Nelson Institute for Environmental Studies
UNIVERSITY OF WISCONSIN–MADISON

NELSON ISSUE BRIEF

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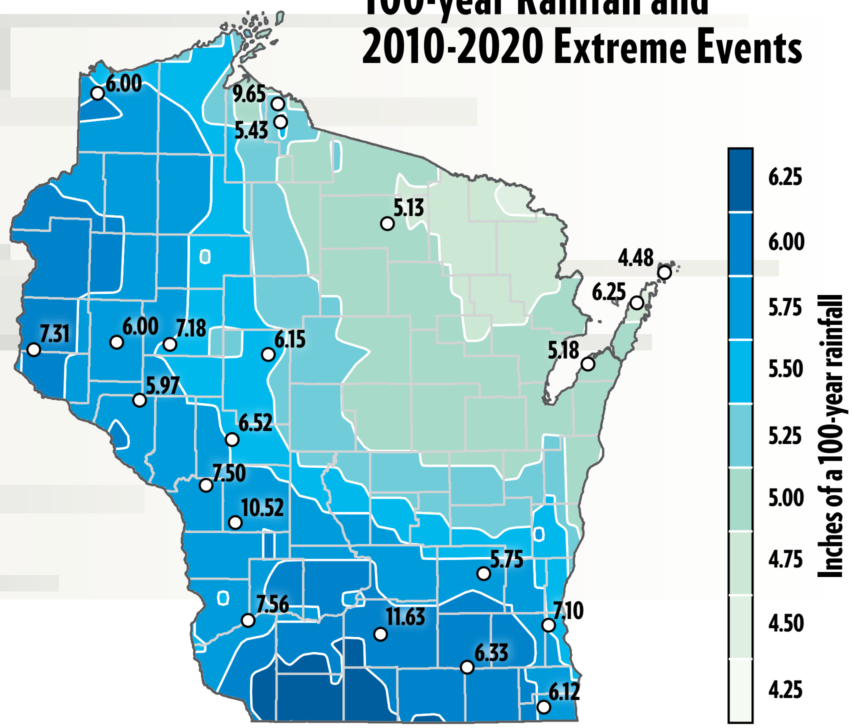
100-year Rainfall and 2010-2020 Extreme Events



NOTES: The extreme rainfall events are the largest independent events that exceeded the 100-year threshold. If an extreme event was recorded at numerous locations, only the largest recorded value was showed. Any two-day events were classified by their largest value recorded.

SOURCE: Center for Climatic Research, Nelson Institute for Environmental Studies, UW-Madison

DATA: UWPD Downscaled Data

WHAT ARE THE IMPACTS OF EXTREME PRECIPITATION EVENTS?

Introduction

Since 1901, the portion of annual precipitation falling during the heaviest one percent of rain events has increased substantially. Research suggests that this trend will continue, resulting in more frequent and intense extreme precipitation events that will have social, economic, and ecological impacts across the state.

In June of 2008, after nearly seven inches of rain in 24 hours, the dam that held Lake Delton broke, causing millions of dollars of property damage and disrupting the tourist season in the Wisconsin Dells area. That storm impacted nearly half of Wisconsin's counties and caused more than $750 million in damage statewide. Similar events have struck across the state: 2018 flooding in the Kickapoo River Valley and the destruction of the Saxon Harbor Marina in Iron County in 2016.

Extreme precipitation also impacts agriculture, as heavy rains in the spring and summer can cause damage to newly planted fields and delay harvest in the fall. The timing of these heavy rains may also contribute to more rain on frozen ground, degrading water quality, and reducing soil moisture. To succeed, farmers will have to adapt to changes in heavy rainfall patterns.

As the people of Wisconsin adapt to more frequent, heavier precipitation events, we present research detailing likely future precipitation changes, adaptation efforts, and ecological, social and economic consequences of the increasing frequency, and intensity of these events.

KEY POINTS

» Climate models suggest Wisconsin will become 10 percent wetter and precipitation will come in larger portions.

» New precipitation models that incorporate satellite data can expose threats to existing water infrastructure and guide planning for new projects.

» Heavy precipitation events will change the ecology of natural areas by increasing the frequency and intensity of flooding.

