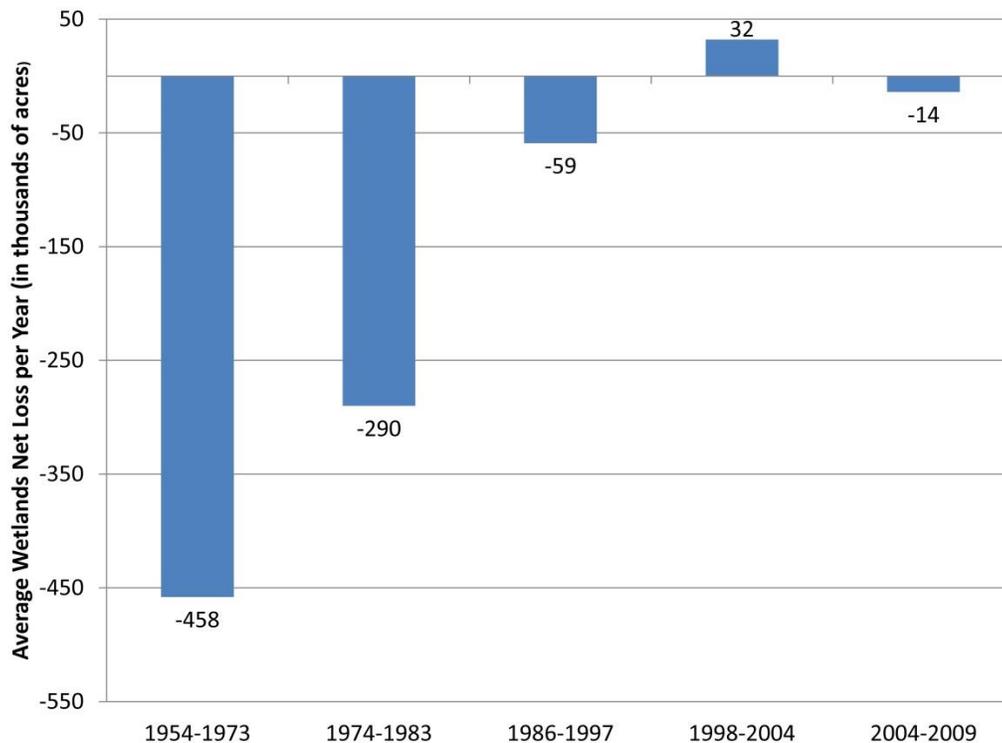
The Clean Water Act reduces wetland loss by requiring permits for the filling or draining of wetlands.²⁰ Those proposing to fill wetlands must show that they have taken steps to avoid wetlands impact and that they will provide compensation for unavoidable impacts.²¹

As a result of the act, the loss of wetlands slowed dramatically. According to the U.S. Fish and Wildlife Service, in the 20 years prior to enactment of the Clean Water Act,

wetlands were decreasing at an average rate of 458,000 acres per year.²² After the Clean Water Act was enacted, the rate of wetlands

loss slowed, and there was even an increase in wetlands acreage from 1998 to 2004.²³

Figure 1: The Rate of Wetlands Loss Before and After the Clean Water Act (1954-2009)



Clean Water Act Loophole Threatens Wetlands

The Clean Water Act's ability to safeguard wetlands is threatened, however, by a loophole in the law that could leave many wetlands outside of the law's protection.²⁴

In 2006, the Supreme Court, in a case brought by a Michigan developer who filled wetlands without a permit, issued a decision that left in doubt Clean Water Act protection for 20 million acres our nation's wetlands – leaving them vulnerable to being

damaged or destroyed.²⁵ Indeed, the 2004-2009 timeframe saw a return to annual national wetland loss after the improvements of the prior six years. (See Figure 1.)

Protect Our Communities from Worsening Flood Risks: Restore the Clean Water Act

America's wetlands protect our homes and businesses from damaging flooding while helping to clean our water and provide habitat for wildlife. To safeguard our wetlands, we need to ensure that they enjoy the full protection of the federal Clean Water Act.

In April 2014, the U.S. Army Corps of Engineers and the Environmental Protection Agency (EPA) proposed a rule that would restore full Clean Water Act protections to thousands of wetlands (as well as streams) across the country. More than 800,000 Americans have indicated their support for this clean water rule – including hundreds of mayors and other local community officials.

To protect our communities from flooding, the Obama administration should finalize the proposed clean water rule as soon possible so that

our remaining wetlands are once again protected.

This rule will also help protect our communities by protecting thousands of headwaters and intermittent streams that feed drinking water sources for one in every three Americans.

In a warming world, the risk of flooding, and its impact on communities, is likely to grow. As the following pages detail for 15 states across the country, wetlands are our first line of defense against that threat, and federal, state and local officials should do everything in their power to protect them for the future. In addition, officials should enact policies to curb global warming pollution to reduce the risk of extreme flooding in the years ahead.

America's Wetlands: Critical Protection Against Flooding

Wetlands are more than just scenic parts of America's natural landscape. They are also home to wildlife and perform many vital functions that protect the health of our waterways and communities. By trapping sediment and filtering excess nutrients and pollutants out of the water that flows through them, wetlands support water quality.

Of crucial importance for our towns and cities, wetlands also offer flood protection by absorbing large amounts of water that may fall during a storm before releasing it slowly into the environment. An acre of wetland one foot deep can hold approximately 330,000 gallons of water.²⁶ This can reduce flood peaks and slow water flow.²⁷ Even isolated wetlands can help by reducing storm water runoff that might contribute to local flooding.²⁸ All told, the nation's inland wetlands provide over \$237 billion worth of water flow regulation annually.²⁹

The Clean Water Act is the nation's most important tool for safeguarding wetlands – protecting our communities from flooding

and preserving the quality of our water. Since its enactment, the Clean Water Act has succeeded in reducing the rate of wetlands loss nationwide. In fact, the rate of wetlands loss slowed after the law was passed and wetland acreage increased modestly between 1998 and 2004.³⁰ However, a recently exposed loophole in the law has cast doubt over the Clean Water Act's reach and puts millions of acres of wetlands at risk of destruction. The Environmental Protection Agency (EPA) has proposed a rule that would close this loophole – a step that would be the biggest victory for clean water in more than a decade.

The following section describes the importance of wetlands as protection against flooding in 15 states. To protect wetlands in those states and across America, the EPA must finalize its proposed Clean Water Act rule this year.

Colorado

According to data from the National Wetlands Inventory, Colorado boasts approximately 1 million acres of freshwater wetlands statewide.³¹ Approximately 75,000 acres of the state's freshwater wetlands lie in the 100-year-flood zones for which flood hazard data are available from FEMA.³² (See Table 1.)

In Boulder County, the scene of a once-in-a-thousand-years storm and associated major flooding in September 2013, there are approximately 10,000 acres of freshwater wetlands, of which approximately 2,600 acres are located in 100-year-flood zones. (See Figure 2.) Together, these wetlands are capable of holding approximately 3.4 billion gallons of water.³³

Boulder County's Dramatic September 2013 Floods

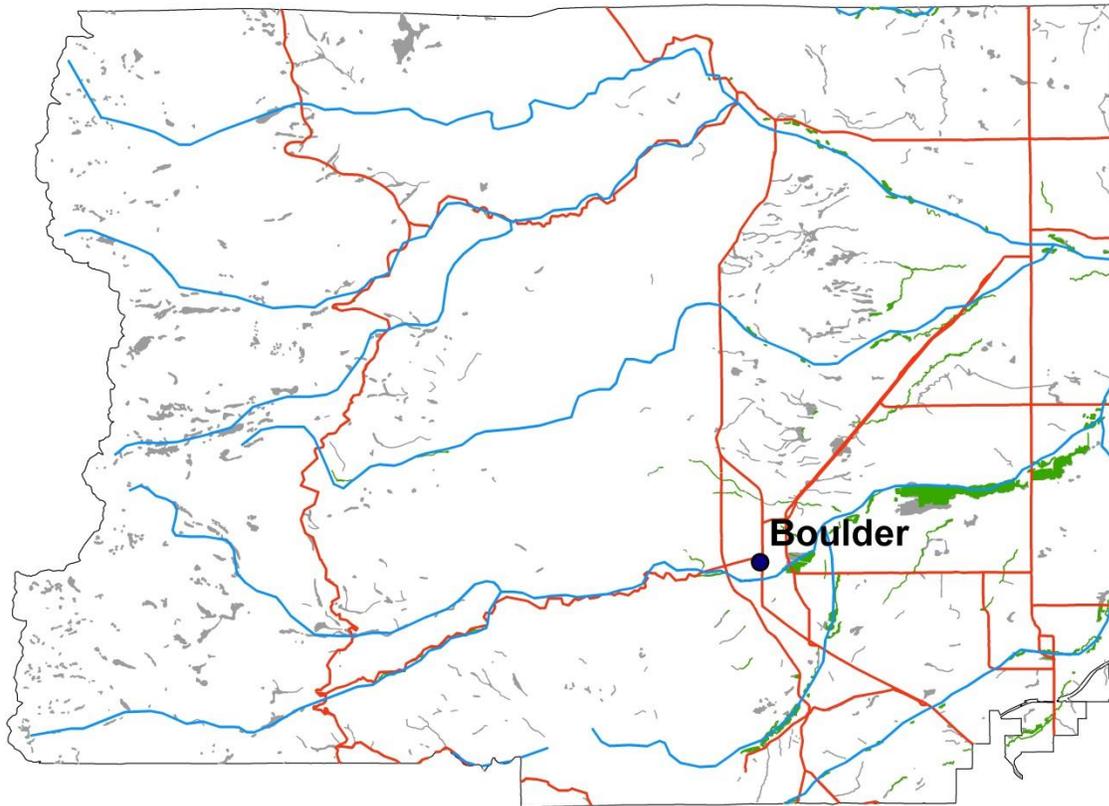
In September 2013, a rainfall event with the statistical likelihood of occurring once every 1,000 years based on historical trends struck Boulder. It caused flooding that killed four people and caused 7,600 county residents to apply for federal assistance.³⁴

This extreme rainstorm struck Colorado after an unusually dry month, and Boulder was hit exceptionally hard by the storm. The Boulder area received 12 inches of rain over a two-day period, causing Boulder Creek to reach the highest water level observed in downtown Boulder since 1894.³⁵ Flood water damaged 150 miles of roadways in the county, including washing away the main highway connecting Boulder to Lyons, a nearby mountain community.³⁶ The estimated damage to county road infrastructure was between \$100 million and \$150 million. More than 1,100 people were evacuated by air and 707 others were

evacuated by road due to the flooding event.³⁷ This event set new one-day, two-day and seven-day records for total rainfall in Boulder.³⁸

Paving over or otherwise destroying wetlands reduces the ability of a landscape to absorb rainfall from extreme precipitation events such as this one, which could exacerbate flooding and its impacts on nearby communities.

