ON TO 2050 Stormwater and Flooding Strategy Paper

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Introduction

Urbanization and climate change are leading to more frequent and intense flooding events in northeastern Illinois. A central message of GO TO 2040 was to integrate land use policies and site planning with water resources, which remains an important guiding principle to achieve a variety of environmental and economic goals. However, amidst growing evidence of increasing frequency and intensity of storm events, the extent and costs of urban flooding, and the continued costs of riverine flooding, CMAP identified the need for a refined set of strategies to improve stormwater management and reduce flooding damages in the region.

This strategy paper reviews the impacts of flooding, and explores policy recommendations and strategies for ON TO 2050 to better protect communities from floodwaters and prepare for tomorrow's storms. The policy directions in this paper build on GO TO 2040 by providing additional specificity on both the recommendations and implementation. This paper was drafted in conjunction with other policy work on water quality and water supply issues, presented in the Water Resources strategy paper.[1] This paper integrates the lessons learned from regional stakeholder engagement, review of the GO TO 2040 plan and implementation achievements, and national best practices research. In addition, CMAP staff analyzed the direct and indirect impacts of flooding and conducted a series of interviews with stakeholders involved with stormwater management in communities that have experienced flooding.

CMAP staff utilized the expertise of the CMAP Environment and Natural Resources working committee to provide key input into the scope, direction, and content of this strategy paper. Since 2014, CMAP has been a member of the Calumet Stormwater Collaborative, a coalition of nonprofit organizations, government agencies, and other stormwater professionals facilitated by the Metropolitan Planning Council (MPC). That experience has informed this paper and members of the collaborative have been key advisors in policy development. In addition, CMAP consulted with and received feedback from representatives from the Metropolitan Water Reclamation District of Greater Chicago (MWRD) and the six other county stormwater management agencies or departments, Forest Preserve and Conservation Districts, Illinois State Water Survey (ISWS), Illinois Department of Natural Resources (IDNR), U.S. Army Corps of Engineers (USACE), and the Illinois Association for Floodplain and Stormwater Management (IAFSM). Special thanks to the Federal Emergency Management Agency (FEMA), who provided critical datasets that informed CMAP's analysis of past flooding damages as well as the creation of a regional flooding susceptibility index to identify priority areas for flooding mitigation activities.[2]

[1] "ON TO 2050 Water Resources Strategy Paper," Chicago Metropolitan Agency for Planning, 2017, http://www.cmap.illinois.gov/documents/10180/653821/Water+Strategy+Paper_FINAL_+9-21-17.pdf/b7aa6b24-a482-4718-b51f-e82effc34a9e.

[2] CMAP developed the regional flooding susceptibility index with support from the John D. and Catherine T. MacArthur Foundation.

Flooding impacts in the Chicago region

While flooding is a natural process, development and changing precipitation patterns due to climate change have changed the way water flows through the landscape. The causes of flooding are quite complex and are the result of a series of interrelated factors having to do with environmental conditions, climate change, development extent and location, stormwater system design and maintenance, and our regulatory structure. Development often results in the creation of impervious cover, which prevents the infiltration of rainwater into the ground and generates additional stormwater runoff absent other infiltration, retention, or detention measures. As the volume of stormwater runoff increases, some locations experience urban flooding when the capacity of local drainage systems, such as storm sewers and ditches, are overwhelmed. This can lead to ponding of water in streets and yards as well as water entering buildings through the foundation or through sewer backups in combined sewer areas. As the rain continues, the increased stormwater volumes ultimately enter rivers and streams, contributing to overbank flooding. The impacts from flooding can be quite severe, in terms of damages to homes and businesses as well as to residents and community assets, such as water quality, open space, and transportation networks.

This section will review what is known about existing damages from flooding, how those damages are distributed spatially throughout the region, how flooding impacts the region's abilities to implement the regional vision, and how flooding damages are projected to continue to rise in the face of increasing intensity and frequency of storm events due to climate change.

The region experiences significant and chronic damages from flooding

Around the globe, urban and riverine flooding presents significant economic, social, and environmental challenges. In 2015, IDNR conducted a study of the cost and prevalence of urban flooding within the State of Illinois.[3] Using data from private insurance claims,[4] National Flood Insurance Program (NFIP) claims, and Federal disaster relief claims from Individual Assistance (IA) and Public Assistance (PA) programs, IDNR found that flooding in urban areas across the state resulted in $2.319 billion in damages between 2007 and 2014 (Figure 1). Approximately 79 percent, or $1.832 billion, of those payouts were located in six of the seven counties of the CMAP region.[5] IDNR found that a majority of the payments could be tied to five specific storm events and that 90 percent of damage claims were for locations outside of the mapped 100-year floodplain. This highlights the highlighting the degree to which Illinois' floodplain maps have become out of date and no longer accurately reflect the risk that communities and developers must plan to address. It also sheds light on the level of impact experienced from

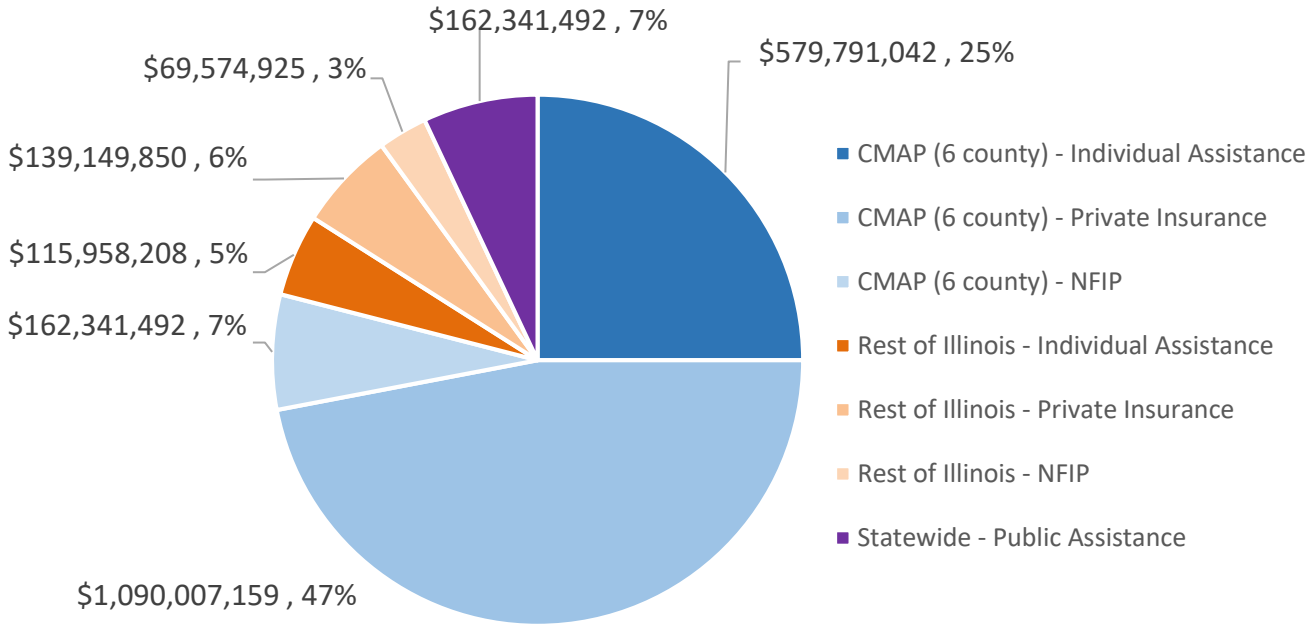
[3] Brad Winters, et al, "Report for the Urban Flooding Awareness Act," State of Illinois Department of Natural Resources, Office of Water Resources, June 2015, http://www.isws.illinois.edu/hilites/more.asp?id=ufaa&fr=hi

[4] Private insurance claim data represents data from riders focused on basement/foundation flooding, including sump pump failure and sewage backup not due to riverine flooding.

[5] The UFAA report did not include Kendall County in the CMAP region.

urban flooding in the region, yet many existing programs and strategies are focused on riverine, not urban, flooding.

Figure 1. Total insurance and disaster relief payouts by claim type and region for the State of Illinois, 2007-2014.



Source: 2015 State of Illinois Department of Natural Resources.

To better understand the location and costs of flooding damages within the Chicago region, CMAP evaluated NFIP policies, claims, and payments, FEMA disaster relief IA grants, and Small Business Administration (SBA) loans from 2003 to 2015[6] by zip code.[7] Combined, NFIP, IA, and SBA programs provided the Chicago region with $907 million in flood relief between 2003 and 2015. Figure 2 highlights the total damage payments associated with NFIP, IA, and SBA payments by Zip code normalized by 2010 households during this time period. The majority of payouts come from FEMA IA grants (65 percent), followed distantly by NFIP claims (18 percent).

To interpret the results, it is helpful to have a better understanding of the different features of these three federal programs. Created in 1968, the NFIP was designed to supplement private insurance policies, such as renters and homeowners insurance, that do not typically cover losses from riverine flooding. Today, NFIP policies are mandatory for all newly constructed or renovated structures with federally-backed mortgages located within the 100-year floodplain,

[6] This exact time period of the preceding analysis is from October 1, 2003 to February 26, 2015. This time period was chosen based on the available data from all three datasets.

[7] Zip code geography was the smallest analysis unit available across all three datasets.

and are available on a voluntary basis for renters and property owners located outside of these areas as long as the community or county has adopted FEMA-approved floodplain management regulations.[8] In order to file an NFIP claim, the property owner must have a policy and be able to show that the damages were caused by flooding.[9] NFIP policies have been purchased in almost every applicable Chicago area community.

In the Chicago region, 63 percent of paid NFIP claims were located within the 100-year floodplain. Paid claims in the floodplain accounted for 72 percent or $115 million of the total payments from NFIP (Table 1). The average payment for claims in the 100-year floodplain was slightly higher than payments made outside of this area. Approximately 37 percent of paid NFIP claims and 28 percent of all NFIP payments are generated by policyholders who are not required to purchase NFIP flood insurance.

Table 1. NFIP claims and payments in relation to the 100-year and 500-year floodplain, in the Chicago region from 2003 to 2015.[a]

	Filed Claims	Claims with Payment	Average Payment	Total NFIP Payouts
100-year floodplain	6,250	5,261	$ 21,984	$ 115,659,786
500-year floodplain[b]	1,273	1,005	$ 12,806	$ 12,869,589
Outside floodplain	2,816	2,101	$ 15,169	$ 31,869,155
Total	10,339	8,367	$ 19,170.38	$ 160,398,530

[a] Does not include claims/payments for addresses that could not be matched using geo-coding.

[b] The percentage of claims filed for locations within the 500-year floodplain does not include the area also identified in the 100-year floodplain.

Source: 2017 Federal Emergency Management Agency.

Following a presidentially declared disaster, local residents, businesses, and governments are eligible for federal relief programs through FEMA's Individual Assistance (IA) grant programs. Presidentially declared disasters are reserved for events of such severity and magnitude that the state or local governments cannot effectively respond.[10] The disasters are declared by county and are not limited to floodplain locations. The region experienced five presidentially declared disasters related to flooding between 2003 and 2015 (Table 2). The FEMA IA grant program consists primarily of one-time grants to residents and businesses for immediate relief and structural repairs and are available to all residents regardless of income.