» Local communities and governments are responding to increased precipitation events in creative ways, building resilience through social connection.

Climate Change and Extreme Precipitation

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When we think about climate change, the weather variables that most readily come to mind are temperature and precipitation. Obviously, temperature rises in a warming climate, but how will precipitation change? Weather records collected across Wisconsin since the late 1800s indicate that our climate has recently become wetter, with more extreme precipitation. In fact, the 2010s was by far the wettest decade in state history and was accompanied by many damaging and even deadly floods.

One reason for this trend is that warm air can hold more moisture than cold air. Wisconsin's wettest three months (June, July, and August) are also our warmest months, and summer is typically the season with the most extreme daily precipitation. As the atmosphere warms, these summer storms wring out even more precipitation. Under future warming scenarios, climate models predict that most of the world will receive a higher proportion of their precipitation in heavier doses. However, only certain places will become wetter overall, because rainfall and snowfall also depend on atmospheric circulation patterns that guide weather systems. For example, when jet stream winds steer high-pressure cells our way, we can get stuck in a prolonged dry pattern even while long-term precipitation increases.

Climate models project that Wisconsin will become wetter in the future compared with the climate of today and the recent past. Most estimates suggest that our state's total precipitation will increase by around ten percent during the current century, and that the greatest changes will occur in winter and spring. Interestingly, the 2010s was even wetter than that estimate of future precipitation levels, which suggests that either climate models are underestimating future changes or that random variability has made Wisconsin wetter recently. Isolating the influence of human-caused climate change on observed precipitation trends is challenging, because natural variations in the climate system also contribute to extreme weather and can cause both a long string of rainy days and an extended drought.

As the "signal" from a warming climate increasingly outweighs the "noise" from natural variability, the future changes predicted by climate models should emerge. In Wisconsin this means a high likelihood that heavy downpours will become more frequent and intense (see figure 1). It appears, however, that the existing spatial pattern of precipitation will largely persist: southern and western Wisconsin will likely be impacted the most, but everywhere in the state will probably experience an upward trend. Some of the most important questions that University of Wisconsin-Madison climatologists are researching to improve predictions include: (1) Will changing global circulation patterns make the expected increase in extreme precipitation more severe or less severe?; (2) Will extreme precipitation events be more frequent, more intense, or both?; and (3) Will a wetter Wisconsin occur gradually or abruptly?

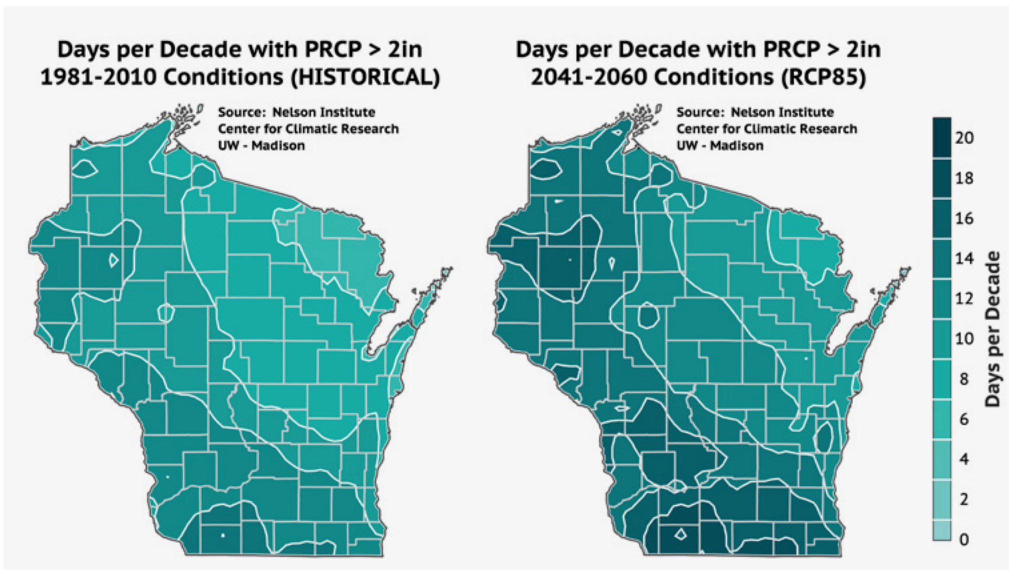

Figure 1: Projected change in the frequency of heavy precipitation days (more than two inches of rainfall) by mid-century (2041-2060) versus the recent past (1981-2010). Projection is based on a set of statistically downscaled global climate models driven by the high-end RCP8.5 greenhouse gas emissions scenario. Illustration courtesy of Dan Vimont and David Lorenz, Center for Climatic Research, Nelson Institute for Environmental Studies, UW-Madison.