Figure 2: Freshwater Wetlands in 100-Year-Flood Zones in Boulder County, North of Denver



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 1: Wetland Acreage in 100-Year-Flood Zones in Colorado and Boulder County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (24 of 64 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	1,028,306	74,627	339,341
Boulder County	10,241	2,550	3,379

Connecticut

According to data from the National Wetlands Inventory, Connecticut boasts approximately 177,000 acres of freshwater wetlands.³⁹ Approximately 48,000 acres of the state's freshwater wetlands are in the 100-year-flood zones for which flood hazard data are available from FEMA.⁴⁰ (See Table 2.)

In Fairfield County, which experienced flooding in the wake of a Nor'easter in April 2007, there are approximately 17,000 acres of freshwater wetlands, of which more than 6,000 acres are located in 100-year-flood zones. (See Figure 3.) Together, these wetlands are capable of holding more than 5.5 billion gallons of water.⁴¹

Nor'easter Causes Flooding in Connecticut

On April 15 and 16, 2007, a Nor'easter struck Connecticut, producing heavy rain and flooding. Rivers and streams overflowed in southwest and south-central Connecticut, which received the heaviest rain. Parts of Fairfield County received as

much as 7.81 inches of rain, and Litchfield County received as much as 6.73 inches of rain.⁴² More than \$6.4 million in federal disaster assistance was granted to residents and businesses from seven Connecticut counties.⁴³

With rainfall events expected to become more intense in the Northeast, Connecticut needs to prepare for future flooding events. The largest rainfall events that strike Connecticut each year became 73 percent more frequent and increased in size by 20 percent between 1948 and 2011, and scientists expect that heavy rainfall events will continue to grow more frequent and intense in the next few decades.⁴⁴

Connecticut has a history of severe floods that have cost the state and its residents millions of dollars.⁴⁵ Preserving the state's marshes and inland wetlands will be a key part of Connecticut's preparedness for such disasters in the future.

Figure 3: Freshwater Wetlands in 100-Year-Flood Zones in Fairfield County in Southwestern Connecticut

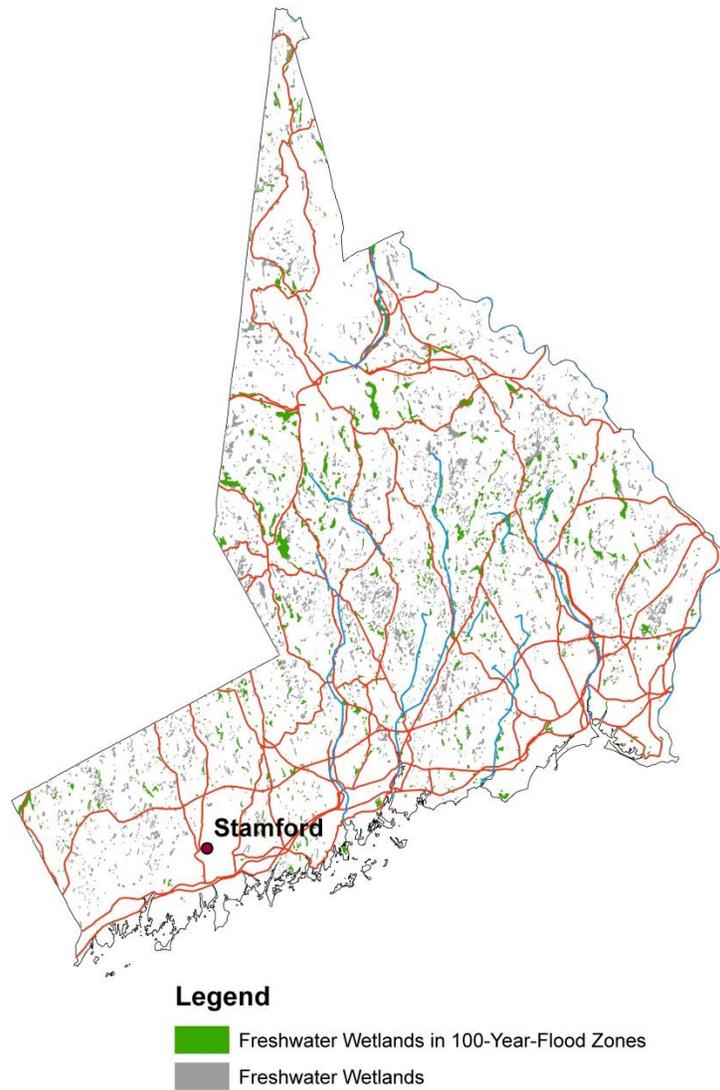


Table 2: Wetland Acreage in 100-Year-Flood Zones in Connecticut and Fairfield County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (5 of 8 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	176,702	47,828	58,312
Fairfield County	16,699	6,228	5,511

Delaware

According to data from the National Wetlands Inventory, Delaware boasts approximately 174,000 acres of freshwater wetlands statewide.⁴⁶ Approximately 40,000 acres of the state's freshwater wetlands lie in 100-year-flood zones.⁴⁷ (See Table 3.)

Delaware's Flood of 2006

In late June 2006, heavy rainfall persisted across the mid-Atlantic region for several days, causing major flooding in several states including Delaware.⁴⁸

Sussex County, in southern Delaware, was hit particularly hard. In the town of Seaford, the flood waters topped a dam at nearby Hearns Pond and caused water to rush downtown, flooding streets and homes and washing away two feet of soil. Four feet of water filled the home of one Seaford resident, which had been inundated by

floodwaters after a similar dam failure just five years earlier. The water caused irreparable damage to the resident's printing business, which he ran out of his home.⁴⁹

Across the area, flooding destroyed bridges, washed away roads, and damaged homes and municipal buildings. As cars floated in the parking lot outside a Seaford Wal-Mart and up to 15 people were evacuated from their homes, Delaware's then-Governor Ruth Ann Minner declared of state of emergency and, in early July, the president declared a major disaster for the state.⁵⁰

Paving over or otherwise destroying wetlands can reduce the ability of a landscape to absorb rainfall from extreme precipitation events, which could exacerbate flooding and its impacts on nearby communities.

Figure 4: Freshwater Wetlands in 100-Year-Flood Zones in Delaware

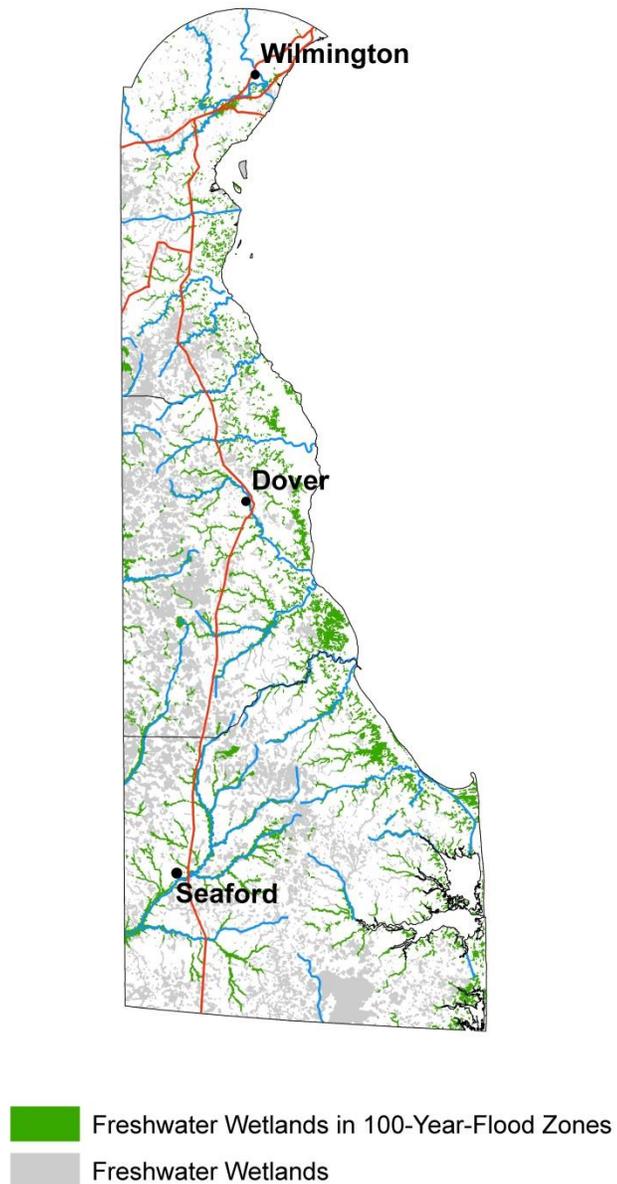


Table 3: Wetland Acreage in 100-Year-Flood Zones in Delaware

Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
174,211	39,941	57,490

Florida

According to data from the National Wetlands Inventory, Florida boasts approximately 9.8 million acres of freshwater wetlands statewide.⁵¹ In the counties for which flood hazard data are available from FEMA, approximately 6.9 million acres of the state's freshwater wetlands are in 100-year-flood zones.⁵² (See Table 4.)