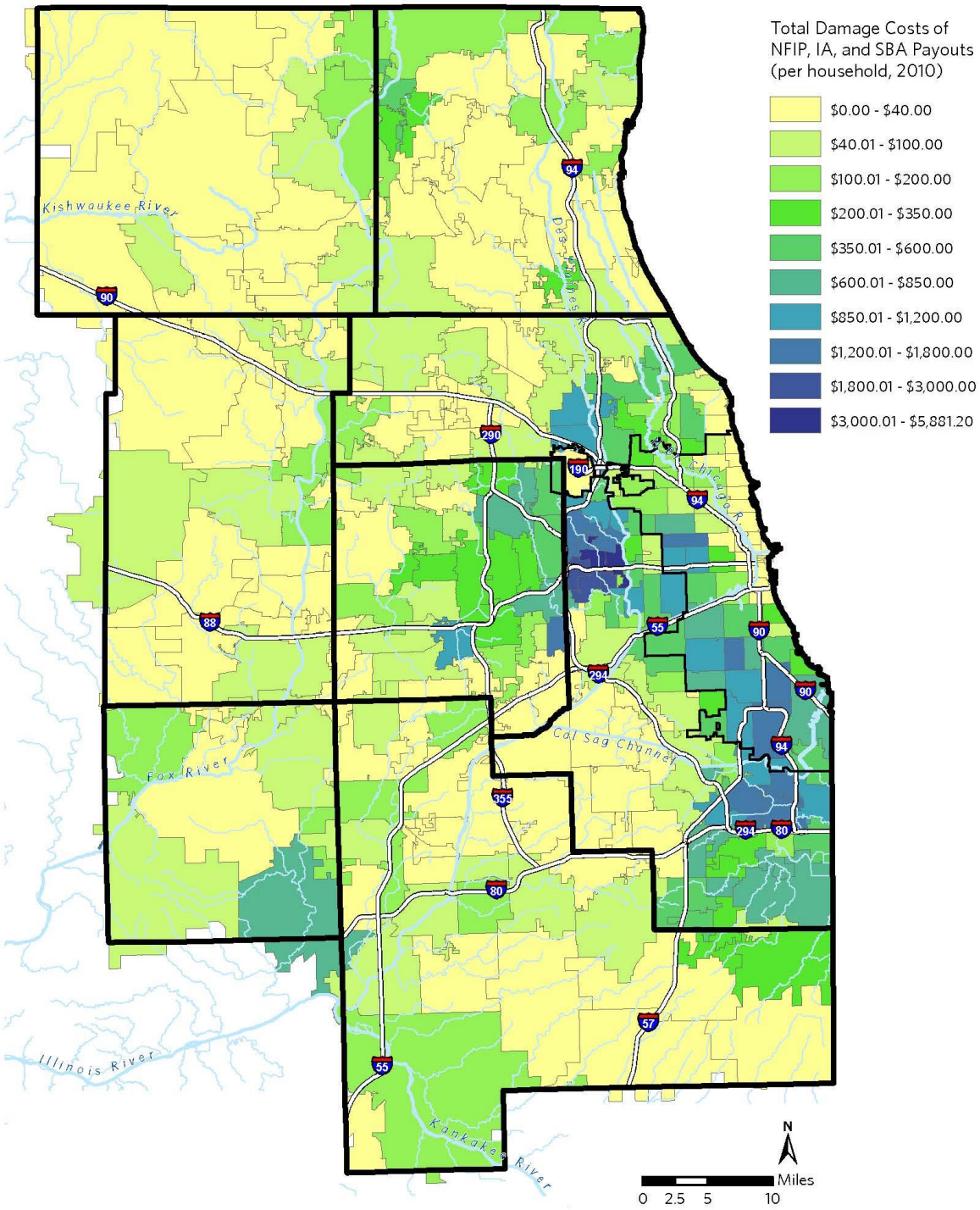
Federal disaster relief grants through the Individual Assistance program to residents and businesses totaled $585 million, making it the largest program providing flood payments in the Chicago region. Approximately 95 percent of all IA payments occurred for locations outside of the 100-year and 500-year floodplain. The IA grant program paid 192,220 claims, with an average of $3,046 per claim, and payments were heavily concentrated in Cook County (93 percent). A quick comparison between IA and NFIP payments shows different distributions –

[8] Almost all communities with floodplains in the Chicago Region are covered by NFIP, see www.fema.gov/cis/IL.pdf

[9] If a sewer backup occurs in the basement that can be attributed to flooding, it is covered.

[10] FEMA Disaster Declaration Process. See www.fema.gov/disaster-declaration-process

Figure 2. Total flooding damage payments associated with NFIP, IA, and SBA programs per 2010 household by zip code in the Chicago region from 2003 to 2015.



Chicago Metropolitan Agency for Planning, 2017.

with IA damages concentrated in southeastern and western Cook County and NFIP payments concentrated in northwestern and western Cook County and eastern DuPage County.

Table 2. Presidentially declared disasters eligible for IA grants by county.

August 20 - 31, 2007 (DR-1729)	Kane, Lake, and Will
June 1 - July 22, 2008 (DR-1771)	Lake
September 13-October 5, 2008 (DR-1800)	Cook, DuPage, Kane, and Will
July 19-August 7, 2010 (DR-1935)	Cook, DuPage
April 16-May 5, 2013 (DR-4116)	Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will

Source: 2017 Federal Emergency Management Agency.

If a resident or homeowner experiences damages in excess of what their NFIP insurance or IA grant will cover, they may be eligible for a low-interest, long-term disaster loan through the Small Business Administration. These loans are intended to be a last resort, and are only eligible for demonstrated needs that are not covered by other relief programs. Access to SBA loans are granted following a presidentially declared disaster or additional disasters identified by the state. The region has experienced four such additional disasters between 2003 and 2015.[11] The Small Business Administration provided the region with $157 million in low-interest disaster loans between 2003 and 2015.[12] Approximately 87 percent of this total, or $137 million, were made to individuals. The remaining $21 million went to local businesses. Similar to the IA program, SBA loans were heavily concentrated in Cook County (82 percent).

While the damages documented through the NFIP, FEMA IA grant program, and SBA loan program help provide a partial understanding of the cost and extent of flooding, it is not comprehensive of the damages experienced in the region. There are a variety of limitations and barriers to consider, including the lack of private insurance data, economic barriers in obtaining insurance, underutilization of available resources, and flooding associated with smaller storm events that may not trigger presidentially declared disasters. Flooding is known to result in property damage under a range of different sized storms. For example, some neighborhoods experience basement backups during 2 to 5-year storm events which will not be captured by disaster relief programs. In addition, this analysis focused on property level damage and did not include disaster relief and hazard mitigation programs for local governments.

CMAP was unable to obtain the private insurance claims data on basement/foundation flooding for this analysis. Reviewing data for six counties in the Chicago region, the Illinois Department of Natural Resources (IDNR) found that private insurance claims accounted for almost $1.09

[11] For purposes of this report, CMAP reviewed SBA loans associated with the five presidentially declared disasters and four additional disasters recognized by the SBA program: March 17-April 20,2008 (IL-00014), July 27-28, 2011 (IL-00032), April 4, 2008 (IN-00022), June 18-19, 2009 (WI-00019).

[12] SBA Disaster Loans are intended to supplement public and private relief programs. Interest rates, repayment periods, and other terms are determined by need, availability or credit, and amount of non-SBA relief received.

billion or 60 percent of payouts when evaluating NFIP, IA, and private insurance payments between 2007 and 2014.[13] In 2014, CNT reviewed the cost and prevalence of flooding within Cook County by zip code between 2007 and 2011 and found that 28 percent of payments came from private insurance.[14,15] While these two studies used different time periods and geographies, the difference in private insurance amounts could be partially attributed to different rates of securing private insurance within the Chicago region.

Parts of the region face greater flooding challenges

As shown above with the available data on flooding damages, parts of the region are more susceptible to flooding. These are largely locations that predate modern stormwater and floodplain management design standards and/or have been impacted by increased development within the watershed or sewershed. When flooding does occur, some populations and communities struggle to recover from flooding damages and may lack the capacity or financial resources to reduce their exposure in the future.

The extent of development and the transformation of the landscape has increased stormwater runoff and contributes to downstream flooding and demands on the drainage system. Wetlands and other permeable landscapes have provided storage and infiltration for rainwater volumes. Agriculture and urbanization have led to large-scale removal of natural habitat and subsequent alteration of drainage patterns through the creation of impervious surface. Much of the Chicago region was constructed before the advent of modern stormwater management principles. The designs of this earlier development focused on conveying runoff from impervious surfaces as quickly as possible and eliminated natural drainage and infiltration capacity. Given this drainage structure – without a focus on managing the stormwater onsite – storm events that overwhelm a portion of the system often lead to flooding elsewhere. Development and infrastructure decisions in one location can have downstream impacts, yet those impacts are not always properly understood or evaluated during the development process, especially across jurisdictional boundaries. In recent years, the loss of storage volume provided by some of these resources have been mitigated for via county stormwater and floodplain management regulations; yet large areas lack proper stormwater management facilities or are impacted by upstream actions.

Development has been constructed in a variety of locations that are more prone to flooding due to environmental conditions. Construction of homes and businesses have occurred within the floodplain, which is an area of higher documented flooding risk. Starting nationally in 1968, mapped floodplains were recognized in development regulations to keep people and

[13] Brad Winters, et al, "Report for the Urban Flooding Awareness Act," State of Illinois Department of Natural Resources, Office of Water Resources, June 2015, http://www.isws.illinois.edu/hilites/more.asp?id=ufaa&fr=hi

[14] Center for Neighborhood Technology, "The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL," 2014, www.cnt.org/sites/default/files/publications/CNT_PrevalenceAndCostOfUrbanFlooding2014.pdf

[15] The private insurance percentage cited here excludes the PA and SBA data also provided by CNT's analysis for Cook County for easier comparison with the percentages cited in IDNR's Urban Flooding Awareness Act report.

investments out of harm's way; yet a significant portion of development predates these regulations. In addition, continued development and increasing precipitation trends may result in the expansion of the floodplain into areas that were not designed to accommodate flood levels. Development has also occurred in areas with hydric and poorly draining soils, areas with a high groundwater table, and low-lying areas. Such conditions, absent an adequate or maintained drainage system, can cause yard ponding and basement flooding or seepage. Basements are prevalent in the region and stormwater can enter a variety of ways, including via the sewer system.

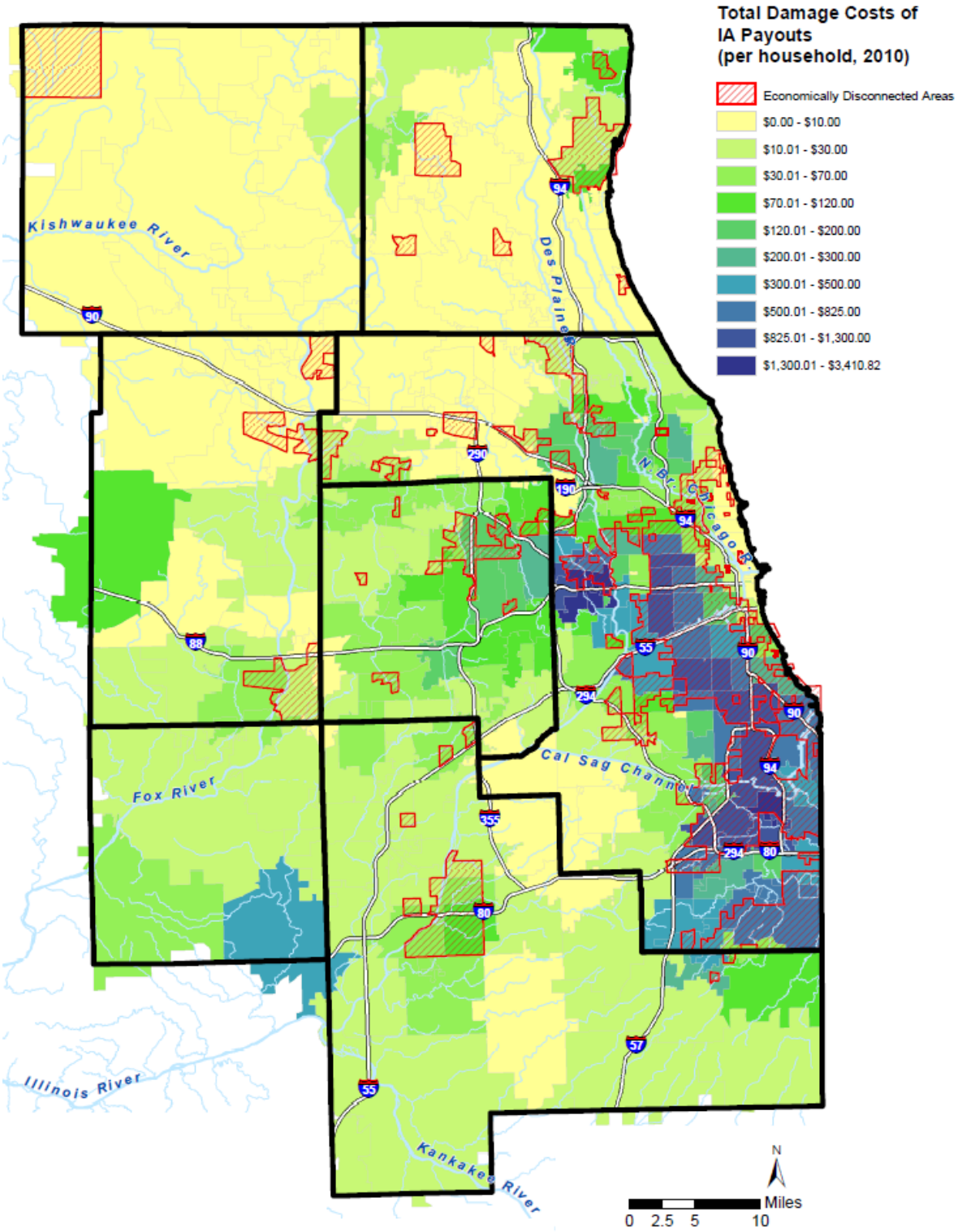
Flooding does not affect all populations equally. Vulnerability to flooding appears to be greater in individuals already facing social vulnerability due to socioeconomic, demographic, and health factors.[16] Through exploration of inclusive growth strategies, CMAP has identified economically disconnected populations that may lack access to critical resources that allow them to participate fully in the regional economy. These same conditions can make it difficult for residents to respond to flooding as it occurs as well as the aftermath of damages it can bring to homes and businesses. During flooding events, the elderly and residents with disabilities or illnesses are most vulnerable to acute, disruptive flooding, particularly when power outages and transportation disruptions interrupt daily needs and medical treatment. Low-income residents may struggle to pay for flood insurance, the clean-up costs and loss of personal belongings, as well as the repairs that could reduce their flood exposure in the future. Renters insurance does not cover flood damage, and most landlords purchase structure-only policies, leaving tenants' possessions unprotected. Figure 3 overlays CMAP's economically disconnected populations with flooding damages documented through the FEMA IA grant program from 2003 to 2015. This grant program was selected given that it is available to all residents and does not require advance participation or other loan requirements as required by NFIP and SBA disaster loans respectively.[17] Many of the zip codes with the highest amount of damages correspond with the census tracts identified as economically disconnected, particularly southeastern and western Cook County.