Extreme Rainfall and Native Prairies

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In May and early June of 2008, a large region in south central Wisconsin, which included most of the drainage area of the Crawfish River, experienced a series of extreme rainstorms. Three unusual June rainfalls recorded at Beaver Dam/Westport had a cumulative total of 30.2 cm (11.9 in) and were the fourth, fifth, and ninth highest daily rainfall events out of the 10,649 events recorded from 2008 to 2019 at that site. This rain fell on a landscape that was already near saturation due to high rainfall and flooding in the autumn of 2007 followed by high snowfall in the winter. The result was a massive flood that peaked in June and slowly receded into July. What made the 2008 flood notable was not only its historical extreme, but the fact that it occurred well into the growing season, which caused it to devastate large areas of recently planted agricultural crops. The average monthly flow for June 2008 is still the greatest recorded at the U.S. Geological Survey (USGS) Milford gauging station since records began in 1931.

Our focus is on the effect of the flood on Faville Prairie, an unplowed remnant managed as a biodiversity reserve by the University of Wisconsin-Madison Arboretum. It is a site of importance in the history of conservation. In the 1930s, Aldo Leopold and his students conducted extensive studies on the then largely-undisturbed "Crawfish Prairie." At the time, the losses of wild prairies and wetlands were ramping up dramatically as farm fields were created by drainage using ditches and subsurface tiling. Leopold's essay "Exit Orchis", lamenting the loss of this pristine wetland prairie complex, prompted a private citizen to buy and donate land for a 92-acre fragment that is now the Faville Prairie.

An aerial view of the flooded Faville Prairie. Photo courtesy of Paul Zedler.

Did these extreme events, which produced flooding to a maximum depth of over a meter and persisted for weeks, do significant damage to this important remnant? When the waters abated, a few species emerged green and growing, but the above-ground parts of many more species were dead. However, by the end of the 2008 growing season, most species had recovered by resprouting. Tradescantia ohiensis (spiderwort) rebounded and flowered in profusion. Populations of several other iconic prairie species, though, were drastically reduced, such as Silphium terebinthinaceum and S. laciniatum (prairie dock and compass plant). Dodecatheon meadia (shooting star) seems to be extinct on-site. Our conclusion is that if a flood like this recurs more often than every 50 years, this highly vulnerable remnant prairie will not survive with its full complement of species. We would expect the site to gradually degrade and to become impoverished in native species, enriched in invasive exotics – a victim of the shift in flood timing and increased rainfall intensity.

Wisconsin's Infrastructure is Increasingly at Risk Due to Extreme Rainfall

INFRASTRUCTURE RISK

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"Ten-year" and "100-year" storms, as measures of extreme rainfall, are used to design much of our civil infrastructure, including bridges, culverts, storm sewers, detention ponds, and dams. The first nationwide analysis of these storms dates from a 1961 publication by the US Weather Bureau called "Technical Paper 40." The National Weather Service released updated results for the Midwest in "Atlas 14" Volume 8 in 2013. Atlas 14 included an additional five decades of data collected since 1961, a time period which saw substantial increases in rainfall depth and frequency—see Figure 2 right. These increases translated into upward revisions of the analyses. In Madison, Wisconsin, for example, the 24-hour, 100-year storm increased from about 6.0 inches of rainfall in Technical Paper 40 to about 6.6 inches in Atlas 14. Climate change is the most likely culprit.