In Escambia County, where Pensacola suffered almost \$15 million in flood damage in the wake of extreme rainfall in April 2014, there are approximately 77,000 acres of freshwater wetlands, of which approximately 63,000 acres are located in 100-year-flood zones. (See Figure 5.) Together, these wetlands are capable of holding more than 25 billion gallons of water.⁵³

Historic Rainfall Caused Millions in Flood Damages in Pensacola

In April 2014, a historic amount of rainfall caused major flooding in Alabama and the

western Florida Panhandle. On April 29, three to eight inches of rain fell, and on April 30, 10 to 15 more inches of rain fell over a nine-hour period, causing flash floods. Pensacola Regional Airport measured more than five inches of rain falling in a single hour and measured the highest amount of rainfall in a single day ever recorded at that station.⁵⁴ The flooding caused an estimated \$14.8 million in damage in Pensacola.⁵⁵ A man in Florida died when his car got stuck in rising waters during the flooding, and the Interstate 10 bridge over Pensacola Bay was inundated.⁵⁶ More than 14,200 Northwest Florida residents applied for disaster assistance and \$66.5 million in assistance was approved to help residents rebuild and recover from the storm.⁵⁷

Figure 5: Freshwater Wetlands in 100-Year-Flood Zones in Escambia County in the Florida Panhandle



Table 4: Wetland Acreage in 100-Year-Flood Zones in Florida and Escambia County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (61 of 67 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	9,758,723	6,870,908	3,220,379
Escambia County	77,028	62,631	25,419

Georgia

According to data from the National Wetlands Inventory, Georgia boasts 4.7 million acres of freshwater wetlands statewide.⁵⁸ Approximately 2.7 million acres are freshwater wetlands in 100-year-flood zones. (See Table 5.)

In Coweta County, one of 17 counties to receive federal disaster declarations in the wake of flooding in September 2009, there are approximately 14,600 acres of freshwater wetlands, of which approximately 12,400 acres are located in 100-year-flood zones. (See Figure 6.) Together, these wetlands are capable of holding almost five billion gallons of water.⁵⁹

Georgia’s “Epic Floods of 2009”

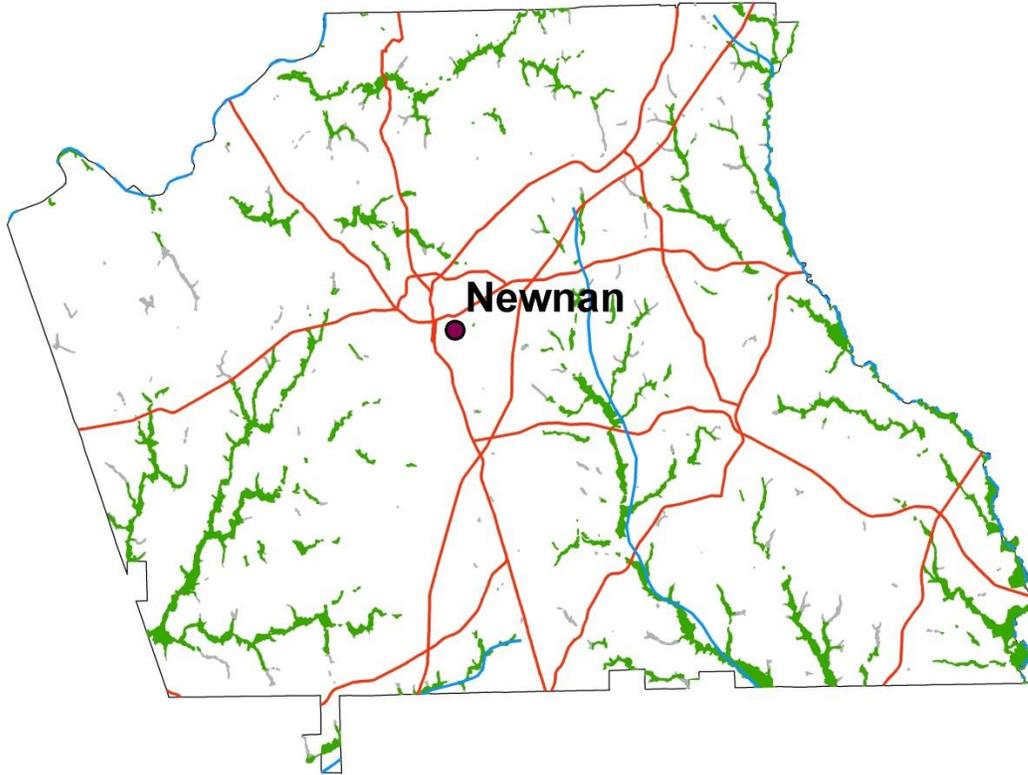
In late September 2009, a six-day extreme rainstorm dropped as much as 20 inches of rain in northern Georgia, causing flooding so severe that 17 Georgia counties were declared federal disaster areas.⁶⁰

The so-called Epic Floods of 2009 broke records nearly a century old, and were so high that 28 river gauges were inundated.⁶¹ The water sent the Sweetwater Creek Basin to its 500-year flood level. The Chattahoochee River and many tributaries reached their 100-year flood levels.⁶²

At least 10 people died in the flooding, and hundreds more had to be rescued from their homes by boat.⁶³ As many as 20,000 buildings – including homes and businesses – were damaged.⁶⁴ Recovery costs were estimated at \$500 million.⁶⁵

Flooding in Georgia is no rarity: in 2014, there were 40 reports of flash floods around the state, causing more than \$500,000 in damage.⁶⁶

Figure 6: Freshwater Wetlands in 100-Year-Flood Zones in Coweta County, Part of the Greater Atlanta Region



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 5: Wetland Acreage in 100-Year-Flood Zones in Georgia and Coweta County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	4,701,772	2,708,587	1,551,585
Coweta County	14,565	12,424	4,807

Illinois

According to data from the National Wetlands Inventory, Illinois boasts more than 1 million acres of freshwater wetlands statewide.⁶⁷ Approximately 582,000 acres of the state's freshwater wetlands are in the 100-year-flood zones for which flood hazard data are available from FEMA.⁶⁸ (See Table 6.)

In Lake County, one of the state's most populous counties and the scene of severe flooding in 2013, there are approximately 24,000 acres of freshwater wetlands, of which approximately 17,000 acres are freshwater wetlands in 100-year-flood zones. (See Figure 7.) Together, these wetlands are capable of holding more than 7.8 billion gallons of water.⁶⁹

Severe Flooding Followed Heavy Rains in Lake County in 2013

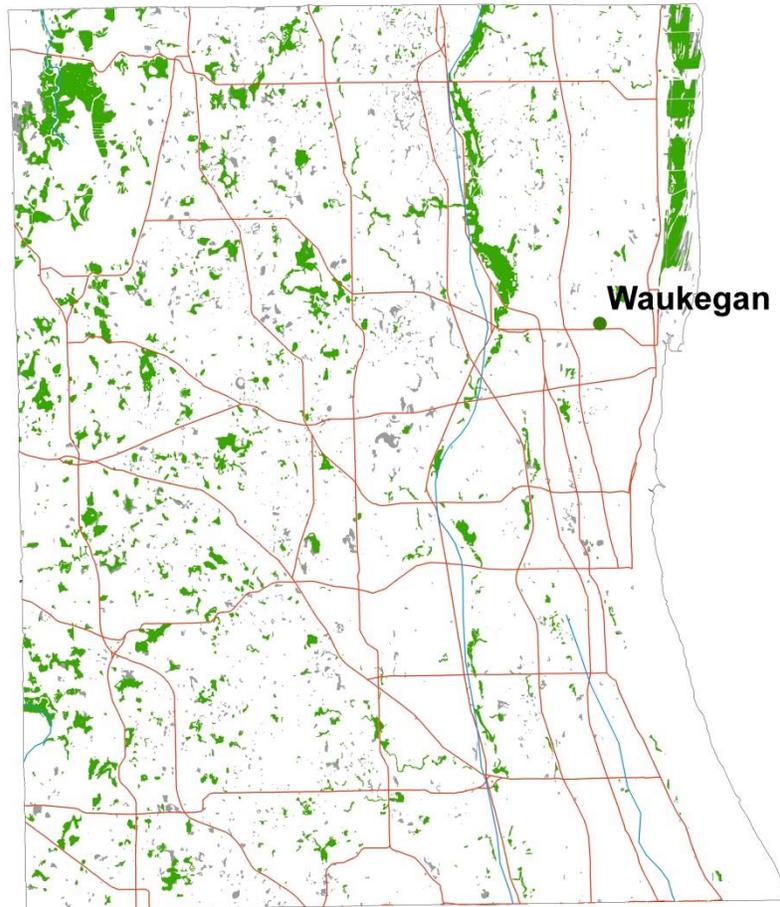
In the spring of 2013, a state of emergency was declared in Lake County after water from multiple periods of heavy rain in the

months of April and May swelled three rivers in the county.⁷⁰ After more than five inches of rain hit the area, the Fox River crested over five feet above its flood level, and the Des Plaines River crested over three-and-a-half feet above its flood level.⁷¹

By the time the disaster had ended, 24,000 people were without power, the city's sewage and storm drainage system – overwhelmed by the volume of storm water – had emptied into Lake Michigan, and 17,000 individuals and households were in need of \$51 million in federal assistance.⁷²

Paving over or otherwise destroying wetlands reduces the ability of a landscape to absorb rainfall from extreme precipitation events, which can exacerbate flooding and its impacts on nearby communities.

Figure 7: Freshwater Wetlands in 100-Year-Flood Zones in Lake County on the Shore of Lake Michigan North of Chicago



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 6: Wetland Acreage in 100-Year-Flood Zones in Illinois and Lake County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (75 of 102 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	1,004,651	582,043	331,535
Lake County	23,785	17,330	7,849

Iowa

According to data from the National Wetlands Inventory, Iowa has approximately 574,000 acres of freshwater wetlands statewide.⁷³ In the counties for which flood hazard data is available from FEMA, approximately 335,000 acres of the state's freshwater wetlands are in 100-year-flood zones.⁷⁴ (See Table 7.)