Communities that have experienced disinvestment, or a persistent lack of private and civic investment after the long-term flight of businesses and/or residents, can be more vulnerable to flooding when it occurs. Disinvested areas may have higher building and lot vacancies, low tax bases with high tax rates, and aging or poorly maintained physical infrastructure, and their residents may experience higher rates of poverty and unemployment. The cost of chronic flooding on public assets is a drain on all municipal governments, but local governments already facing constraints due to disinvestment may have a particularly hard time responding to flooding. They may lack staff to document damages that help obtain public

[16] Lowe, Dianne, Kristie L. Ebi, and Bertil Forsberg. "Factors Increasing Vulnerability to Health Effects before, during, and after Floods," International Journal of Public Health, 2013. 10, 7015-7067; doi:10.3390/ijerph10127015.

[17] Economic factors are likely influencing participation in the NFIP program. IDNR found that the average household income for NFIP claims was $61,626. While the NFIP provides voluntary insurance to most communities in the region, residents may not participate given economic constraints.

Figure 3. Economically Disconnected Areas and IA grant payments per 2010 household by zip code in the Chicago region, from 2003 to 2015.



Chicago Metropolitan Agency for Planning, 2017.

assistance dollars and lack the critical financial resources to repair damages and maintain stormwater infrastructure. In addition, they may lack the capacity to effectively implement floodplain management solutions or develop stormwater management plans that could reduce the risk to residents, businesses, and public assets in the future.

Flooding impacts implementation of regional strategies

Flooding impacts the region's ability to develop an enviable quality of life and economic vitality for all. GO TO 2040 identifies a series of strategies to help us achieve this regional vision, including directing reinvestment and growth to existing communities, maintaining existing roads and transit to foster a robust economy, and protecting and enhancing our natural resources that provide essential services. Yet flooding, particularly chronic flooding, can lead to reductions in quality of life and make it more difficult to implement many of the strategies that are key to regional prosperity.

Property damages from reoccurring flooding can contribute to larger scale disinvestment that is not fully captured in insurance claim or disaster relief data. Flooded areas can become less desirable places to live and work, which may hamper redevelopment and increase disinvestment in the area. Areas that flood show signs of deterioration, including worn building facades, streets, and sidewalks, and flooding also contributes to the devaluation of property. CNT found that wet basements can decrease property values by 10 to 25 percent and are cited as a primary reason for not purchasing a home.[18] According to FEMA, nearly 40 percent of small businesses never reopen following a flooding disaster.[19] These vacant storefronts can decrease property values and vibrancy in downtowns and other commercial areas. The contribution of flooding to disinvestment can make it difficult for the region to pursue infill and redevelopment strategies until stormwater management solutions are in place.

Stormwater runoff carries non-point source pollutants from streets and lawns, which impair water quality and corresponding habitat in streams and rivers. This not only impacts surface water quality but also the quality of groundwater, and can lead to increasing treatment costs for community water suppliers. At the same time, the impervious surfaces that generate stormwater runoff can significantly reduce the infiltration and recharge of rainwater into groundwater systems. In combined sewer systems, excessive stormwater runoff volumes can cause overflows of combined sewage and stormwater into receiving rivers, thereby impairing aquatic habitat and potentially increasing downstream drinking water treatment costs, particularly on the Fox and Kankakee Rivers.

Stormwater entering either a combined sewer system or through inflow and infiltration of a separate sewer system increases the demand on wastewater treatment facilities as it works to

[18] Center for Neighborhood Technology, "The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL," 2014, www.cnt.org/sites/default/files/publications/CNT_PrevalenceAndCostOfUrbanFlooding2014.pdf

[19] Federal Emergency Management Agency, "Make Your Business Resilient," 2016, www.fema.gov/es/media-library/assets/images/116921

treat both sewage and stormwater. Wastewater treatment is expensive and energy intensive, and such investments are wasted if used to treat stormwater. In addition, rising floodwaters can impair infrastructure and facilities used to convey and treat water, such as wastewater and water supply treatment facilities and distribution systems. Stormwater runoff and flooding increase the costs of restoring our water resources and strains the ability of our utilities to provide critical water and wastewater service.

Flooding also affects the performance of the region's transportation network and adds to maintenance and replacement costs over time. Street drainage systems may become overloaded, resulting in street flooding and possible street closures and rerouting. Road and transit closures can cause a cascade of indirect impacts, including declines in economic productivity and emergency service provision. Flooding often results in damage to transportation infrastructure. This can come in the form of catastrophic events, like when riverine flooding washes out bridges and culverts, as well as more subtle changes that shorten the life expectancy of infrastructure. Standing water can weaken the road base, while high soil moisture levels can lead to structural declines in roads, bridges, and tunnels. These impacts can lead to more frequent repair or replacement of components of the system, also contributing to declines in performance.

A changing climate is anticipated to bring more flooding

Northeastern Illinois has already experienced, and is projected to see even greater, changes in temperature and precipitation from climate change. This can result in increases in flooding due to increased frequency and intensity of storm events, reduced soil capacity from drought, and increases in winter rain and denser, heavier snow. Nationwide, the heaviest rainfall events have become heavier and more frequent. Between 1979 and 2009, the region experienced 40 percent more precipitation than the prior 30-year period. Storm events are also getting bigger: up to 40 percent of total annual precipitation in recent years came from the top 10 rainiest days.[20] This has important implications for flooding as the amount and time interval of precipitation can impact how much of the rainwater is absorbed by soils or handled by drainage systems. Storm events with steeper and higher peak discharges can result in more flooding as the soils and sewers quickly reach capacity. A higher frequency of heavy storms can create wet periods, with a higher risk of flooding from a subsequent storm due to saturated soils, full detention ponds, and higher water levels of rivers and streams. A two to three-inch storm during a wet period may do more damage than the same precipitation falling during a more typical period.

Climate change is expected to also bring extended dry periods to the region, particularly in the summer months.[21] Coinciding with high temperatures, these droughts could dry soils and

[20] Brad Winters, et al, "Report for the Urban Flooding Awareness Act," State of Illinois Department of Natural Resources, Office of Water Resources, June 2015, http://www.isws.illinois.edu/hilites/more.asp?id=ufaa&fr=hi

[21] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., "Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program," 2014, http://nca2014.globalchange.gov/report

reduce stormwater infiltration. While on the face of it, drought could be thought to reduce flooding, the decreased infiltration capacity of soils could result in more stormwater runoff when storm events return. Climate change is anticipated to result in more winter precipitation falling in the form of rain rather than snow. When snowfall does occur, it is projected to be more intense, with more snowfall accumulation per event and denser, heavier snow.[22] Snowfall can result in flooding if large amounts of it melt in a short period of time. The risk of flooding increases when the ground is frozen, drainage systems are blocked by snow or ice, and rainfall occurs on top of packed snow.

Strategies for reducing flooding impacts

Many attribute the extent of our flooding issues to historical and continued mismanagement of resources. In the face of potential droughts and increasing issues with drinking water supplies, rainwater is a valuable resource and could utilized to address these and other challenges. Yet stormwater runoff currently contributes to declines in water quality, degrades habitats, damages buildings and infrastructure, and impacts safety and quality of life. CMAP articulated the importance of integrated water resource management in the recent Water Resources strategy paper.[23] This paper builds on those principles and focuses on strategies that can reduce the negative impacts of flooding.

Flooding will inevitably continue in the Chicago region. Extreme events, like those recently experienced in Houston, cannot be fully accommodated via stormwater management techniques without fundamentally changing other assets of the Chicago region. However, flood protection from more frequent storms should be achievable and will ultimately reduce flooding damages over the long term. Currently, some neighborhood drainage systems struggle to handle the two-year storm event. As a region, we need to set baseline priorities so that all residents are safe from frequent storms. We also need to set expectations. The region has a high amount of impervious cover on a flat landscape - rainwater will inevitably pond and accumulate. We have a choice in how we harness and utilize this asset so that it contributes to our region instead of damaging structures and impacting our quality of life.

Achieving a reduction in the negative impacts of flooding will take a variety of approaches and will require participation from a variety of different partners involved in land use and transportation decisions. Strategies to reduce flooding damages must address a range of issues, from updating standards for the built environment to coordinating across jurisdictions to maintain natural resources. The strategies presented in the following section (summarized in Table 3) recommend actions that CMAP should take to improve stormwater management and identify specific agency programs or projects that can implement the recommendations. CMAP

[22] Jaffe, M. and Woloszyn, M. "An Initial Assessment of Winter Climate Change Adaptation Measures for the City of Chicago," 2014, Sea Grant Law and Policy Journal, Vol. 6, No. 2, pp. 5-25.v

[23] "ON TO 2050 Water Resources Strategy Paper," Chicago Metropolitan Agency for Planning, 2017, http://www.cmap.illinois.gov/documents/10180/653821/Water+Strategy+Paper_FINAL_+9-21-17.pdf/b7aa6b24-a482-4718-b51f-e82effc34a9e

functions broadly include transportation programming, the Local Technical Assistance program, local ordinances and toolkits, policy research and development, and ongoing or upcoming work to develop ON TO 2050.