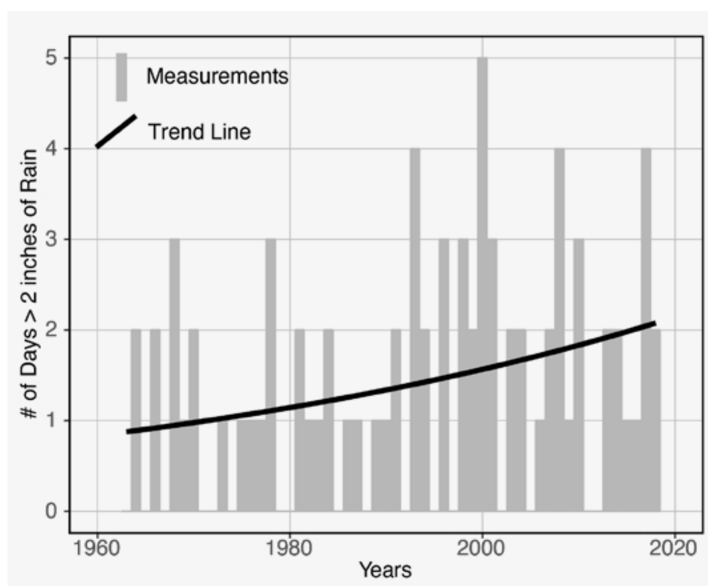

Figure 2: The number of days per year, 1961 through 2018, that had greater than 2 inches of rain in west Madison. The frequency of such days has doubled over this time.

Rainfall extremes continue to increase in frequency and amount. Our recent research shows that Atlas 14 is already out-of-date over much of the country, seriously understating current levels of extreme rainfall. The RainyDay software we developed at UW-Madison provides a fast, low-cost option for improving upon Atlas 14 by drawing on recent storms from around the state. It does so using weather radar, which can observe rainfall patterns over large areas, as opposed to at individual locations like conventional measurements. These improved predictions, illustrated in Figure 3, are now being utilized by several local municipalities for stormwater and floodplain analysis.

Current projections from other UW researchers suggest that today's 100-year storm may occur five times more often by the end of the 21st century. Because water infrastructure is built to last fifty years or more, continued rainfall intensification means that our infrastructure will become more and more vulnerable and inadequate as it ages. We seek to use the best available techniques to project rainfall changes for the next 50 to 100 years. This will help engineers to make more resilient designs, operations, and maintenance plans. Up-to-date analyses of rapidly-changing extreme rainfall events are needed in order to protect Wisconsin's infrastructure, communities, and economy.

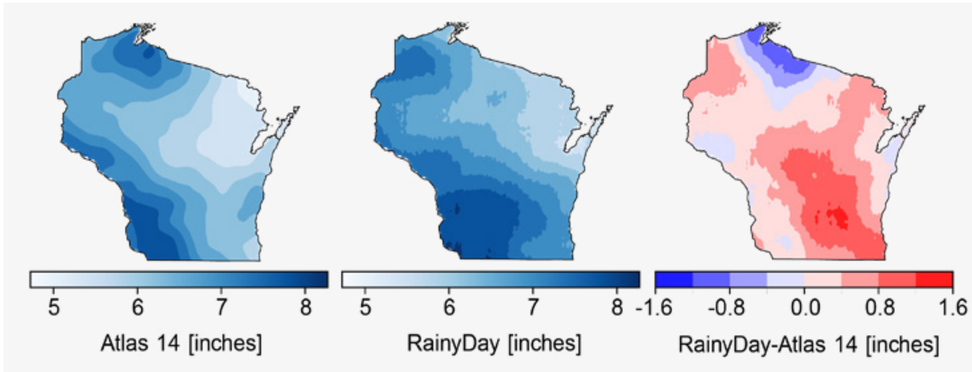

Figure 3: 100-year 24-hour storm rainfall depth projections from NOAA Atlas 14 (left) and RainyDay software (middle). The difference between the two is shown on the map on the right.

How do Soil and Water Conservation Agencies Adapt to Extreme Storm Events?

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Soil and water conservation professionals are responsible for advising farmers and other land managers about soil health and water quality. They are on the front lines of adaptation to extreme storms that cause soil erosion, flooding, and nutrient loss from farms, roads, and other land uses.