In Johnson County, which, along with many other counties in Iowa, suffered from enormous floods in the summer of 2008, there are more than 18,000 acres of freshwater wetlands, of which approximately 17,000 acres are located in 100-year-flood zones. (See Figure 8.) Together, these wetlands are capable of holding more than 6 billion gallons of water.⁷⁵

Iowa's Flood of 2008

The Flood of 2008 is considered one of the worst modern-day floods to strike Iowa – 85 of the state's 99 counties were declared federal disaster areas following the flooding that occurred in May and June of that year.⁷⁶ More than 38,000 people in 16 Iowa counties were displaced from their homes.⁷⁷

The floods caused an estimated \$10 billion in damage across the state, inundated 2.5 to 3 million acres of corn and soybean crops, and washed topsoil away from an estimated

10 percent of the state's cropland.⁷⁸ The floods broke records in Johnson County and Linn County during June 2008 when the Iowa River and Cedar River basins flooded.⁷⁹

In Iowa City, heavy rainfall caused flash flooding on June 4. Buildings on the University of Iowa's campus were flooded, and nearby roads and bridges were closed.⁸⁰ In neighboring Linn County, the city of Cedar Rapids recorded excess rainfall that caused the Cedar River to swell to record high levels – six gauges along the Cedar River measured the largest flood on record for those sites. Ten square miles of the city were flooded, including the downtown area, more than 5,200 homes, the city hall, and the county jailhouse and courthouse. There was an estimated \$736 million in damage caused by the flooding in Cedar Rapids.⁸¹

Although the Flood of 2008 was historic, Iowa cities in the floodplains of the Cedar River and the Iowa River must be prepared for future floods. Preserving the state's wetlands will be a key part of Iowa's preparedness for future disasters and could help prevent future floods from becoming more destructive.

Figure 8: Freshwater Wetlands in 100-Year-Flood Zones in Johnson County, Home to Iowa City



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 7: Wetland Acreage in 100-Year-Flood Zones in Iowa and Johnson County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (51 of 99 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	573,997	334,908	189,419
Johnson County	18,258	17,189	6,025

Maryland

According to data from the National Wetlands Inventory, Maryland boasts approximately 425,000 acres of freshwater wetlands statewide.⁸² In the counties for which flood hazard data are available from FEMA, approximately 106,000 acres of the state's freshwater wetlands lie in 100-year-flood zones.⁸³ (See Table 8.)

In Montgomery County, there are approximately 9,000 acres of freshwater wetlands, of which approximately 5,000 acres are located in 100-year-flood zones. (See Figure 9.) Together, Montgomery County's freshwater wetlands are capable of holding approximately 3 billion gallons of water.⁸⁴

Maryland's Flood of 2006

In late June 2006, heavy rainfall persisted across the mid-Atlantic region for several days, causing major flooding in several states including Maryland.⁸⁵

More than a foot of rain over just a few days and subsequent flooding tragically resulted

in deaths and tens of millions of dollars' worth of damage. Dorchester County, on Maryland's Eastern Shore, suffered \$60 million of flood damage caused in part by washed out roads and highways.⁸⁶ In Frederick County, three people were swept to their deaths after abandoning their car on a flooded road.⁸⁷ In neighboring Montgomery County, which received a major disaster declaration, engineers worked frantically to prevent a dam failure that could have inundated thousands of homes.⁸⁸ The concern about the dam at Lake Needwood, near Rockville, prompted the evacuation of 1,200 nearby homes, as engineers plugged several leaks that appeared in the base of the dam as the water levels rose.⁸⁹

Paving over or otherwise destroying wetlands can reduce the ability of a landscape to absorb rainfall from extreme precipitation events, which could exacerbate flooding and its impacts on nearby communities.

Figure 9: Freshwater Wetlands in 100-Year-Flood Zones in Montgomery County, in the Washington, D.C., Metropolitan Area

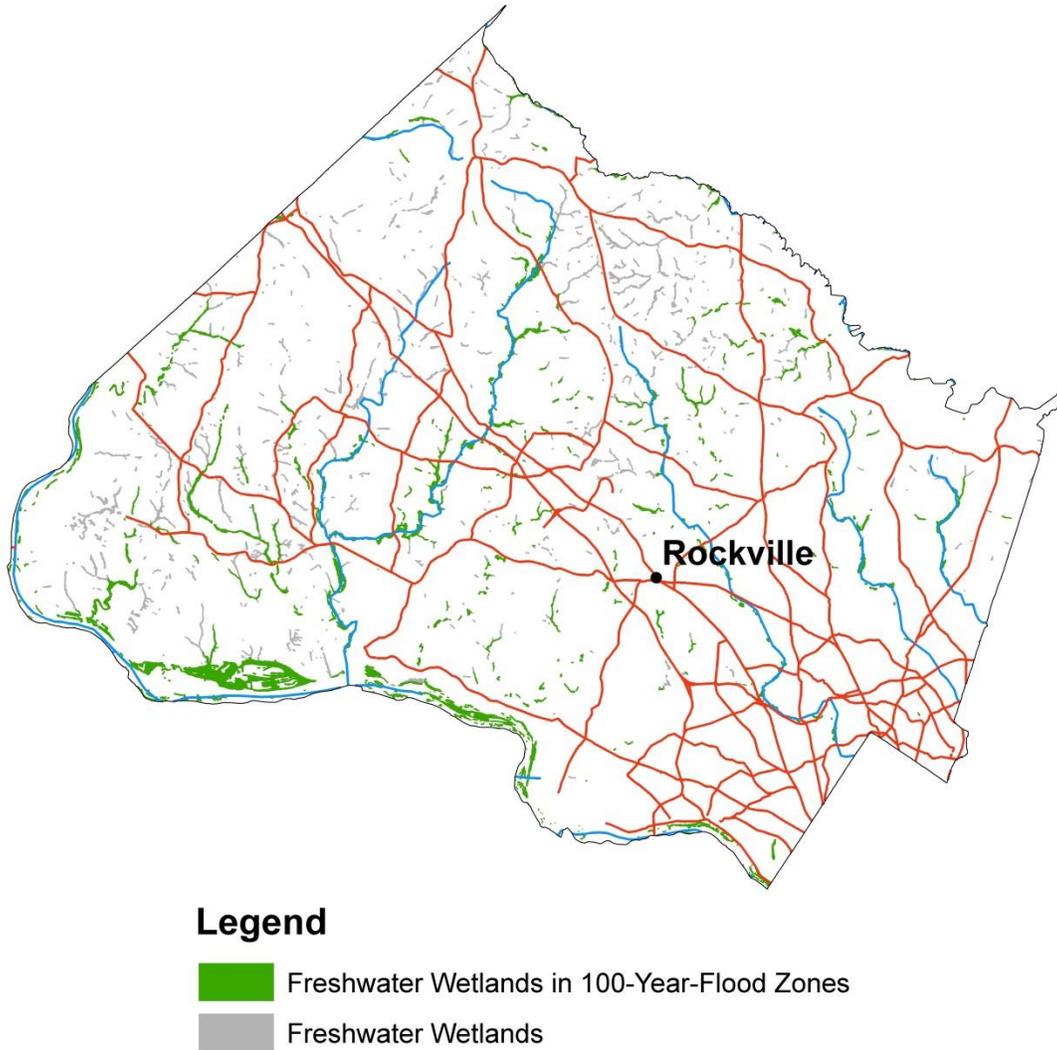


Table 8: Wetland Acreage in 100-Year-Flood Zones in Maryland and Montgomery County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (Acres) (18 of 24 Counties Included)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	425,216	106,137	140,321
Montgomery County	9,085	5,312	2,998

Massachusetts

According to data from the National Wetlands Inventory, Massachusetts has almost 444,000 acres of freshwater wetlands statewide.⁹⁰ Approximately 148,000 acres of the state's freshwater wetlands lie in the 100-year-flood zones for which flood hazard data are available from FEMA.⁹¹ (See Table 9.)

In Bristol County, there are approximately 58,000 acres of freshwater wetlands, of which approximately 24,000 acres are located in 100-year-flood zones. (See Figure 10.) Together, these wetlands are capable of holding more than 19.2 billion gallons of water.⁹²

Extreme Rainfall and Flooding in Eastern Massachusetts in 2005

During a two-week span in October 2005, nine counties across eastern Massachusetts received nearly a foot of rain. A combined seven inches of rain fell on Taunton – a city 40 miles south of Boston – over just two days.⁹³ The city is located on the Mill River, and just downstream of the Whittenton

Pond Dam – a 173-year-old wooden dam built to provide the town with water power in the Industrial Era.

The massive rainstorm threatened the integrity of the 12-foot-high dam, which was the only thing protecting the town of Taunton from rain-swollen Lake Sabbatia, whose waters were beginning to reach nearby homes.⁹⁴ On Monday, October 17, in the middle of the night, parts of the dam broke off under the pressure, sending torrents of water into the Mill River and threatening homes and businesses in the area.

A state of emergency was declared, all schools and businesses were ordered temporarily closed and 2,000 residents were evacuated. In the end, aid given to recover the losses of homes and businesses topped \$2.7 million.⁹⁵

Figure 10: Freshwater Wetlands in 100-Year-Flood Zones in Bristol County in Southeastern Massachusetts

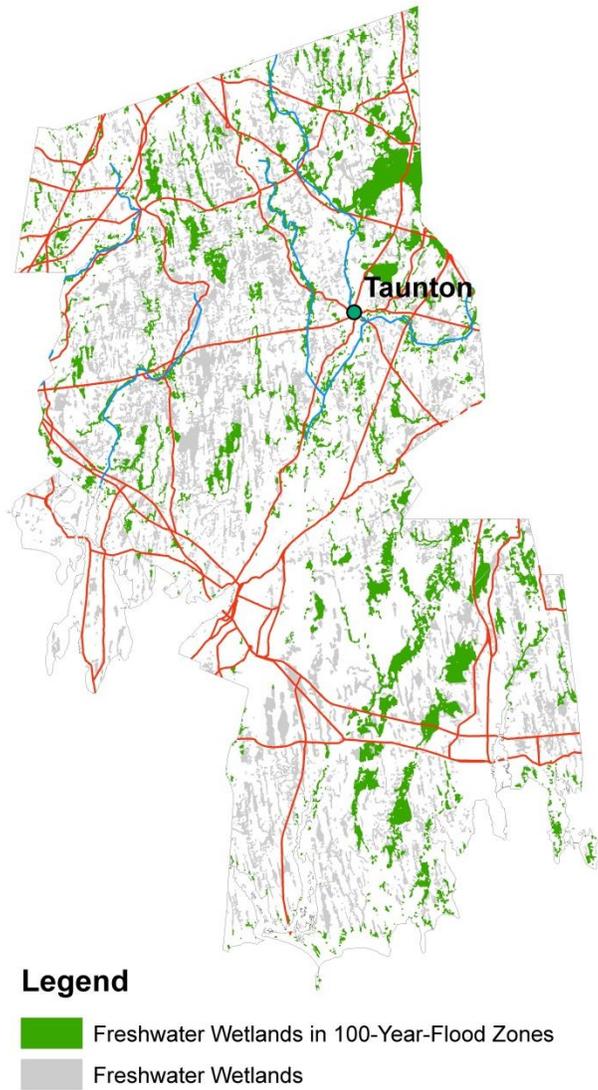


Table 9: Wetland Acreage in 100-Year-Flood Zones in Massachusetts and Bristol County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (11 of 14 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	443,700	148,351	146,421
Bristol County	58,201	24,200	19,206

Minnesota

According to data from the National Wetlands Inventory, there are approximately 10.1 million acres of freshwater wetlands in Minnesota.⁹⁶ In the counties for which there are flood hazard data available from FEMA, approximately 270,000 acres of the state's freshwater wetlands are in 100-year-flood zones.⁹⁷ (See Table 10.)