Table 3. CMAP recommended actions and implementation strategies for stormwater and flooding

Recommended actions	Implementation strategies
Identify and communicate flooding risk and exposure	Update precipitation data and floodplain maps Continue advancing watershed and sewer modeling efforts Enhance understanding of urban flooding risk Assess impacts to vulnerable populations, communities, and critical assets Communicate risk and exposure to residents, businesses
Advance planning efforts to reduce current and future risk	Continue advancing stormwater management ordinances Update municipal plans and ordinances to better manage stormwater Coordinate flood reduction and water quality improvement efforts Enhance floodplain management compliance Prepare for future floods
Invest and maintain grey and green infrastructure	Enhance maintenance of grey and green infrastructure Protect and expand open spaces to enhance stormwater management Encourage coordinated investments with green infrastructure Establish dedicated revenue streams for stormwater management
Increase resiliency of transportation system	Conduct vulnerability assessments to transportation planning Integrate stormwater management in transportation planning and investments Develop and enhance operational strategies to maintain performance
Enhance coordination and information sharing	

1. Identify and communicate flooding risk and exposure

In order to reduce the region's exposure to current and future flooding risk, CMAP should pursue strategies to enhance our understanding of where and when urban and riverine flooding could occur and communicate this risk to stakeholders. Land use and transportation decision-makers must have access to the best available data about flooding risk to make informed decisions. Private actors, such as residents and small business owners, also need to have a better understanding of where and when flooding could affect them so they can take steps toward reducing their risk.

However, reliance on outdated floodplain mapping and precipitation data is hampering the region's ability to identify and communicate riverine flooding risk and exposure. When it comes to urban flooding, its disparate causes makes it difficult to accurately map risk at a small scale, such as the property level. The distribution of flooding impacts across the region is uneven, which creates a need for decisionmakers to identify demographic groups and communities particularly vulnerable to flooding. CMAP has drafted regional urban and riverine flooding

susceptibility indexes to help identify the areas of the region most in need of mitigation activities. These and other strategies are important steps to better identify and communicate flooding risk for more informed decision-making.

1.1 Update precipitation data and floodplain maps

Floodplain maps are the most commonly used tool to identify areas at risk of riverine flooding. The insurance industry uses these maps, known as Flood Insurance Rate Maps (FIRMs), to determine whether a property owner is required to purchase federal flood insurance through the National Flood Insurance Program (NFIP). The region's floodplain maps are undergoing improvements. The Illinois State Water Survey (ISWS) is completing a multiyear project to update the region's FIRMs and digitize them to enhanced user functionality. As part of this work, ISWS is also incorporating engineering studies (H&H), collected information, or incorporating new engineering data submitted by others as Physical Map Revisions (PMRs) into the Digital FIRMs. However, the underlying data used to create the region's floodplain maps relies on outdated rainfall data, which results in maps that may not accurately reflect riverine flood risk. The data used in floodplain modeling and remapping continues to rely on precipitation accounts from 1901 to 1983,[24] which does not account for precipitation patterns we have experienced since 1983, nor does it take into account the effects of a changing climate.

Additional data gaps hinders the region's ability to identify and communicate riverine flood risk. Base flood elevations (BFEs) are instrumental in communicating the water surface elevation and mapped BFEs exist for the 1 percent annual chance flood.. However, some stream reaches in the region lack mapped floodplains.[25] For other reaches, upstream development and new structures, such as bridges or culverts, can alter the extent of the floodplain and are not always incorporated into floodplain remapping exercises.

There are a number of activities CMAP and its partners can pursue to update floodplain maps and educate the public on their use. CMAP should support efforts by the Counties, Metropolitan Water Reclamation District, and State to obtain resources to enhance data and modeling. CMAP supports IDNR's efforts to update Bulletin 70 with current precipitation data and supports proper funding for IDNR and ISWS to conduct updates on a regular basis. Future updates should integrate precipitation projections that account for future climate scenarios, especially since long term investments are being based on this information. As new regional climate models evolve, IDNR and ISWS should be funded to integrate this information on a regular basis.

IDNR and ISWS should have adequate funding to ensure that the region's floodplain maps are updated to reflect current precipitation and development conditions. CMAP also supports

[24] Huff, F. A., and J. R. Angel, "Rainfall Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois (Bulletin 70)," Illinois State Water Survey, 1989, www.isws.illinois.edu/atmos/statecli/RF/rf.htm

[25] "Identification of unmapped Special Flood Hazard Areas in Illinois," Illinois State Water Survey, 2017, www.illinoisfloodmaps.org/sfharisk.aspx

efforts to increase transparency of floodplain mapping, particularly identifying when maps were modeled and what data contributed to their creation. This information will help prioritize efforts to bring floodplain maps up-to-date based on changes in watershed conditions. Within their service areas, MWRD provides an inundation layer that accounts for their sewer infrastructure system. This is a valuable planning tool for communities facing riverine flood risk and regular updates should be performed to reflect current precipitation data as well as new development and infrastructure.

While updating precipitation data and floodplain and inundation maps will be performed by other partners, CMAP can play a supporting role. CMAP should work with the ISWS, IDNR, and FEMA to identify existing data inputs or data gaps, such as building footprints, that could improve floodplain mapping. Upon developing building footprint data for the entire region, CMAP should map the elevation of structures relative to the expected height of flood (known as the base flood elevation) for different percent chance storms to define low and high risk areas. CMAP should also work with regional partners to obtain better land surface elevation data, as it becomes available.[26]

1.2 Continue advancing watershed and sewer modeling efforts

USACE, MWRD, County stormwater agencies, and municipalities have greatly enhanced our understanding of how our existing regional and local drainage system operates, the location of flooding problem areas, and how potential solutions could address flooding. Through stormwater modeling, governments, often in partnership with the engineering consulting industry, have produced watershed plans and detailed sub-area plans that provide the region with critical information about flooding risk and corresponding solutions. Hydrologic and hydraulic (H&H) models estimate how rainfall is converted to runoff and how stormwater volumes are routed through the sewer network (or overland) to a river, regional sewer, or a treatment plant.[27] These models are the primary way infrastructure managers estimate flood levels and duration for different storm events and understand how different grey and green infrastructure solutions would address a given flooding problem. These studies are critical for targeting investments to priority areas, and understanding the vulnerability of other infrastructure assets as well as cascading economic impacts from flooding.

CMAP supports continued efforts to advance and maintain up-to-date modeling efforts and expand studies to watersheds or sewer systems that have yet to be reviewed. CMAP's development of a land use model could help incorporate future land use conditions and their corresponding water resource impacts into modeling efforts. Large scale studies performed by

[26] Maidment, David R. "Flood map accuracy," Testimony before the Ad Hoc Subcommittee on Disaster Recovery and Ad Hoc Subcommittee on State, Local, and Private Sector Preparedness and Integration Committee on Homeland Security and Governmental Affairs, U.S. Senate, July 28, 2010, www.nationalacademies.org/OCGA/111Session2/testimonies/OCGA_147146

[27] "Model Behavior: A Framework for Regional, Interjurisdictional, and Multi-level Stormwater Planning," Metropolitan Planning Council and CH2M, November 14, 2016, www.metroplanning.org/uploads/cms/documents/mpc_regionalstormwatermodeling_2016-11-10.pdf

the USACE are often funded through the Water Resources Development Act, Energy and Water Development Appropriations Act, or the Great Lakes Restoration Initiative.[28] CMAP supports continued support for the USACE through these funding programs in order to continue advancing watershed and sewer modeling efforts. At the county and municipal scale, funding for watershed and sewer modeling comes from a variety of sources. CMAP identifies a range of funding approaches in strategy 3 for these efforts as well as coordination opportunities in strategy 5.

MPC and CH2M, an engineering firm, developed a proposal for a modeling framework to address the multi-jurisdictional nature of stormwater management.[29] The proposal seeks to build a single regional hydrologic and hydraulic (H&H) model that would enable local planners and community leaders to quickly evaluate the regional impact of local decisions. Additionally, the tool would allow communities to identify the primary drivers of existing flooding, and prioritize the most cost-effective strategies for addressing them, regardless of jurisdictional boundaries. Building a regional scale model would not only provide a more precise understanding of flood drivers and impacts, but also enable lower-capacity communities to conduct more in-depth analysis than would otherwise be possible and inform state and county investments.

Because of the large scale of the project, a state or federal agency would likely need to take the lead in developing the tool itself. MPC and partners – USACE, MWRD, counties, CMAP, IEPA, the City of Chicago, and other individual municipalities – should continue to explore how to implement such program. To that end, the Calumet Stormwater Collaborative's Data and Modeling viewer[30] is a first step in building more awareness of what models currently exist in the region.

1.3 Develop planning tools to understand urban flooding risk

In recent years, CMAP and regional partners have undertaken approaches to better understand urban flooding risk and damages. CNT's Prevalence and Cost of Urban Flooding[31] shed significant light on the issue and influenced a statewide study.[32] Ongoing studies include the

[28] David Bucaro, USACE, Communication to the Calumet Stormwater Collaborative, March 3, 2017, www.metroplanning.org/uploads/cms/documents/csc_presentation_usace_authorities_03mar2017pptx.pdf

[29] "Model Behavior: A Framework for Regional, Interjurisdictional, and Multi-level Stormwater Planning," Metropolitan Planning Council and CH2M, November 14, 2016, www.metroplanning.org/uploads/cms/documents/mpc_regionalstormwatermodeling_2016-11-10.pdf

[30] "Calumet Stormwater Collaborative Data and Modeling Mapping Viewer," 2017, www.arcgis.com/home/webmap/viewer.html?webmap=a46bb8d241e4419cbc72577fe9d5e70f

[31] Center for Neighborhood Technology, "The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL," 2014, www.cnt.org/sites/default/files/publications/CNT_PrevalenceAndCostOfUrbanFlooding2014.pdf

[32] Brad Winters, et al, "Report for the Urban Flooding Awareness Act," State of Illinois Department of Natural Resources, Office of Water Resources, June 2015, http://www.isws.illinois.edu/hilites/more.asp?id=ufaa&fr=hi

National Academy of Sciences' (NAS) research and analysis on regions across the country, including Chicago, which have experienced significant damage from urban flooding.[33]

CMAP has developed urban and riverine flooding susceptibility indexes to identify priority areas across the region for flooding mitigation activities. The urban flooding susceptibility index includes all developed areas of the region outside of the FEMA 100-year floodplain or MWRD 100-year inundation layer within Cook County (Figure 4). Unlike riverine flooding, which has been modeled and studied for years, urban flooding risk has been largely unknown outside of infrequent and individual modeling efforts often carried out by municipalities. The urban flooding susceptibility index is the first regional attempt to fill this knowledge gap. The riverine flooding susceptibility index pertains to developed areas of the region within the FEMA 100-year floodplain or MWRD 100-year inundation layer within Cook County, and highlights areas within floodplains that have greater mitigation needs (Figure 5). This largely reconfirms priority areas that have long been recognized and studied by county stormwater agencies and USACE.

The regional flooding susceptibility indexes can help CMAP and partners focus stormwater planning efforts and investments within the region. It does not replace more technical efforts, but can instead begin to identify where those technical studies and corresponding investments are needed. More details on the methodology of the indexes are included in the appendix. CMAP should use the indexes to prioritize and inform land use and transportation plans developed through the Local Technical Assistance (LTA) program (Strategy 2.2). Other potential applications of the indexes are explored in other strategies of this paper.

As national and local studies advance our understanding of urban flooding, CMAP should continue to refine the flooding susceptibility indexes to improve their accuracy and utility. Possible refinements could improve the use for assessing impacts to the transportation network and incorporating updated precipitation data and future projections into the index, particularly for urban flooding. Once refinements have been made, CMAP should host the indexes on the CMAP website and develop a guide to help municipalities, community organizations, and other units of government utilize the information in planning activities and communicate potential risk to the public.