We surveyed staff who work in soil and water conservation department (or district) offices in Upper Mississippi River Basin states in 2016 to better understand how and why conservationists have adapted to extreme storm events. The survey had a 43 percent response rate with 276 staffers responding to our survey from seven states: Illinois, Indiana, Iowa, Minnesota, Missouri, Ohio, and Wisconsin.

The majority of respondents thought that increases in large storms would have "some" to "a great deal" of negative impact on landowners and operators (93 percent WI, 90 percent regional), as well as on water quality (98 percent WI, 90 percent regional). In response to the impacts of these storms, most respondents' offices have made changes to conservation planning and implementation (see figure 4).

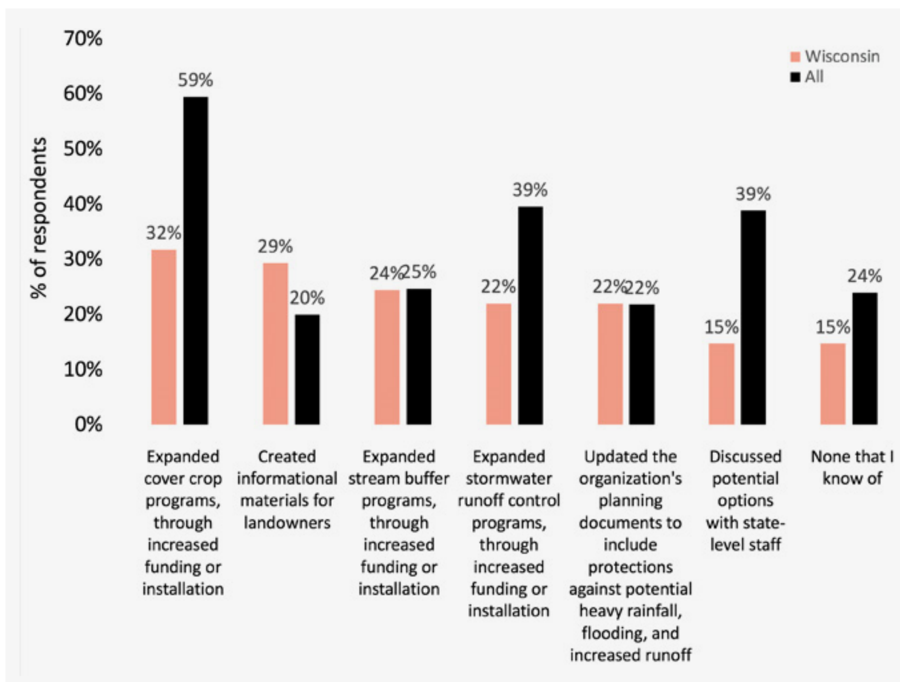

Figure 4: Response to the question "What changes, if any, has your office made related to the impacts of extreme storm events on water quality? Choose all that apply." The percentage of respondents who indicated "yes" is shown (n=276).

Conservation staffers were "somewhat" to "quite a bit" concerned about the impacts of climate change on the county where they work, on average. However, about one-quarter (25 percent WI, 25 percent regional) were only "a little" to "not at all" concerned. Staff who were more concerned about climate change were more likely to work in offices that provide updated informational material for landowners, discuss options with state staff, and update planning documents dealing with large storm events. Staff with high climate change concern were no more likely to work in offices doing expanded cover crop and stream buffer programs or increased stormwater control measures.

In climate change adaptation there is often a delay while implementation catches up to planning. In contrast, conservation staff in our survey were more likely to have adopted certain adaptation actions like cover crops than they were to have updated their plans. But this did not always reflect conscious climate concern: we found that conservation program staff were more concerned with climate change if they were engaged with adaptation planning strategies (e.g., planning document updates) than if they were involved with implementing adaptations on-the-ground (e.g., expanded stream buffer installation). Also, weather projections were more often used in offices that were both updating plans and implementing adaptation measures on the ground than they were in offices doing just one of these.

Adaptation to climate change by conservation agencies is complex and depends on the decisions of field staff in a variety of programs. Our study contributes to efforts to understand how adaptation decision-making actually works in the public sector.

Prairie Creek; Image courtesy of Wisconsin Department of Natural Resources.