In Ramsey County, home to St. Paul and one of 35 counties that experienced a state of emergency during severe flooding in June 2014, there are approximately 9,000 acres of freshwater wetlands, of which approximately 5,000 acres are located in 100-year-flood zones. (See Figure 11.) Together, these wetlands are capable of holding more than 2.8 billion gallons of water.⁹⁸

Widespread Flooding in June 2014

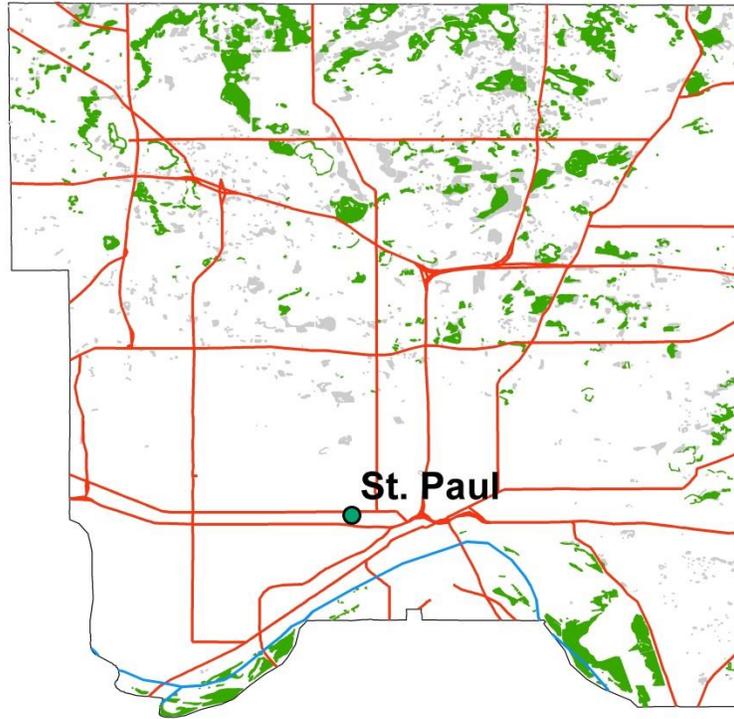
Flooding affected vast stretches of Minnesota during the month of June 2014. The Mississippi River, the Crow River and the St. Croix River overflowed as excessive rain and unusually large amounts of melting snow exceeded river capacity.⁹⁹ June 2014 was the wettest month on record for Minnesota.¹⁰⁰

This severe flooding caused a state of emergency in 35 counties. Soybean and corn

crops were negatively affected, and flooding in St. Paul caused road closures. In Delano, businesses near the overflowing Crow River were evacuated.¹⁰¹ At Blue Mounds State Park, near Luverne, floodwaters from Blue Mounds Creek caused a dam to wash out and drain Lower Mound Lake.¹⁰² The Minnesota National Guard was deployed to the town of Henderson, which was isolated by mudslides and flooded roads.¹⁰³

This is not an isolated incident for the state. A study by the Minnesota Department of Health revealed that significant numbers of Minnesotans are highly vulnerable to flash floods.¹⁰⁴ Extreme rain events are a primary cause of such flooding, and these large rain storms are occurring at a higher frequency than had previously been recorded. Scientists predict that global warming will make heavy rainfall events even more frequent.¹⁰⁵ Preserving the state's wetlands will be a key part of Minnesota's preparedness for such events in the future by maintaining the landscape's ability to absorb excess rainfall.

Figure 11: Freshwater Wetlands in 100-Year-Flood Zones in Ramsey County, Home to St. Paul



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 10: Wetland Acreage in 100-Year-Flood Zones in Minnesota and Ramsey County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (28 of 87 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	10,126,944	270,063	3,341,892
Ramsey County	8,630	5,093	2,848

New Jersey

According to data from the National Wetlands Inventory, New Jersey boasts approximately 687,000 acres of freshwater wetlands statewide.¹⁰⁶ In the counties for which flood hazard data are available from FEMA, approximately 125,500 acres of the state's freshwater wetlands are in 100-year-flood zones.¹⁰⁷ (See Table 11.)

In Gloucester County, there are approximately 32,000 acres of freshwater wetlands, of which approximately 14,000 acres are located in 100-year-flood zones. (See Figure 12.) Together, these wetlands are capable of holding more than 10.6 billion gallons of water.¹⁰⁸

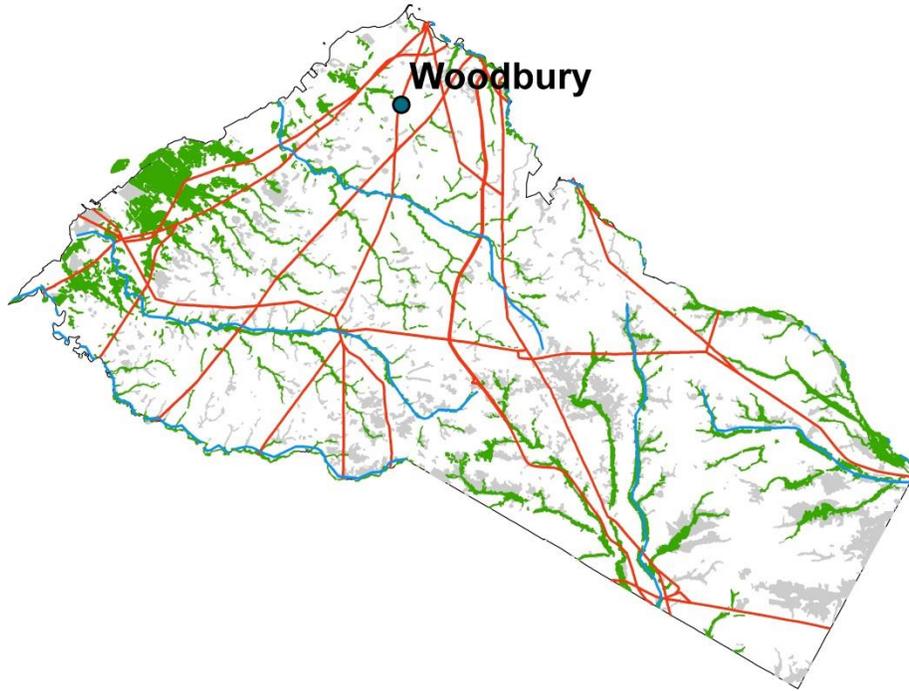
Heavy Rainfall Stresses New Jersey's Infrastructure

From July 12 to 14, 2004, record rainfall hit parts of southern New Jersey. Areas

recorded between eight and 12 inches of precipitation in a single 24-hour period, and six U.S. Geological Survey gauges witnessed record flood peaks.¹⁰⁹ As a result, 17 dams were either partially or totally breached, leading to the closure of at least 25 roads and the evacuation of hundreds of residents.¹¹⁰

Paving over or otherwise destroying wetlands reduces the ability of a landscape to absorb rainfall from extreme precipitation events, which can exacerbate flooding and its impacts on nearby communities.

Figure 12: Freshwater Wetlands in 100-Year-Flood Zones in Gloucester County in Southern New Jersey



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 11: Wetland Acreage in 100-Year-Flood Zones in New Jersey and Gloucester County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (14 of 21 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	686,832	125,531	226,654
Gloucester County	32,145	14,344	10,608

New York

According to data from the National Wetlands Inventory, New York has approximately 2 million acres of freshwater wetlands statewide.¹¹¹ In the counties for which flood hazard data are available from FEMA, approximately 183,000 acres of the state's freshwater wetlands lie in 100-year-flood zones.¹¹² (See Table 12.)

In Orange County, the scene of severe flooding in the wake of Hurricane Irene in 2011, there are approximately 35,000 acres of freshwater wetlands, of which roughly 16,000 acres are located in 100-year-flood zones. (See Figure 13.) Together, these wetlands are capable of holding almost 11.6 billion gallons of water.¹¹³