[33] "Urban Flooding in the United States," The National Academies of Sciences, Engineering, and Medicine, Division on Earth and Life Studies , Policy and Global Affairs, Office of Special Projects, Water Science and Technology Board, PGA-OSP-16-04, https://www8.nationalacademies.org/cp/projectview.aspx?key=49844

Figure 4. Regional urban flooding susceptibility index

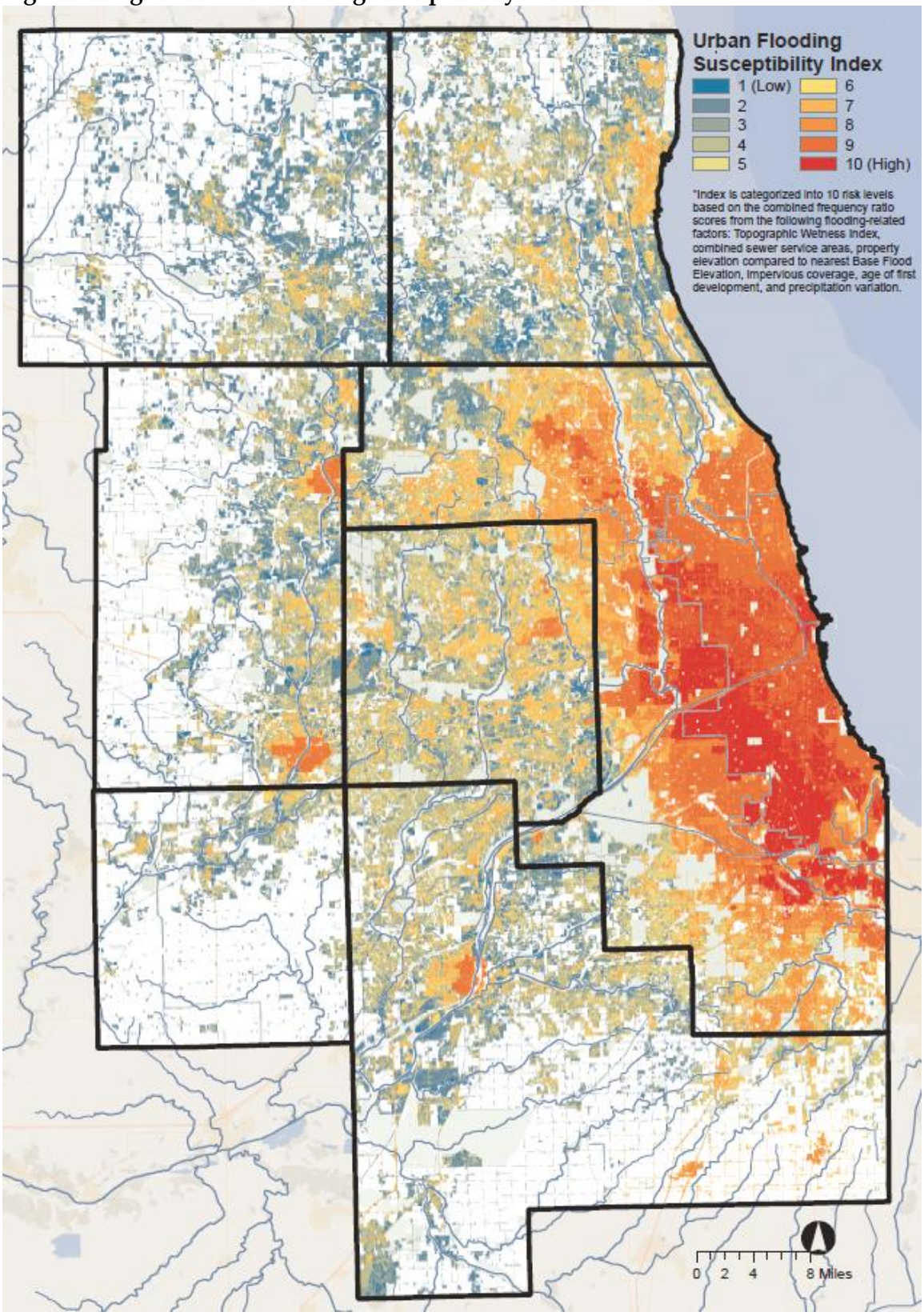
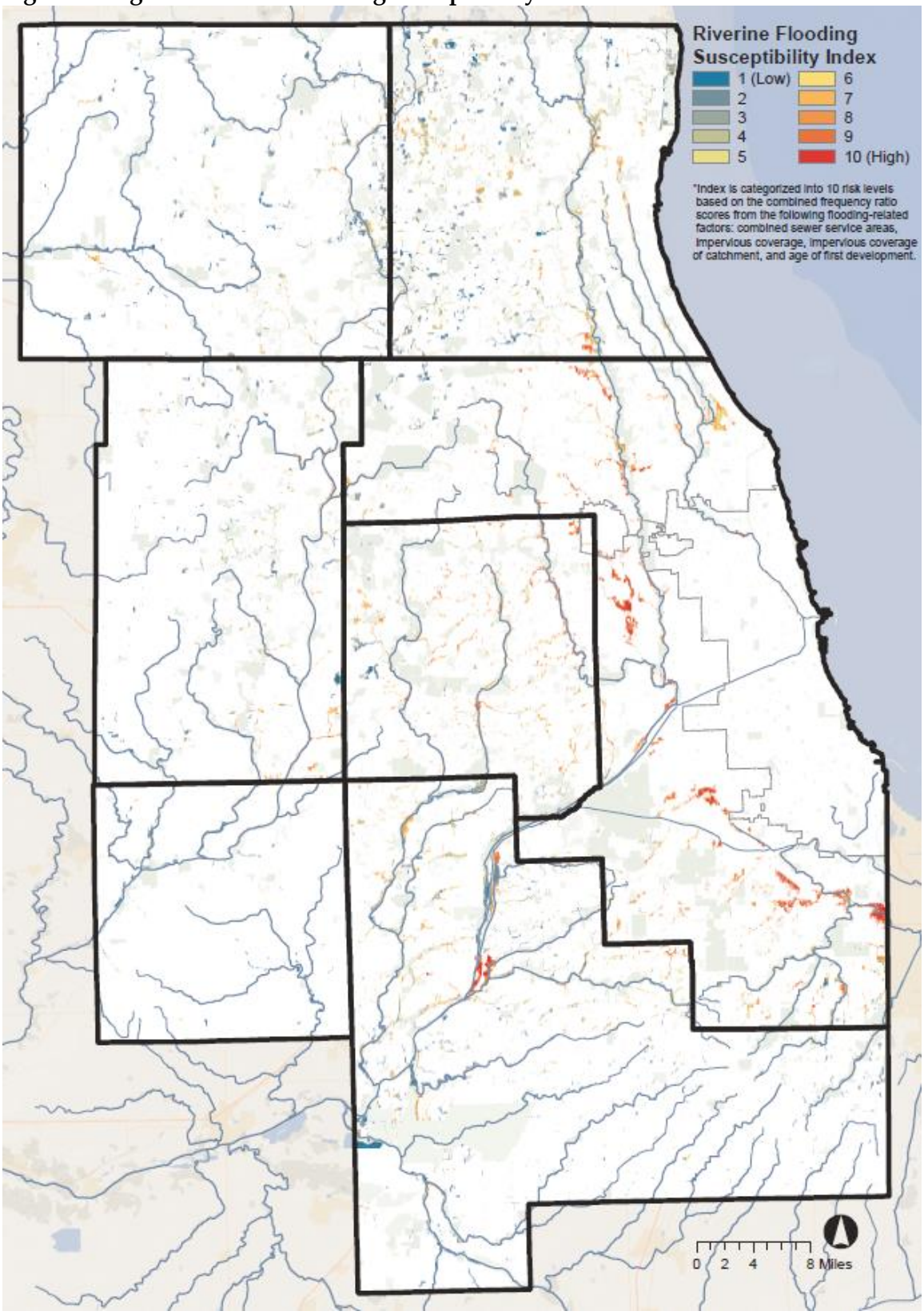


Figure 5. Regional riverine flooding susceptibility index



1.4 Assess impacts to vulnerable populations, communities, and critical assets

Flooding does not affect all communities in the region equally. A community's geographic location, physical and socioeconomic characteristics, and capacity[34] can significantly influence its degree of vulnerability to flooding. In addition, critical assets that are vital components of our region's infrastructure can also be vulnerable to flooding and in turn can hamper safety and response efforts if damaged during flooding events. There are several strategies CMAP and regional partners can pursue to help decision makers identify demographic groups, communities, and critical facilities particularly vulnerable to flooding. Once identified, strategies to reduce risk and exposure can be planned for, see strategy 2.2.

CMAP's climate resilience strategy paper recommends conducting a more targeted analysis to better understand the effects of climate change on vulnerable communities. Building on national research, CMAP and partners should explore how flooding impacts specific demographic groups in the region. As a start, CMAP has used economically disconnected areas, which were identified in the Inclusive Growth strategy paper,[35] as populations that may have difficulty responding to flooding damages for a variety of reasons related to income and access to resources. The Centers for Disease Control has created a Social Vulnerability Index, which uses U.S. census information to identify communities that may need support in preparing for hazards or recovering from disaster.[36] CMAP and partners should evaluate this and other tools to identify populations that could be more vulnerable to flooding. CMAP and partners should also use factors of disinvestment or other community capacity constraints that may make it difficult for a local government to respond to flooding damages.

Combined with socioeconomic and community factors, the regional flooding susceptibility indexes can help inform an analysis of which populations and communities may be more vulnerable to flooding. County and municipal planners should identify populations that could be vulnerable to flooding when conducting land use, transportation, hazard mitigation, and stormwater management plans and identify strategies to reduce flooding impacts. Through the LTA program, CMAP can include local assessments of vulnerable populations and communities, review the specific impacts faced from flooding, and draft responsive strategies. CMAP's Municipal Capacity strategy paper outlines several strategies to help assist low-capacity communities with stormwater management.[37]

In addition to vulnerable populations, centralized facilities, such as energy generation and distribution facilities, hospitals, water and wastewater treatment plants, telecommunication

[34] CMAP has defined municipal capacity the ability of a municipality to ensure services are provided on a sustained basis in pursuit of local and regional objectives. For more details, see Municipal Capacity Strategy Paper, LINK

[35] "ON TO 2050 Inclusive Growth Strategy Paper," Chicago Metropolitan Agency for Planning, 2017, http://www.cmap.illinois.gov/documents/10180/515753/Inclusive+Growth+strategy+paper/0f01488d-7da2-4f64-9e6a-264bb4abe537

[36] "Social Vulnerability Index," Centers for Disease Control, Agency for Toxic Substances and Disease Registry, 2014, https://svi.cdc.gov/

[37] "Municipal Capacity Strategy Paper," Chicago Metropolitan Agency for Planning, 2017, to be released soon.

facilities, and transportation control centers, can be vulnerable to riverine and urban flooding. In addition, industrial facilities and brownfields may present further risks to the community if flooded. Facility operators can conduct flooding vulnerability assessments for critical regional and community facilities to improve physical and operational preparedness for flooding. Partners that directly control assets are the main implementers of this strategy, but CMAP can help municipalities identify important local assets and make recommendations in LTA-supported plans to ensure provision of critical services during and after a flood.

1.5 Communicate risk and exposure to residents, businesses

Residents and businesses owners make important private decisions on where to locate and how to maintain their properties, yet often key information about stormwater management and flooding is not available to them or is poorly understood. This can lead to increases in flooding risk and corresponding damages. Private building and property maintenance decisions are happening all the time, yet there are distinct decision points where partners can provide better data and information that lead to more informed decision-making. Disclosures of previous flooding are required during points of sale or lease, but existing property owners have a financial incentive to suppress this information given the potential impact to the value of the property. In addition, real estate agents may not be educated on their role to inform buyers and sellers in the process. This leaves new tenants or owners unaware of the potential risk of future flooding events and potentially distorts the market for these locations. Additionally, data on previous private insurance and National Flood Insurance Program (NFIP) payments are protected and cannot be used by buyers to make a more informed purchase. IDNR has identified a range of activities during the sale of private properties to increase potential buyers understanding of the potential flood risk of a property and the available insurance options.[38] CMAP supports efforts to ensure that the sale of property is informed by accurate flood risk information.