Stories from the Flood: Extreme Precipitation in the Driftless Area

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With the help of local partners in Southwestern Wisconsin—Vernon County Land and Water Conservation Department, Valley Stewardship Network, Driftless Writing Center, Trout Unlimited Driftless Area Restoration Effort, Monroe County Land Conservation Department, Kickapoo Valley Reserve—we are working to better understand how floods and restoration projects impact the landscape. Our research works across the biophysical sciences and the humanities to come to a richer understanding of how individual and policy decisions impact flooding, how perennial grasslands can increase flood resilience by reducing runoff and erosion, and how flooding impacts people's lives, in hopes of planning together for a better future.

UNDERSTANDING DRIFTLESS FLOODING

The Kickapoo and Coon Creek watersheds have experienced at least three 100-year floods in the last decade. The worst of these, in August 2018, caused an estimated $29 million in damage—almost $1,000 per person—to businesses, homes, and public infrastructure in Vernon County alone. A couple of years later, communities are struggling to make repairs and, with the leadership of local community groups, beginning a public discussion about what flood resilience might look like. The major question is no longer whether the next catastrophic flood will happen, but how soon. In response, local non-governmental organizations (NGOs) and farmers have promoted agricultural conservation practices and stream restoration projects, but efforts are complicated by uncertainty about which approaches might produce the most beneficial impacts.

HOW DO FLOODS AFFECT STREAM RESTORATION SITES?

We conducted pre- and post-restoration stream channel and habitat surveys at Kickapoo watershed stream restoration sites that featured riparian tree removal, streambank resloping, and the installation of riprap and habitat structures. Sampling through August/September 2018 flooding on Conway Creek and July 2019 flooding on Billings and Warner Creeks showed: (1) floods can change stream channels as much as construction from stream channel restoration can; (2) restoring the original slope to an entrenched streambank—without also restoring a wider flood-carrying channel—does not dissipate enough flood energy to prevent flood impacts downstream; and (3) flooding seems to prompt a spike in methane emissions—a potent greenhouse gas—from Valley streams, particularly when floodwaters enter a restoration site before vegetation has a chance to reestablish post-construction.

HOW DO STREAM RESTORATIONISTS SHAPE STREAMS?

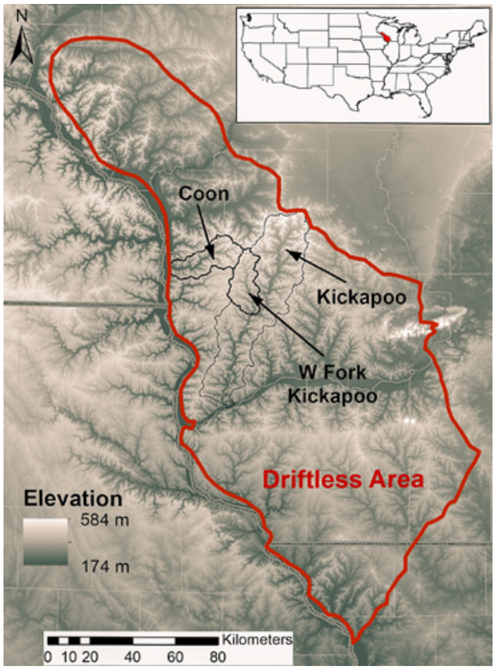
To place these stream changes in their human contexts, we are interviewing and hosting workshops with restoration managers to ask how they balance tradeoffs between flood protection, trout habitat, and agricultural land uses. We've found that while managers tend to focus on their own particular interest areas—habitat, hydrology, geomorphology, or watershed-based perspectives—they share some perspectives, as well. The vast majority emphasize that stream restoration should be done with the goal of recreating a natural and dynamic connection between streams and their floodplains, rather than simply aiming to design a localized static channel and bank form. However, this goal is confounded by the threat of flooding as managers feel pressure to create a stable stream that can ride out the next flood surge unchanged. At a stakeholder workshop, many managers echoed these views, but also said they felt strongly that channel-focused restoration efforts need to work in concert with land use changes in the larger watershed around the channel. In other words, the restoration of a stream itself, whether resulting in a static channel or a changing one, can't begin to address the continued impacts of flooding without widespread changes to upland land management practices.