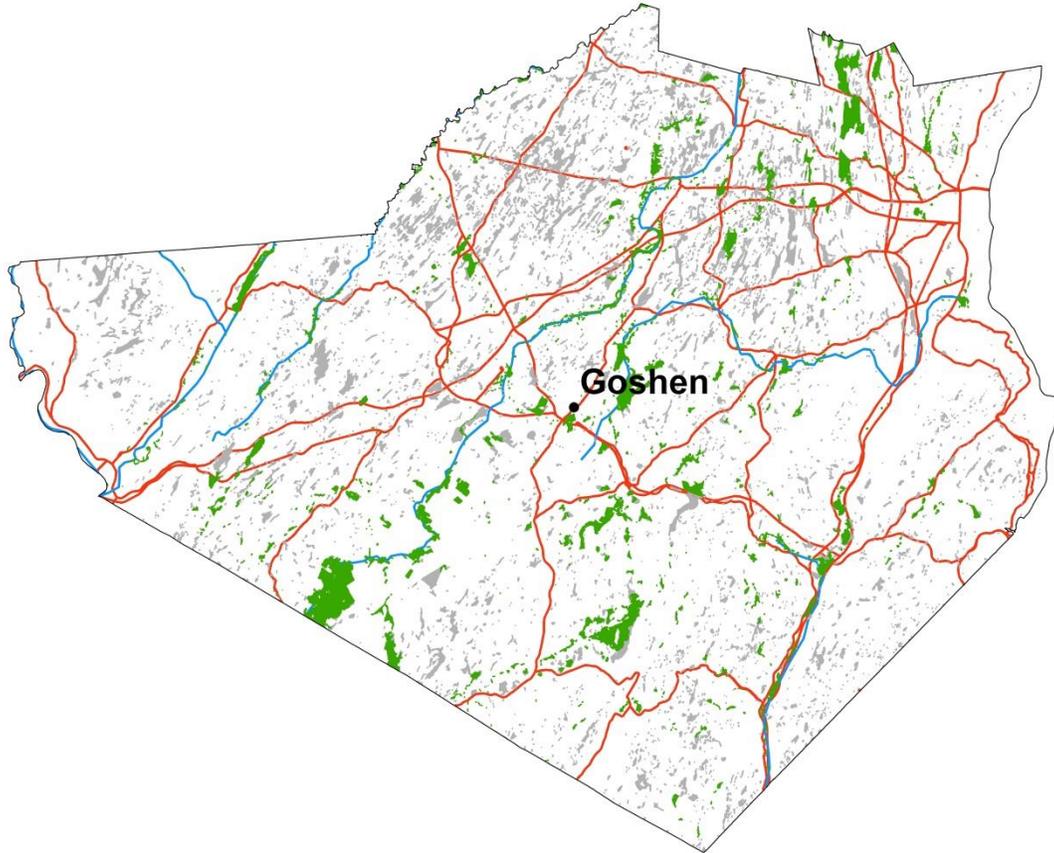
Hurricanes Can Bring Heavy Rainfall – and Flooding – to New York

New York is vulnerable to flooding caused by rain from tropical storms that travel north along the eastern seaboard of the United States. Some of the worst flooding events in the state's recent history were caused by hurricanes, including Hurricane Irene in 2011.

In August 2011, Hurricane Irene traveled northward toward New York from North

Carolina, where it made landfall in the United States as a Category 1 storm.¹¹⁴ Upstate New York was hardest hit, with 11 inches of rain falling on the Hudson Valley in a single day. In the village of Washingtonville in Orange County, up to eight feet of water submerged buildings and forced hundreds of people from their homes.¹¹⁵ Flood damage from Irene and another tropical storm that followed mere days later forced the village's library to relocate its collection.¹¹⁶ Residents in nearby Goshen experienced sewage backflows after floodwater inundated the town's drainage and sewage infrastructure, adding insult to injury for homeowners already struggling to tackle the damage caused by the heavy rains.¹¹⁷ The storm washed out roads and bridges, destroyed homes and municipal buildings, and ruined crops, causing at least \$81 million in damage in Orange County alone.¹¹⁸

Figure 13: Freshwater Wetlands in 100-Year-Flood Zones in Orange County, Part of the New York City Metropolitan Area



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 12: Wetland Acreage in 100-Year-Flood Zones in New York and Orange County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (Acres) (27 of 62 Counties Included)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	1,959,046	182,773	646,485
Orange County	35,077	15,696	11,575

Pennsylvania

According to data from the National Wetlands Inventory, there are approximately 377,000 acres of freshwater wetlands in Pennsylvania.¹¹⁹ In the counties for which we have flood hazard data, approximately 164,000 acres of the state's freshwater wetlands are in the 100-year-flood zones for which flood hazard data are available from FEMA.¹²⁰ (See Table 13.)

In Montgomery County, a part of the greater Philadelphia area that experienced severe rainfall during a 2007 Nor'easter, there are approximately 3,000 acres of freshwater wetlands, of which approximately 2,000 acres are located in 100-year-flood zones. (See Figure 14.) Together, these wetlands are capable of holding approximately 949 million gallons of water.¹²¹

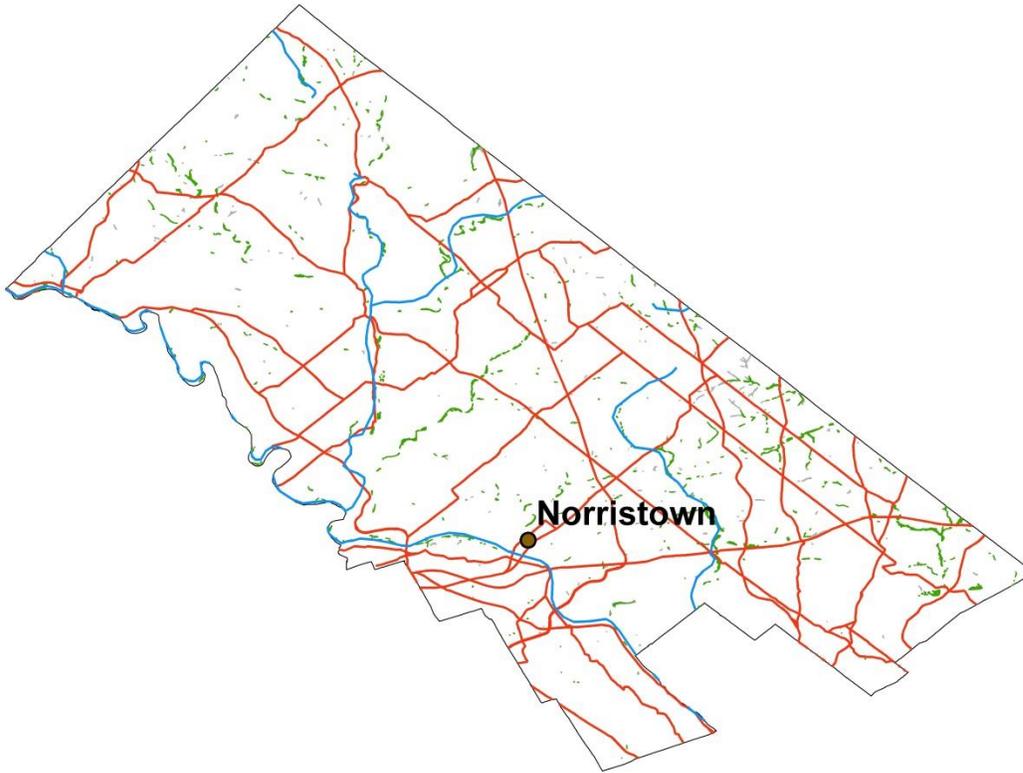
Nor'easters Cause Flooding in Pennsylvania

Philadelphia is located at the confluence of the Delaware and Schuylkill Rivers, and is

thus especially vulnerable to flooding.¹²² In 2007, a Nor'easter caused heavy downpours in Pennsylvania.¹²³ A number of areas saw record flooding, while Philadelphia experienced nearly six inches of rainfall.¹²⁴ The Nor'easter caused a total of \$3 billion in damage across the country and caused nine deaths.¹²⁵

Paving over or otherwise destroying wetlands reduces the ability of a landscape to absorb rainfall from extreme precipitation events, which could exacerbate flooding and its impacts on nearby communities.

Figure 14: Freshwater Wetlands in 100-Year-Flood Zones in Montgomery County in the Philadelphia Metropolitan Area



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 13: Wetland Acreage in 100-Year-Flood Zones in Pennsylvania and Montgomery County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (57 of 67 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	377,223	163,562	124,483
Montgomery County	2,875	2,149	949

Virginia

According to data from the National Wetlands Inventory, Virginia has approximately 1 million acres of freshwater wetlands statewide.¹²⁶ Approximately 529,000 acres are freshwater wetlands in 100-year-flood zones. (See Table 14.)

Within the city limits of Richmond, the scene of major flooding in the wake of 2004's Hurricane Gaston, there are 792 acres of freshwater wetlands, of which 524 acres are located in 100-year-flood zones. (See Figure 15.) Together, these wetlands are capable of holding approximately 261 million gallons of water.¹²⁷

Hurricanes Often Bring Heavy Rainfall – and Flooding – to Virginia

Virginia is vulnerable to flooding caused by rain from tropical storms that travel northeastward from the Gulf of Mexico.¹²⁸

Three of the worst flooding events affecting the state were caused by hurricanes – Hurricane Camille in 1969, Hurricane Agnes in 1972 and Hurricane Juan in 1985.¹²⁹

On August 30, 2004, Hurricane Gaston traveled northward across Virginia, producing heavy rainfall over the Richmond metro area that caused severe flash floods.¹³⁰ Nine people died in the flash floods created by the storm, and 5,798 homes, 97 businesses and 2,077 vehicles were destroyed. Richmond, Hopewell, Colonial Heights and Petersburg were declared disaster areas. In all, the storm caused an estimated \$130 million in damage.¹³¹

Figure 15: Freshwater Wetlands in 100-Year-Flood Zones in Richmond

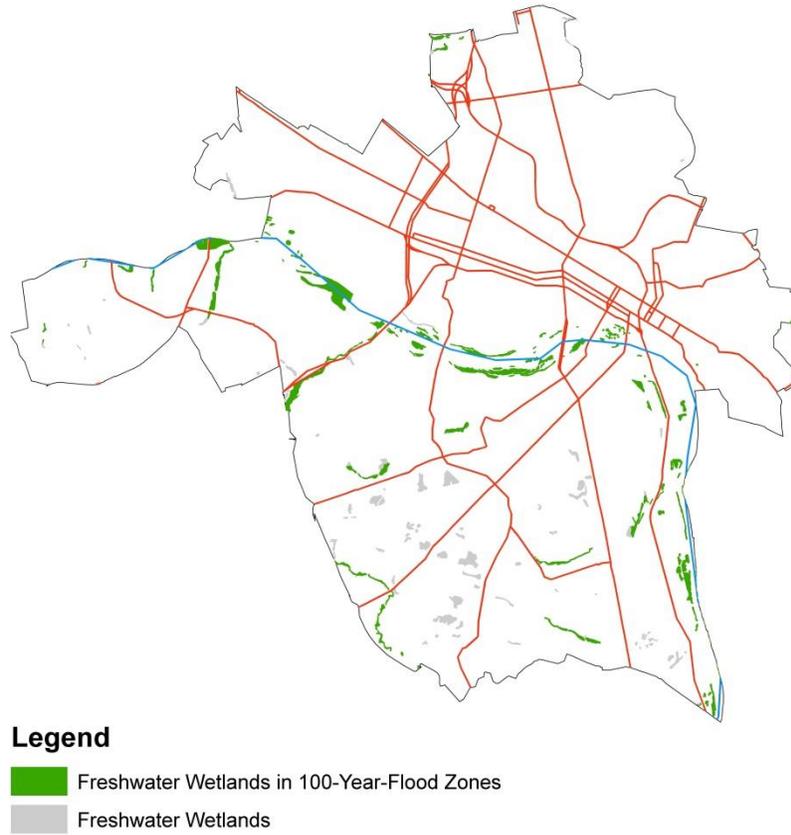


Table 14: Wetland Acreage in 100-Year-Flood Zones in Virginia and Richmond

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	999,742	528,664	329,915
City of Richmond	792	524	261

Wisconsin

According to data from the National Wetlands Inventory, Wisconsin boasts 5.4 million acres of freshwater wetlands statewide.¹³² Approximately 1.4 million acres of the state's freshwater wetlands lie in the 100-year-flood zones for which flood hazard data are available from FEMA.¹³³ (See Table 15.)