The NFIP was established to help provide affordable flood insurance, help communities repair damaged homes and businesses, and promote floodplain management. However, this program has been recognized by some as perpetuating development and redevelopment in flood-prone areas despite floodplain risks and regulations because it is not adequately communicating the risk of developing in these areas.[39,40] The Biggert-Waters Flood Insurance Act of 2012 was designed to reduce the number of discounted or subsidized insurance premiums through a number of reforms, including increasing rates until full-risk rates[41] are reached, phasing out

[38] Brad Winters, et al, "Report for the Urban Flooding Awareness Act," State of Illinois Department of Natural Resources, Office of Water Resources, June 2015, http://www.isws.illinois.edu/hilites/more.asp?id=ufaa&fr=hi

[39] Hayat, Becky and Robert Moore, "Addressing affordability and long-term resiliency through the National Flood Insurance Program," 2015, Environmental Law Reporter. 45 ELR 10338

[40] Jarvis, Brooke. "When Rising Seas Transform Risk into Certainty," April 18, 2017, New York Times https://www.nytimes.com/2017/04/18/magazine/when-rising-seas-transform-risk-into-certainty.html?_r=0

[41] Full-risk rates are those rates that generate premiums that are sufficient to pay for the anticipated losses and expenses.

grandfathered policy rates, and creating a reserve fund.[42] However, the rapid rate increases led to the passage of the Homeowners Flood Insurance Affordability Act of 2014, which reinstated many of the subsidized aspects of the program. A recent GAO report found that current NFIP premiums do not reflect the full risk of loss and may not be communicating the risk of flooding.[43] CMAP supports efforts to reform the NFIP program so that the level of risk is adequately communicated, the premiums reflect the full risk of loss, and low income property owners are provided options.

Local communities provide their residents with an array of tools to help understand flooding risk. From interactive websites that display floodplain boundaries to informational brochures that explain flooding risks and solutions, municipalities are helping to educate local decision makers. Additional communities can learn from these techniques as well as utilize an array of educational resources provided by FEMA and IDNR. Most educational efforts are currently focused on the risks of riverine flooding and should be expanded to cover urban flooding risks and solutions. CNT has led the way in educating residents on the complex causes of urban flooding on individual properties. Through factsheets and My RainReady, an interactive website that helps residents analyze their home conditions, CNT is educating property owners and renters about what makes a home more susceptible to flooding and what steps to take to reduce their risk of flooding in the future.[44] Many communities are providing a similar physical assessment on site through their cost share programs to help property owners identify priority improvements. Similarly, the CNT RainReady Home program can help assess and construct needed improvements on a home as part of a cost share program with municipalities.[45]

Adequate warning of potential flooding events could allow property owners to prepare for impending storms. Current work by the Midwest Regional Climate Center on a flash flood warning system, technological advances that alert utility mangers of infrastructure conditions, and other partnerships with media and retail establishments could alert the region when conditions could result in urban or riverine flooding. These messages could be followed up with key action steps to avoid damage and reduce exposure. Currently, the Friends of the Chicago River has an alert system that targets residents of combined sewer areas to decrease water usage during large storm events to prevent combined sewer overflow. CMAP supports continued efforts to reach out to residents and prepare them for future flooding.

[42] United States Government Accountability Office Report to Congressional Addressees, "Flood Insurance: Comprehensive Reform Could Improve Solvency and Enhance Resilience," April 2017, GAO-17-425.
[43] United States Government Accountability Office Report to Congressional Addressees, "Flood Insurance: Comprehensive Reform Could Improve Solvency and Enhance Resilience," April 2017, GAO-17-425.
[44] Center for Neighborhood Technology, "My RainReady," http://myrainready.cnt.org/
[45] Center for Neighborhood Technology, "RainReady Home Program," http://rainready.org/our-services/rainready-home

2. Advance planning efforts to reduce current and future risk

Improving how stormwater is addressed in planning efforts for developing and redeveloping areas remains a critical priority for the region in order to minimize runoff volumes and reduce flooding risk. Many best practices are already being implemented at the county and municipal scales and can be used throughout the region. Continued updates to county stormwater management ordinances, integration of stormwater management issues into local planning and development ordinances, coordination between water quality and flood control efforts, and continued improvement in floodplain management and pre-disaster planning are essential.

2.1 Continue advancing county stormwater management ordinances

In the Chicago region, all counties have the authority to manage stormwater in both unincorporated and incorporated areas.[46] Each county has established minimum standards for stormwater management in a unified framework throughout the county. In general, the objective of stormwater management ordinances is to limit the amount of stormwater runoff coming from new development or redevelopment sites, which helps achieve both water quality and flood reduction goals. This is accomplished mainly through onsite detention storage and, increasingly, volume control practices. Onsite detention storage is designed to hold a specified amount of runoff and only release flow at a specified release rate. Volume control practices require an amount of runoff volume be retained and/or infiltrated on site when possible, which can include green infrastructure practices.

Following large flooding events in the late 1980s, the region began to adopt county-wide stormwater management ordinances, which has led to dramatic improvements in how stormwater is handled on new and redeveloping sites. CMAP's predecessor, the Northeastern Illinois Planning Commission (NIPC), developed a model stormwater drainage and detention ordinance to advance incorporation of stormwater best management practices. The design requirements for stormwater management have rapidly evolved in recent years as practitioners have improved watershed and runoff models, learned from local, national, and international design techniques, and gained experience in long-term maintenance needs of green and grey stormwater infrastructure. Counties should continue to learn from one another and regularly update stormwater management ordinances to reflect best practices, incorporate new information, and ultimately reduce stormwater volumes and runoff generated from new and redeveloping areas. There are a number of areas where continued improvements could occur, including:

> **Enhance protection from urban flooding.** Locations outside of the floodplain are experiencing localized flooding issues, often due to depressional areas and/or elevation issues. Development in these areas could benefit from similar protection techniques currently used for structures located in floodplains, such as avoid siting structures in

[46] Illinois Compiled Statutes, 55 ILCS 5/5-1062, www.ilga.gov/legislation/ilcs/fulltext.asp?DocName=005500050K5-1062

known inundation areas and adapting structure design to handle stormwater flows, through a variety of means including green infrastructure.

Adapt standards to current and future precipitation. Effective stormwater ordinances depend on accurate rainfall frequency information to then establish detention and volume control standards. Yet current precipitation patterns exceed those used in the region's ordinances, meaning projects approved today may not be designed for today's storms.[47] The precipitation data used for a given project can greatly affect the design, functionality, and lifespan of the stormwater infrastructure. Recent work by the Illinois State Water Survey to update Bulletin 70 should be incorporated as quickly as possible into county stormwater management ordinances (strategy 1.1). In addition, the counties should investigate how to account for future precipitation projections, especially for critical, long-term investments.

Strengthen volume reduction through green infrastructure techniques. Almost all of the region's county stormwater ordinances recognize green infrastructure solutions and the application of these techniques is growing. Counties should continue to develop volume control requirements and encourage structural and non-structural stormwater best management practices (BMPs).[48] Improvements to streamline the implementation of green infrastructure designs should be used throughout the region. For example, MWRD recently updated their technical reference manual to include green infrastructure facility specifications, providing a valuable resource for the development community.

Tailor standards to watershed and development conditions. Watersheds are not uniform in their ability to handle stormwater volumes, therefore development standards should be tailored to these conditions. In 2017, the Cook County Release Rate Assessment found that there is value in varying release rate requirements across watersheds.[49] Lake County has established watershed specific release rates.[50] Other counties should consider replicating this approach. In addition, development area thresholds that trigger stormwater management regulations vary across the region, from 5,000 sq. ft. of development disturbance to three acres. Each development site,

[47] Brad Winters, et al, "Report for the Urban Flooding Awareness Act," State of Illinois Department of Natural Resources, Office of Water Resources, June 2015, http://www.isws.illinois.edu/hilites/more.asp?id=ufaa&fr=hi

[48] Some structural BMPs are based on natural systems and rely on soil and plants to infiltrate and treat water, such as raingardens, swales, and filter strips, while others are more similar to grey infrastructure, such as dry wells. Non-structural BMPs include a range of techniques, including incorporating existing landscape features into a site plan to manage stormwater at its source and minimizing disturbed areas through clustering and concentrating development and reducing the size of impervious areas.

[49] Amanda Flegel, "Evaluating Release Rates for Specific Watersheds in Cook County, Association of State Floodplain Managers, May 4, 2017, http://www.floods.org/Files/Conf2017_ppts/J8_Flegel.pdf

[50] Lake County Stormwater Management Commission, "Watershed Development Ordinance," October 13, 2015, https://www.lakecountyil.gov/DocumentCenter/View/3445

particularly infill locations, is an opportunity to reduce the impact of flooding and make water quality improvements. Development trends vary and change across the region; County ordinances should reflect these differences and harness the land cover change that is occurring to improve stormwater management.

Explore Transfer of Benefits Programs. Transfer of benefits programs, such as stormwater credit trading, provide a market-based way to advance improved stormwater management in the region. MWRD and county stormwater agencies require on-site retention for projects that exceed the area development threshold established to require a permit. For property owners with space or other constraints that would make meeting the requirements on their property difficult -- which can be common for infill sites -- credit trading programs allow eligible properties to meet a portion of their retention requirements by buying stormwater "credits" from other property owners, thus installing improvements offsite. These programs provide flexibility to meet stormwater requirements and have the potential to achieve greater flood mitigation goals than a simple on-site retention requirement. For example, disinvested properties that flood could be retrofitted with green infrastructure to provide relief to the surrounding area as well as satisfy offsite retention requirements for a development upstream.

Partners in the region are undertaking a study to explore the feasibility of establishing a stormwater credit trading system in Cook County. CMAP should support these efforts and encourage research on whether such a program could alleviate concerns in floodprone areas. CMAP and partners should also advocate for the program to develop long term plans for ongoing maintenance and corresponding costs to ensure stormwater improvements installed offsite will continue to perform as designed over the lifespan of the infrastructure.

CMAP should encourage continued updates to county stormwater ordinances. NIPC model ordinances were instrumental in an era when most of the counties did not have stormwater ordinances in place. Further refinements will now need to be more tailored to specific county ordinance structures and processes. Region-wide applicability of an updated model ordinance would be limited; therefore, CMAP should explore providing assistance to counties, perhaps through a coordination role, in helping to advance updates to their ordinances to reflect best practices and emerging information about climate change and development trends (strategy 5).

2.2 Update municipal plans and ordinances to better manage stormwater

Municipal planning efforts can advance stormwater management in a variety of ways. At a broader scale, comprehensive plans should recognize the stormwater retention and detention services provided by existing natural areas and open spaces in the planning area or watershed. These assets should be accounted for in future land use maps and corresponding zoning districts. In addition, land use and transportation plans can acknowledge areas where environmental conditions create unnecessary risk if developed. For example, South Elgin is

contemplating a zoning overlay district of their regulatory floodplain to provide better direction on the types of appropriate uses for these areas. Municipal comprehensive and capital improvement plans can account for watershed planning recommendations as well as stormwater management plans to help implement stormwater best management practices. Sub-area, corridor, and downtown plans can provide site-specific recommendations to improve stormwater management. For example, specific street or local parks can be identified for green infrastructure strategies such as permeable pavements, bioswales, and wetland restoration. Land use and transportation plans should respond to the impacts that flooding could pose to vulnerable populations, specific employment centers, and critical facilities.

CMAP and partners can provide assistance to municipalities as they seek to integrate stormwater management considerations into planning efforts. CMAP has been exploring how to help communities struggling with flooding to prioritize limited resources into effective projects. Existing studies, such as County watershed plans and municipal H&H models, can help inform land use and transportation plans. Where absent, the regional flooding susceptibility index can be applied at the local scale to identify priorities for plan implementation. Additional datasets that provide more information on where water could flow or pond, such as topographically derived flowpaths and depressions, can help planners identify areas that should remain or be restored to an open condition or are ideal locations for site-scale green infrastructure.