THE POWER OF STORY

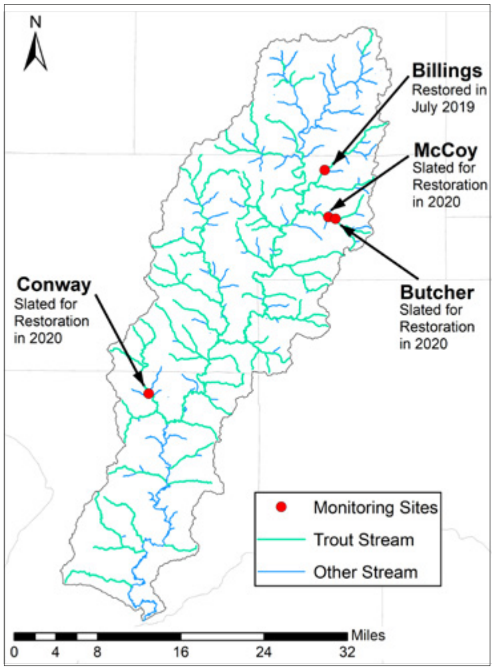
Science is only part of the solution to future flooding. It is crucial we listen to residents living through flooding and to their ideas about moving forward. We have been working with the Driftless Writing Center on "Stories from the Flood," a community-based project to collect and share stories about catastrophic flooding in the Kickapoo and Coon Creek watersheds. Stories from the Flood aims to help flood-affected residents process their trauma, document the damage of the 2018 floods, and build a community conversation about how to live well together with floods. Through community workshops and individual meetings, an all-volunteer force has collected almost 100 oral history narratives to date, and that archive is growing.

This archive will be central to our collective understanding of Wisconsin's flood history and changing present, offering a roadmap for communities recovering from the increasingly common impacts of flooding. By the time of the Stories from the Flood Celebration in November 2019, the archive had already documented a widespread acknowledgment that the frequency and magnitude of flooding in the area is worsening. The archive showed that 2018 flooding wrought catastrophic damage on homes, businesses, farms, and infrastructure. The flood cleanup also left a long-lasting suite of health impacts, including lingering gastrointestinal distress and respiratory issues, and community members continue to suffer the negative mental health impacts of living chronically in the liminal space between two floods. There is a significant need for flood recovery assistance, both financial and emotional, and a need for coordinated planning and better access to recovery resources. But, the archive is also filled with stories of flood recovery and resilience: of neighbors helping neighbors, community members organizing donation centers, strangers arriving to muck out barns and rebuild houses, community meal sharing, and smart analyses of the strengths communities can build from as they plan for the future.

We need projects like Stories from the Flood that document and call attention to the stories of those impacted by flooding. Communities across the Kickapoo and Coon Creek watersheds, and around Wisconsin, will benefit from addressing the needs that are becoming visible through this work: improved infrastructure, improved flood modeling, updated floodplain mapping, access to recovery funds, prevention and treatment of flood borne illness, and mental health resources. And, we all need to live in awe and wonder of our region's waterways, doing our collective best to slow water running off the landscape, to reconnect our streams to their natural floodplains, to support land management practices that address accelerated soil erosion, and to connect with each other to live well together into the future.



Location of Wisconsin's Kickapoo and Coon Creek watersheds in the Midwest's Driftless Area.



Kickapoo Watershed showing restoration monitoring site locations.


Extensive flooding in the Kickapoo River watershed in August 2018.


Impact of a flash flood in July 2019 on a recently completed restoration project on Billings Creek.


Gays Mills Community Center. Photo courtesy of Tim Hundt.


Student volunteers collect a flood story from Angie and Elmer McCauley as part of the Stories from the Flood project. Photo courtesy of Sydney Widell.

RESOURCES

Wisconsin Initiative on Climate Change Impacts – How is Wisconsin's Climate Changing?
wicci.wisc.edu/climate-change.php#0

Wisconsin's Changing Climate: Impacts and Adaptation
wicci.wisc.edu/publications.php

U.S. Global Change Research Program Indicator Platform
globalchange.gov/browse/indicators

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