In Dane County, the scene of damaging floods in 2008, there are approximately 49,000 acres of freshwater wetlands, of which approximately 32,500 acres are located in 100-year-flood zones. (See Figure 16.) Together, these wetlands are capable of holding more than 16 billion gallons of water.¹³⁴

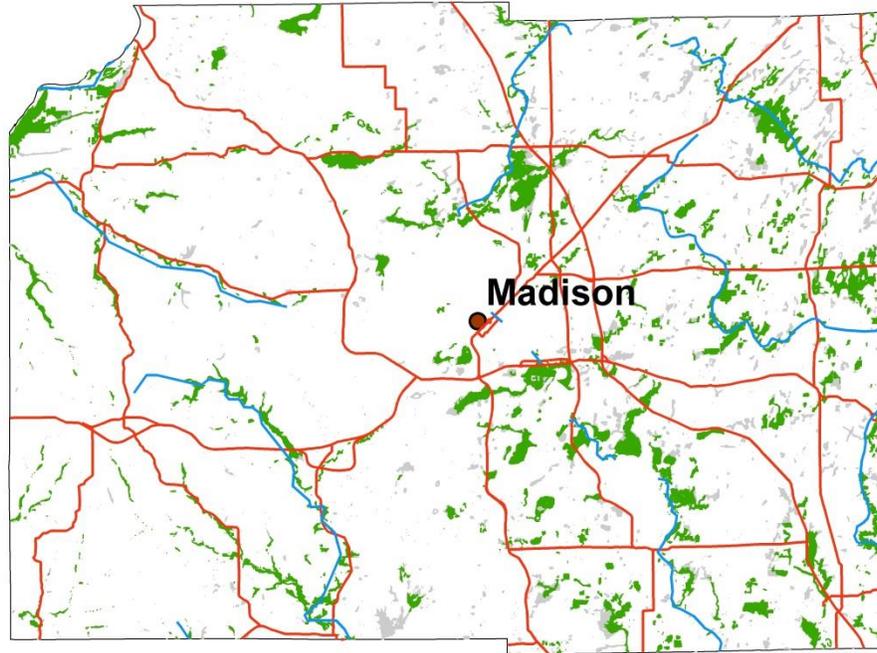
Wisconsin's Flood of 2008

The Flood of 2008 struck vast stretches of the Midwest, including southern Wisconsin, in June 2008. After a winter of heavy snowfall and saturated soil, heavy rain on June 7 and 8 caused streams and lakes to rise.¹³⁵ In Dane County, heavy rainfall caused Lake Mendota and Lake Monona to rise to their 100-year flood levels (flooding

with a probability of occurring once every 100 years).¹³⁶ Just north of Dane County, the storm caused a dam to collapse and Lake Delton to drain, washing away homes and a highway and threatening nearby residents in the town of Gay Mills.¹³⁷ After the flooding, 31 counties in Wisconsin were declared federal disaster areas.¹³⁸ In Dane County, 1,635 people applied for federal assistance and received a total of \$1.8 million in disaster relief.¹³⁹

Dane County is home to the state capital, the main campus of the University of Wisconsin and many acres of farmland. More than half of Dane County falls within the Rock River Basin and the Crawfish River Basin.¹⁴⁰ Paving over or otherwise destroying wetlands reduces the ability of the landscape to absorb rainfall from extreme precipitation events, which can exacerbate flooding and its impacts on the county's communities.

Figure 16: Freshwater Wetlands in 100-Year-Flood Zones in Dane County, Home to Madison



Legend

- Freshwater Wetlands in 100-Year-Flood Zones
- Freshwater Wetlands

Table 15: Wetland Acreage in 100-Year-Flood Zones in Wisconsin and Dane County

	Freshwater Wetlands (Acres)	Freshwater Wetlands in 100-Year-Flood Zones (58 of 72 Counties Included) (Acres)	Potential for Floodwater Absorption (All Freshwater Wetlands) (Millions of Gallons)
Statewide	5,431,290	1,395,954	1,792,326
Dane County	49,092	32,518	16,200

Methodology

To derive an estimate for the acreage of wetlands in 100-year-flood zones (i.e. an area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year, also known as a “Special Flood Hazard Area” (SFHA) in FEMA terminology), we began by establishing the specific types of wetlands we would focus on in our analysis.¹⁴¹

Relying on the categories of wetlands used by the U.S. Fish and Wildlife Service’s National Wetlands Inventory, we eliminated wetland types that include bodies of water, estuaries and marine wetlands, leaving the following to be included in our analysis:

- Freshwater Forested and Shrub wetlands
- Freshwater Emergent wetlands
- Other Freshwater wetlands¹⁴²

We conducted the bulk of our analysis using ArcGIS mapping software and downloaded the appropriate data files and map layers for analysis. Wetlands data are available state-by-state. We downloaded the geodatabase files for the states under consideration.¹⁴³ Flood hazard area data are produced at the county or municipal level but can be downloaded by state via the FEMA National Flood Hazard Layer (NFHL). We downloaded the single state file for the states under consideration.¹⁴⁴ Most states do not have flood hazard data available for all jurisdictions within a state. We considered as many jurisdictions as possible. The absence of flood hazard data for some jurisdictions in many of the states considered means that our wetlands estimates for each state are likely to be conservative.

Once a state’s files were added to ArcGIS, we filtered the flood hazard data using a feature in the attribute table of the layer that indicates whether each flood hazard area examined is a SFHA. We created a new map layer from the filtered selection. This layer showed only the 100-year-flood zones.

To narrow down the statewide wetlands data, we first used the attribute table of the layer to select and highlight only the freshwater wetlands. We created a layer representing those data. We then used the “clip” geoprocessing tool in ArcGIS to clip the wetlands data to the extent of the newly created SFHA layer, creating yet another layer. At this point, we had two layers for analysis: one that showed all freshwater wetlands and one that showed all freshwater wetlands that also lie in SFHAs. We repeated this process at the county level to discern county-level data.

To calculate the acreage of the wetlands, we used ArcGIS’ “Calculate Geometry” feature to add a field to the attribute table for each map layer under consideration containing the area of each polygon in the layer. We then exported the attribute table to a comma-delimited text file, which we subsequently copied into Microsoft Excel where we could use a sum function to total the acreage.

Notes

¹ Gary P. Johnson, Robert R. Holmes Jr. and Lloyd A. Waite, U.S. Geological Survey, *The Great Flood of 1993 on the Upper Mississippi River—10 Years Later*, May 2004.

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⁵ “Why are Wetlands So Important to Preserve?,” *Scientific American*, 19 June 2013.

⁶ Definition of wetland: United States Environment Protection Agency, *Wetlands Definitions*, accessed at water.epa.gov, 17 March 2015

⁷ North Carolina State University Water Quality Group, *Types of Wetlands and Their Roles in the Watershed*, accessed at www.water.ncsu.edu, 17 March 2015.

⁸ United States Environmental Protection Agency, *Wetlands: Protecting Life and Property from Flooding*, accessed at water.epa.gov, 17 March 2015.

⁹ U.S. Geological Survey, *Technical Aspects of Wetlands: Wetland Hydrology, Water Quality, and Associated Functions*, accessed at water.usgs.gov, 17 March 2015.

¹⁰ Donald L. Hey and Nancy S. Philippi, “Flood Reduction through Wetland Restoration: The Upper Mississippi River Basin as a Case History,” *Restoration Ecology*, 3(1)4-17, doi: 10.1111/j.1526-100X.1995.tb00070.x, 7 April 2006.

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¹³ National Weather Service, *Hydrologic Information Center – Flood Loss Data*, accessed at www.nws.noaa.gov, 17 March 2015.

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¹⁷ Ann Vileisis, *Discovering the Unknown Landscape: A History of America’s Wetlands*, (Washington, D.C.: Island Press, 1999), 3.

¹⁸ Thomas E. Dahl, U.S. Fish and Wildlife Service, Gregory J. Allord, U.S. Geological Survey, *History of Wetlands in the Conterminous United States*, accessed at water.usgs.gov, 18 March 2015.

¹⁹ U.S. Government Printing Office, *An Act to Amend the Federal Water Pollution Control Act, Public Law 92-500*, “Declaration of Goals and Policy, Section 101,” 18 October 1972.

²⁰ United States Environmental Protection Agency, *Section 404 Permitting*, accessed at water.epa.gov, 19 March 2015.

²¹ Ibid.

²² The Emergency Wetlands Resources Act (1986) requires the U.S. Fish and Wildlife Service to report on the status and trends of wetlands in the lower 48 states every ten years: U.S. Environmental Protection Agency, *Report on the Environment: Wetlands*, accessed at cfpub.epa.gov, 19 March 2015.

²³ Ibid.

²⁴ U.S. Environmental Protection Agency, *Syllabus: Rapanos et ux. et al. vs. The United States*, accessed at www.epa.gov, 20 March 2015.

²⁵ “Government, Developer Settle Dispute Over Michigan Wetlands,” *Associated Press*, 30 December 2008; Alexandra Fields, Environment America, *EPA Proposes Biggest Step for Clean Water in a Decade* (news release), 25 March 2014.