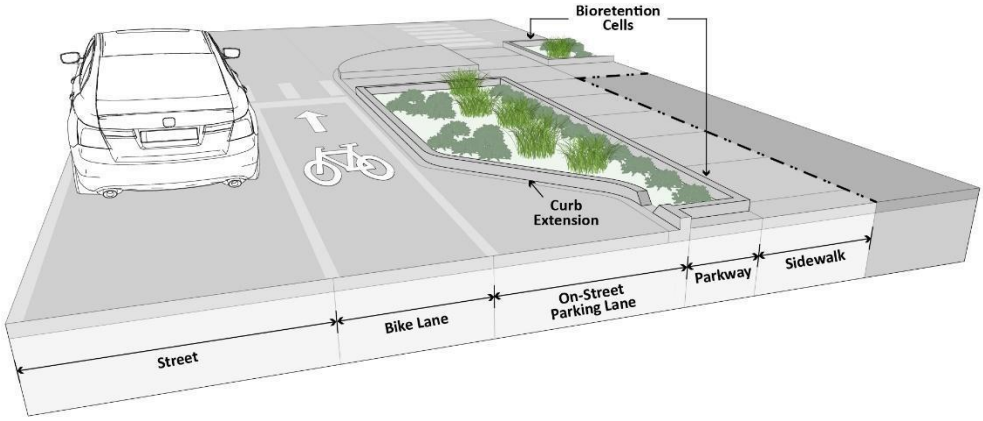
Development regulations at the municipal scale also play a role in the amount of stormwater runoff generated and how it is managed on a site. CMAP has made a number of recommendations for improved stormwater management in municipal development ordinances, and these have been highlighted in GO TO 2040 as well as recent strategy papers.[51] Overall, efforts to reduce the amount of impervious cover allowed on a site, through building design to surface parking requirements, are important techniques to improving stormwater management. Conservation design principles that protect existing water resources and minimize the development footprint are particularly important for newly developing areas. Other communities will need to integrate structural and non-structural best management practices into their development standards to promote the integration of these techniques in redeveloping areas. Some communities in the region, such as Downers Grove, are leading the way in protecting their existing neighborhoods by recognizing local drainage problem areas in site plan review and encouraging redevelopment to avoid or account for increased stormwater flows in these locations. Other communities are working to ensure that long-term maintenance provisions are established for stormwater best management practices during the development process.

[51] "ON TO 2050 Water Resources Strategy Paper," *Chicago Metropolitan Agency for Planning*, 2017, http://www.cmap.illinois.gov/documents/10180/653821/Water+Strategy+Paper_FINAL_+9-21-17.pdf/b7aa6b24-a482-4718-b51f-e82effc34a9e

Communities should also work to improve the implementation of county stormwater management ordinances. Municipalities can encourage specific practices already allowed in the county ordinance by updating their own zoning and subdivision ordinances to encourage these techniques. Such activities can help integrate stormwater management into the initial site design process and ultimately lead to more effective and less expensive designs. Municipalities can also choose to enact stronger stormwater management ordinances and many have down so in order to meet their flood reduction or water quality goals. For example, the City of Berwyn lowered the development area threshold for compliance with the Cook County Watershed Management Ordinance when they realized very few development sites would trigger the requirements given their compact development pattern.

Improving stormwater management in development ordinances is ultimately up to municipal decision makers. However, CMAP and partners can assist in a variety of ways. Through CMAP's Local Technical Assistance program, CMAP is already actively helping municipalities update zoning and subdivision ordinances and can continue to streamline the incorporation of green infrastructure practices in municipal development regulations.[52] For example, CMAP is assisting the Village of Park Forest update their subdivision ordinance to include specifications for green infrastructure within new streets (Figure 6). In the future, CMAP should explore datasets and design mechanisms for protecting developing and redeveloping areas from urban flooding problem areas, such as low-lying areas or depressions in the landscape.

Figure 6. Example of green infrastructure designs in subdivision ordinance standards.



The Village of Park Forest's proposed unified development ordinance provides specifications for bioretention cells in curb extensions and other configurations in the street right-of-way. Source: CMAP.

[52] "Silver Creek and Sleepy Hollow Creek Watershed Comprehensive Plan and Ordinance Assessment," Chicago Metropolitan Agency for Planning, 2013, http://www.cmap.illinois.gov/programs-and-resources/lta/silver-creek-sleepy-hollow-watershed

2.3 Coordinate flood reduction and water quality improvement efforts

In addition to causing flooding, stormwater runoff is one of the main contributors to water quality issues in the Chicago region.[53] However, the Clean Water Act's focus on specific pollutants has been recognized as hindering effective stormwater management because it ignores the volume of discharges.[54] Stormwater volumes bring contaminants but also surges that increase erosion and degrade aquatic habitats. In addition, pollutants coming from stormwater vary over time, which can make monitoring difficult to implement.[55] Several years ago, US EPA began a process of reviewing the effectiveness of existing stormwater regulations but ultimately deferred on a rulemaking to reduce discharges from newly developed and redeveloped sites and address other regulatory challenges. While the US EPA continues to focus on stronger implementation of existing standards, the National Research Council suggested that a more straightforward way to regulate stormwater management would be to use flow or impervious cover as a measure of stormwater pollutant loading and organize this process through a watershed-based permitting system.[56] Such a mechanism could result in more coordination between flood reduction and water quality strategies as standards are tailored to the conditions of a particular drainage basin.

More recently, IEPA has expressed interest in exploring how green infrastructure features could support both water quality protection and flood reduction goals.[57] IEPA's water quality standards already require municipalities to consider the use of green infrastructure in their own practices and consider requiring the use of green infrastructure practices in new development.[58] In particular, the general NPDES permit states that each permittee should adopt strategies that incorporate stormwater infiltration, reuse, and evapotranspiration of stormwater in the project to the maximum extent possible.[59] IEPA has considered establishing statewide post-construction performance standards to articulate how much a permittee must minimize runoff and pollution. In 2013, a coalition of partners proposed the use of post-construction stormwater performance standards as part of the NPDES permitting process for construction sites and small municipal

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[53] "ON TO 2050 Water Resources Strategy Paper," *Chicago Metropolitan Agency for Planning*, 2017, http://www.cmap.illinois.gov/documents/10180/653821/Water+Strategy+Paper_FINAL_+9-21-17.pdf/b7aa6b24-a482-4718-b51f-e82effc34a9e

[54] National Research Council, "Urban Stormwater Management in the United States," 2008, http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12465

[55] National Research Council, "Urban Stormwater Management in the United States," 2008, http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12465

[56] National Research Council, "Urban Stormwater Management in the United States," 2008, http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12465

[57] Amy Walkenbach, Illinois Environmental Protection Agency, Communication to the Calumet Stormwater Collaborative, March 3, 2017, http://www.metroplanning.org/uploads/cms/documents/csc_3-03-17_meeting_summary.pdf

[58] General NPDES Permit No. ILR40, last reissued February 10, 2016, http://www.epa.illinois.gov/topics/forms/water-permits/storm-water/ms4/index

[59] General NPDES Permit No. ILR40, last reissued February 10, 2016, Section IV.B.5.a.and b, http://www.epa.illinois.gov/topics/forms/water-permits/storm-water/ms4/index

separate storm sewer systems (MS4s).[60] Several other states already have retention-based post-construction performance standards.[61] Within the region, this could result in more uniformity between county retention requirements and the use of stormwater best management practices. CMAP supports continued efforts to develop post-construction stormwater performance standards.

As the national and state conversation continues, CMAP and partners should work to coordinate water quality and flood prevention work and contribute lessons learned to state and national policymakers. Watershed planning activities are the main mechanisms CMAP uses to improve water quality. Through watershed plans, CMAP should explore how flooding issues can be identified and solutions could be designed to meet water quality goals. As a first step, this could include review of the regional flooding susceptibility index or other flooding analyses to help inform the location and design of stormwater best management practices.

County stormwater agencies are integrating water quality and flood reduction efforts and should continue to explore innovative practices in the future. For example, MWRD and partners are amending several detailed watershed plans to include a water quality focus that meets Section 319 requirements. Lake and Will Counties use data developed through watershed plans to dictate watershed-specific release rates used in county stormwater management standards. CMAP and partners should work with IEPA to explore techniques and innovations in the watershed planning process, including the addition of watershed-specific release rates to CMAP produced watershed plans. .

The ON TO 2050 Water Resources Strategy Paper identified improvements to how watershed planning recommendations could be better integrated into local decision-making. Incorporating flooding analysis and solutions into watershed plans could be a key way of increasing the number of stakeholders interested in watershed plan implementation. It could also help leverage existing funding sources to achieve both water quality and flood reduction goals. Through its LTA program, CMAP should continue to integrate watershed plan recommendations into other local planning efforts, such as capital improvement plans and development ordinance updates.

2.4 Enhance floodplain management compliance

The NFIP is a voluntary program where property owners can gain access to flood insurance, disaster assistance, and mitigation grants when the local community commits to enforcing local floodplain management regulations. The IDNR Office of Water Resources is the state agency

[60] Post-Development Stormwater runoff standards Workgroup and Association of Illinois Soil and Water Conservation Districts, "Stormwater Performance Standards Recommendations," Submitted to Illinois Environmental Protection Agency, June 28, 2013

[61] U.S. Environmental Protection Agency Office of Water, Water Permits Division, "Municipal Separate Storm Sewer System Permits: Post-Construction Performance Standards & Water Quality-Based Requirements, A Compendium of Permitting Approaches," EPA 833-R-14-003, June 2014, https://www3.epa.gov/npdes/pubs/sw_ms4_compendium.pdf

responsible for coordinating compliance with the NFIP and works closely with FEMA, IEMA, ISWS and local and county partners. As of 2017, all Chicago region communities with floodplains in their boundaries participate in the NFIP.[62]

Floodplain management standards are designed to prevent new development from increasing the flood threat and to protect new and existing buildings from anticipated flooding.[63] One of the central elements of floodplain management involves review of new development and redevelopment within the regulatory floodplain. All counties in the Chicago region have established minimum floodplain standards through their watershed development or stormwater management ordinance, based on IDNR's established standards. [64] Floodway and floodplain development applications are forwarded to counties for review and approval, regardless of whether a community is certified to execute stormwater management regulations. This review process continues to be a very important part of county services; CMAP found nearly 12,000 acres of greenfield development occurred within the floodplain between 2001 and 2015.[65] Redevelopment or substantial changes to existing development within the floodplain also occurred and triggered county review but the regional total is not known.

In addition to issuing or denying floodplain development permits, communities agree to enforce adequate land use and control measures as well as inspect all development to assure compliance, maintain records of floodplain development, assist in the creation or update of floodplain maps, and help property owners understand and navigate floodplain risk and regulations. The Community Rating System (CRS) is a voluntary program that incentivizes community efforts beyond the minimum NFIP standards by reducing flood insurance premiums for property owners within the community. To receive a CRS flood insurance premium reduction, a community must demonstrate additional floodplain management activities related to public information, mapping and regulations, flood damage reduction, and flood preparedness to FEMA.[66]

Land use planning techniques, land acquisition and restoration, educational programs, and warning systems and emergency plans once flooding is happening are all recommended tools

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[62] The City of Berwyn is the only community in the CMAP region without a regulatory floodplain. Unincorporated areas may also be eligible for national flood insurance through county participation in the program.

[63] FEMA, "Answers to Questions about the NFIP," FEMA F-084, March 2011, https://www.fema.gov/media-library/assets/documents/272

[64] Illinois General Assembly, Administrative Code, "Title 17: Conservation, Chapter 1: Department of Natural Resources, Subchapter H: Water Resources, Part 3706 Regulation of Construction within Floodplains," ftp://www.ilga.gov/jcar/admincode/017/01703706sections.html

[65] "Lands in Transition Strategy Paper," *Chicago Metropolitan Agency for Planning, 2017,* **http://www.cmap.illinois.gov/onto2050/strategy-papers/lands-in-transition**.

[66] FEMA, "National Flood Insurance Program Floodplain Management Requirements, A Study Guide and Desk Reference for Local Officials, Unit 9: Flood Insurance and Flood Management," https://www.fema.gov/pdf/floodplain/nfip_sg_unit_9.pdf

to meet NFIP criteria.[67] Land use planning measures that steer development and critical utilities and facilities away from floodplains are key activities that can only take place at the municipal scale. Communities can receive CRS credit for preparing, implementing, and periodically updating comprehensive plans that address the community's flood problem. In addition, communities that keep currently vacant floodplain lands free of development, and/or restore these lands to a natural state can receive additional CRS credit. CMAP and its partners can assist communities in meeting these requirements through the comprehensive planning process. CMAP should work with FEMA and IASFM to better understand how plans produced through the LTA program can meet CRS requirements.