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²⁷ Joy P. Michaud, *At Home with Wetlands: A Landowner’s Guide*, 2nd ed., (Olympia, WA: State of Washington, Department of Ecology, 2001); State of Washington, Department of Ecology, *Functions and Values of Wetlands*, accessed at www.ecy.wa.gov, 17 March 2015.

²⁸ Washington State Department of Ecology, *Functions and Values of Wetlands*, accessed at www.ecy.wa.gov, 31 March 2015.

²⁹ See note 11.

³⁰ See note 22.

³¹ For the purposes of this analysis, we exclude bodies of water (rivers, streams, lakes, ponds and oceans) and any marine or estuarial wetlands. The term “freshwater wetlands” thus refers to the following categories of wetlands as delineated by the U.S. Fish and Wildlife Service: Freshwater Forested and Shrub wetland; Freshwater Emergent wetland; and Other Freshwater wetland. For more on wetland categories, see: U.S. Fish and Wildlife Service, National Wetlands Inventory, *Wetlands Mapper Legend Categories*, accessed at www.fws.gov/wetlands, 13 March 2015.

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³⁵ Michon Scott, “Historic Rainfall and Floods in Colorado,” *National Oceanic and Atmospheric Administration*, 17 September 2013.

³⁶ 150 miles: Charlie Brennan and John Aguilar, “Eight Days, 1,000-year Rain, 100-Year Flood,” *Boulder Daily Camera*, 21 September 2013, available at http://www.dailycamera.com/news/boulder-flood/ci_24148258/boulder-county-colorado-flood-2013-survival-100-rain-100-year-flood; Lyons: Ibid.

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⁴⁶ See note 31.

⁴⁷ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones.

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⁵¹ See note 31.

⁵² We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all Florida counties, which limited our analysis.

⁵³ See note 33.

⁵⁴ Five inches: NOAA National Weather Service, *North Central Gulf Coast Historic Flash Flood Event – 29-30 April 2014*, accessed at www.srh.noaa.gov, 26 March 2015; Daily rainfall record: Eric Holthas, “The Calamitous Climate Responsible for Florida’s Rainfall Record,” *Slate*, 30 April 2014.

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⁵⁹ See note 33.

⁶⁰ As much as 20 inches of rain: U.S National Weather Service Forecast Office, Peachtree City, Georgia, *The Epic Floods of 2009*, 23 February 2010, available at www.srh.noaa.gov; the 17 counties are Bartow, Carroll, Catoosa, Chattooga, Cherokee, Cobb, Coweta, DeKalb, Douglas, Fulton, Gwinnett, Heard, Newton, Paulding, Rockdale, Stephens and Walker, per Federal Emergency Management Agency, *Disaster Assistance Can Help Flood Survivors in 17 Georgia Counties* (press release 1858-011), 28 September 2009.

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⁶² Ibid.

⁶³ Ibid.

⁶⁴ Ibid.

⁶⁵ U.S. National Weather Service Forecast Office, Jacksonville, Florida, *Flood Safety Preparedness Week March 16-20, 2015*, 15 March 2015, accessed at www.srh.noaa.gov.

⁶⁶ Ibid.

⁶⁷ See note 31.

⁶⁸ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all Illinois counties, which limited our analysis.

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⁷² Federal Emergency Management Agency, *Federal Disaster Aid to Illinois Residents Reaches \$51 Million* (press release), 24 May 2013.

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⁷⁴ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of particular flood hazard zones. These data are not available in ArcGIS format for all Iowa counties, which limited our analysis.

⁷⁵ See note 33.

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⁷⁹ See note 77.

⁸⁰ NOAA National Weather Service, *Flooding in Iowa*, accessed at www.floodsafety.noaa.gov, 26 March 2014.

⁸¹ See note 77.

⁸² See note 31.

⁸³ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data were not available in ArcGIS format for all Maryland counties, which limited our analysis.

⁸⁴ See note 33.

⁸⁵ Dartmouth College, *2006 Global Register of Major Flood Events*, accessed at www.dartmouth.edu, 7 April 2015.

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⁸⁸ Federal Emergency Management Agency, *Designated Areas: Maryland Severe Storms, Flooding, Tornadoes*, accessed at www.fema.gov, 24 April 2015.

⁸⁹ See note 86.

⁹⁰ See note 31.

⁹¹ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all Massachusetts counties, which limited our analysis.

⁹² See note 33.

⁹³ Gina Pace, “Town Braces For Massive Flood,” *CBS News*, 18 October 2005.

⁹⁴ Pam Belluck, “South of Boston, Wary Officials Watch a Weakened Dam,” *New York Times*, 19 October 2005.

⁹⁵ Ibid.

⁹⁶ See note 31.

⁹⁷ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all Minnesota counties, which limited our analysis.

⁹⁸ See note 33.

⁹⁹ Julie Bosman, “Vast Stretches of Minnesota Are Flooded as Swollen Rivers Overflow,” *New York Times*, 24 June 2014.

¹⁰⁰ Minnesota Department of Natural Resources, *Record Setting Rainfall in June 2014*, 2015.

¹⁰¹ See note 99.

¹⁰² Minnesota Department of Natural Resources, *Blue Mounds State Park Storm Damage*, 2015, available at www.dnr.state.mn.us.

¹⁰³ Mike Durkin, “7 Places Hit Hardest by Minnesota Flooding,” *Fox 9 News*, 20 June 2014; Minnesota National Guard Public Affairs, *Minnesota Guardsman to Respond to Flooding in Henderson* (press release), 20 June 2014.

¹⁰⁴ Minnesota Department of Health, *Minnesota Climate Change Vulnerability Assessment 2014*, October 2014.

¹⁰⁵ “Exceptionally heavy rain episodes” are defined as those that reach “six inches or more over a coverage of 1,000 square miles”: Ibid.

¹⁰⁶ See note 31.

¹⁰⁷ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all New Jersey counties, which limited our analysis.

¹⁰⁸ See note 33.

¹⁰⁹ U.S. Geological Survey, *Flooding in New Jersey: July 12-14, 2004 flooding in southern New Jersey*, accessed at nj.usgs.gov, 26 March 2015.

¹¹⁰ Delaware River Basin Commission, *Flooding Events in the DRB*, accessed at www.state.nj.us, 26 March 2015.

¹¹¹ See note 31.

¹¹² We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all New York counties, which limited our analysis.

¹¹³ Based on an acre of wetland one foot deep holding 330,000 gallons of water. See note 1.

¹¹⁴ Lixion A. Avila and John Cangialosi, National Hurricane Center, National Oceanic and Atmospheric Administration, *Tropical Cyclone Report: Hurricane Irene (AL092011), 21-28 August 2011*, 14 December 2011.

¹¹⁵ John Sullivan, “Hundreds in Washingtonville Displaced by Irene,” *Times Herald-Record* (Middletown, NY), 2 September 2011.

¹¹⁶ John Sullivan, “Help Sought As Library Forced to Move,” *Times Herald-Record* (Middletown, NY), 16 September 2011.

¹¹⁷ John Sullivan, “Raw Sewage Worried Rescuers in Goshen,” *Times Herald-Record* (Middletown, NY), 8 September 2011.

¹¹⁸ Chris McKenna, “Toll from Summer’s Storms Estimated at \$115M So Far,” *Times Herald-Record* (Middletown, NY), 4 March 2012.

¹¹⁹ See note 31.

¹²⁰ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all Pennsylvania counties, which limited our analysis.

¹²¹ See note 33.

¹²² City of Philadelphia, *Flood Watch: Rains Carry Significant Flooding Potential*, 10 March 2011.

¹²³ “Dramatic Photos: Philly’s Flood History,” *NBC Philadelphia*, accessed at www.nbcphiladelphia.com/multimedia, 26 March 2015.

¹²⁴ National Weather Service, *Northeast Winter Storm (Nor'easter) April 15-16, 2007*, accessed at www.erh.noaa.gov, 26 March 2015.

¹²⁵ Ibid.

¹²⁶ See note 31.

¹²⁷ See note 33.

¹²⁸ U.S. Geological Survey, *Virginia: Floods and Droughts*, Water-Supply Paper 2375, p. 543-550, accessed at md.water.usgs.gov, 26 March 2015.

¹²⁹ Ibid.

¹³⁰ Virginia Department of Emergency Management, *Hurricane History: Hurricane Gaston*, April 2005.

¹³¹ Ibid.

¹³² See note 31.

¹³³ We relied on the National Flood Hazard Layer produced by the Federal Emergency Management Agency (FEMA) for data on the presence and extent of flood hazard zones. These data are not available in ArcGIS format for all Wisconsin counties, which limited our analysis.

¹³⁴ See note 33.

¹³⁵ Faith A. Fitzpatrick, et al., U.S. Geological Survey, *Flood of June 2008 in Southern Wisconsin*, 2008.

¹³⁶ Karyn Saemann, “Treading Water – When Winter Gives Way to Spring, Lake Levels and Flooding Will Be on the Front Burner,” *The Capital Times*, 7 January 2009.

¹³⁷ “Storm Causes Dam to Collapse in Wisconsin,” *New York Times*, 10 June 2008.

¹³⁸ See note 135.

¹³⁹ Laura Sparks, “Interactive Map: Flood of 2008,” *Wisconsin State Journal*, 5 June 2013.

¹⁴⁰ See note 135.

¹⁴¹ A Special Flood Hazard Area (SFHA) is an area covered by the “base flood,” which is defined as the flood “having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the ‘100-year flood,’” per Federal Emergency Management Agency, *Base Flood*, accessed at www.fema.gov/national-flood-insurance-program/base-flood, 13 March 2015; Federal Emergency Management Agency, Special Flood Hazard Area, accessed at www.fema.gov/floodplain-management/special-flood-hazard-area, 13 March 2015.

¹⁴² U.S. Fish and Wildlife Service, National Wetlands Inventory, *Wetlands Mapper Legend Categories*, accessed at www.fws.gov/wetlands, 13 March 2015.

¹⁴³ U.S. Fish and Wildlife Service, National Wetlands Inventory, *Download Seamless Wetlands Data by State*, www.fws.gov/wetlands, 13 March 2015.

¹⁴⁴ Federal Emergency Management Agency, *Flood Map Service Center*, accessed at www.msc.fema.gov/portal, 13 March 2015.