IDNR reviews community compliance with NFIP requirements on a rolling basis through Community Assistance Visits. The frequency at which this occurs has been impacted by funding constraints within IDNR. If a community is out of compliance, IDNR may issue a probation or suspension from the program which could result in the loss of access to NFIP flood insurance for property owners. An assessment of how Chicago region communities are meeting NFIP requirements is not available at this time. Such an assessment could inform CMAP and partners on how best to assist communities meet and exceed program requirements. IDNR has recognized the need to expand CRS resources to improve outreach to communities.[68] CMAP supports efforts that improve IDNR's ability to conduct the community assistance visits, train stakeholders, and coordinate with regional partners on how best to assist communities. Partnerships with other organizations, such as the county stormwater agencies and planning departments, APA-IL, ILASFM, could assist in educating about the benefits and techniques of floodplain management. Community capacity issues likely hinder NFIP compliance as municipalities struggle to maintain data, retain or train certified floodplain managers on staff, and conduct damage assessments after storms.

2.5 Prepare for future floods

The Chicago region needs to be prepared for future flooding events. Planning in advance of potential flooding disaster can reduce risks to health and safety as well as costs and damages. Municipalities and counties should consider a full range of mitigation activities from grey and green infrastructure to property acquisition. Federal assistance can help local governments reduce exposure to future flooding. The Federal Disaster Mitigation Act of 2000 (DMA2k) requires communities to adopt a FEMA-approved hazard mitigation plan to be eligible for funds through the Hazard Mitigation Grant Program (HMGP). These grants are available following a presidentially declared disaster, and must be used for projects conforming to the hazard mitigation plan. To remain eligible for HMGP funds, participating communities must update their plan every five years. These plans are strictly voluntary, but the importance of

[67] FEMA, ""National Flood Insurance Program Floodplain Management Requirements, A Study Guide and Desk Reference for Local Officials, Unit 1: Floodplain Management," https://www.fema.gov/pdf/floodplain/nfip_sg_unit_1.pdf

[68] Brad Winters, et al, "Report for the Urban Flooding Awareness Act," State of Illinois Department of Natural Resources, Office of Water Resources, June 2015, http://www.isws.illinois.edu/hilites/more.asp?id=ufaa&fr=hi

HMGP funding has made hazard mitigation planning commonplace across the nation. All seven counties in the Chicago region maintain FEMA-approved plans, and the City of Des Plaines has adopted its own, highly specific plan. These documents differ in both scope and content, but they share a common goal of reducing community vulnerability before, during, and after a disaster.

Counties play a key role in helping municipalities access federal assistance. From helping to prepare FEMA-approved hazard mitigation plans to helping communities document damages and demonstrate the need for public assistance, counties are performing a vital role. Continued efforts to maintain up-to-date plans that reflect priorities should be supported by CMAP and partners. The Illinois Emergency Management Agency (IEMA) has a 2013 Illinois Natural Hazard Mitigation Plan, which is up for renewal.[69] IEMA has partnered with the Illinois State Water Survey to develop a project and mitigation action tracking database. Counties and municipalities should be sure that key flooding mitigation projects are identified in local mitigation plans so that they can be entered into the system. CMAP and partners should support continued pre-disaster planning efforts and identify opportunities for more coordination.

3. Invest and maintain grey and green infrastructure

The region's flood control and stormwater system is a network of natural habitats, open spaces, waterways, large- and small-scale facilities, MWRD's Tunnel and Reservoir Plan (TARP), local sewer systems, and private sewer laterals. Some of the grey infrastructure was built in the last few decades, but much of it dates back to the early and middle 1900s when much of the Chicago region was developed. The Chicago region should focus efforts on maintaining the existing flood control and stormwater system to ensure it performs as designed and to maximize the return on investment by extending its lifespan. At the same time, the grey and green stormwater infrastructure that is in place does not provide the capacity needed to handle the runoff from continued urbanization and current and projected precipitation. Green infrastructure has the potential to expand our flood control and stormwater system while at the same time result in an array of co-benefits that are not available under grey infrastructure solutions.

Stormwater management funding is necessary to maintain and improve grey and green infrastructure systems. Storm sewers, culverts, and a host of other stormwater infrastructure components need repair, but funding for capital improvements can be difficult to secure. Communities across the Chicago region struggle to maintain adequate funding for maintenance and improvements. External funding mechanisms, such as grants and low-interest loans, are available to communities but are unlikely to cover the growing costs of stormwater

[69] Illinois Emergency Management Agency, "2013 Illinois Natural Hazard Mitigation Plan," 2013, https://www.illinois.gov/iema/Mitigation/Documents/Plan_IllMitigationPlan.pdf

management. Similarly, federal assistance, in the form of the NFIP program and disaster relief programs, have been essential; however, these programs are struggling to provide the needed technical and financial assistance. Nationally, sea level rise and storm surges in coastal cities as well as flooding and storm events throughout the country will continue to strain federal resources.

CMAP and its partners can pursue a series of strategies to help provide communities with the support they need, including helping communities establish a dedicated revenue source, utilize grant programs to fund pilot projects, and promote the use of low-interest loans. Coordinated investments that include green infrastructure at the beginning of the design process can be more cost effective and achieve a range of co-benefits.

3.1 Enhance maintenance of grey and green infrastructure

Routine maintenance of grey and green infrastructure is a critical step to ensure optimal performance and lengthen its lifespan. Like other infrastructure, deferring maintenance and repair work of drainage assets can increase long term costs. Ownership and maintenance responsibilities for the region's flood control and stormwater systems is distributed among different entities, including USACE, IDOT, IDNR, MWRD, county governments, forest preserve and conservation districts, local governments, homeowners associations, and individual homeowners. CMAP and partners can pursue several strategies to assist public and private entities in maintaining existing drainage assets, including buried pipes and structures, as well as detention basins and drainage swales.

As with other asset management activities, communities should assess the condition of the drainage system and develop plans to bring it into a good state of repair. Meant to ensure the long-term sustainability of infrastructure, asset management plans help utility managers decide when to repair, replace, or rehabilitate particular assets. It can also inform a long-term funding strategy for maintenance and improvements. However, many communities do not have an up-to-date inventory of their existing stormwater assets and therefore are unable to properly assess the condition and maintenance needs. Communities across the region should develop and/or maintain an inventory of drainage assets including above and below ground facilities. Some neighborhood stormwater facilities are under private ownership and, like public assets, require maintenance and rehabilitation to meet performance goals. These facilities can be problematic for communities and stormwater agencies without long-term maintenance requirements built in from the outset (strategy 2.2).

Some of the region's stormwater agencies conduct inventories and assessments of detention basins on private property through watershed planning efforts. DuPage County recently created an online application to allow volunteers to input basin assessment findings. MWRD and the South Suburban Mayors and Managers Association (SSMMA) are both connecting municipalities with technology to update and digitize their local sewer atlases. Other programs, such as flow and smoke testing, can help inform communities of the conditions of their underground assets. CMAP should support sharing of information such as detention basin

assessments, particularly those conducted as part of CMAP-led watershed plans. CMAP and partners should also encourage coordination among stormwater agencies in data collection, whether via online applications or other mechanisms.

Once maintenance needs are determined, annual operational needs and capital projects should be incorporated into municipal budgeting processes and capital improvement plans. With many communities struggling to conduct routine maintenance of other municipal assets, this can be difficult without additional funding (strategy 3.4). In addition, green infrastructure maintenance may require additional training of staff to be done effectively. These conditions present an opportunity for service sharing of maintenance activities for both grey and green infrastructure across multiple communities. In addition, private entities can play a role. Currently, High Bridge, a social enterprise company, is hiring and training local Calumet residents to install and maintain green infrastructure treatments across several communities in southern Cook County. County and municipal partners should explore mechanisms to perform green infrastructure maintenance on a sub-regional level to improve the performance and longevity of these assets.

3.2 Protect and expand open spaces to enhance stormwater management

The region's network of natural resources provides a range of ecosystem services, including an estimated $4.2 billion in flood control annually.[70] Maintaining biodiverse ecosystems can help the region mitigate and prepare for climate change, but open space areas will face increasing flood events or pressures to handle stormwater runoff to the potential detriment of other habitat goals. Land managers, conservation organizations, and state and private funders of conservation already recognize the value natural habitats provide in flood control and have been building better connections between land acquisition, stewardship efforts and stormwater management goals. CMAP and partners should explore how these existing services can be maintained and enhanced over time. Innovative mechanisms, such as the transfer of benefits programs, could be utilized to acquire unprotected natural areas and contribute to their stewardship and long term maintenance. Review of the regional flooding susceptibility index at the watershed scale may help inform open space acquisition priorities to retain existing natural habitats that are currently providing flood control services.

Property acquisition or buyouts remove people and property from harm's way, eliminate repetitive losses, and can be less costly than providing protection through large-scale flood control infrastructure, such as dams or reservoirs. In Wisconsin, buyouts were found to result in a return on investment ratio of 1.32.[71] Pursuing buyouts also removes development from the floodplain, which enhances their natural functions to hold and infiltrate floodwaters and reduce

[70] CMAP. Green Infrastructure Vision 2.3: Ecosystem Service Valuation. 2015. https://datahub.cmap.illinois.gov/dataset/green-infrastructure-vision-2-3-ecosystem-valuation

[71] "Loss Avoidance Study: Wisconsin Property Acquisition and Structure Demolition," FEMA, Federal Insurance and Mitigation Administration, https://www.fema.gov/media-library-data/1492193978667-8b228ed3251229b6a86dac730e56e925/FEMA_Factsheet_Wisconsin_LAS_508.pdf

pollutants. FEMA's Hazard Mitigation Grant Program (HMGP) is the primary funding source for buyouts and other flood mitigation projects.[72] Administered by the Illinois Emergency Management Agency, the HMGP assists communities with an adopted hazard mitigation plan to pursue buyouts after a presidentially declared disaster. Eligible properties must be within the Special Flood Hazard Area (SFHA) and/or meet a certain cost-benefit ratio. Typically, a property with a structure in the floodplain valued at or below $280,000 is eligible for funding through HMGP and does not require performing a cost-benefit analysis. CMAP and partners can encourage or assist communities in developing an acquisition strategy for repetitive-loss, considerably damaged, or foreclosed properties to reduce future urban and riverine damages.

Local efforts by the counties, MWRD, and local governments have garnered both support and funding to reduce future damages through buyout programs and individual projects. Lake County's Voluntary Floodplain Buyout Program has received over $13 million in HMGP funds and acquired over 200 homes and parcels since 1997.[73] MWRD recently initiated a Flood-Prone Property Acquisition program to assist communities to pursue buyouts in the SFHA or inundation area mapped by MWRD, and/or serve as the local sponsor for the 25 percent local match requirement from the HMGP. DuPage County designated a portion of its Community Development Block Grant – Disaster Recovery Grant (CDBG-DR) funds to fund strategic buyouts and serve as a match for HMGP buyouts.[74] The City of Des Plaines received nearly $11.5 million to remove 47 flood-prone homes from the floodplain.[75] Counties should continue these efforts and seek additional opportunities for communities to participate, especially low-capacity communities.

3.3 Encourage coordinated investments with green infrastructure

Large portions of the region were built before the advent of modern stormwater management techniques, lack adequate drainage, and require retrofits to improve stormwater management. The Village of Downers Grove analyzed an existing post-war neighborhood to determine how much stormwater detention would have been required if built today. For a 1,000 acre residential neighborhood that is 42 percent impervious, 350 acre feet of detention would be needed for it to meet contemporary standards. And yet only 15 acre feet is currently being provided via stormwater management facilities within the neighborhood.[76] Given that this area, as well as other existing residential neighborhoods, are unlikely to see the level of redevelopment that would provide the necessary stormwater management capacity, this comparison illustrates the

[72] FEMA Hazard Mitigation Grant Program, https://www.fema.gov/hazard-mitigation-grant-program

[73] Lake County Stormwater Management Commission, Voluntary Floodplain Buyout Program website. See https://www.lakecountyil.gov/2372/Voluntary-Floodplain-Buyout-Program

[74] DuPage County Community Development Block Grant – Disaster Recovery Assistance website. See https://www.dupageco.org/cdbg-dr/

[75] FEMA, "FEMA Awards $11,447,584 grant to City of Des Plaines." See https://www.fema.gov/news-release/2016/08/30/fema-awards-11447584-grant-city-des-plaines

[76] In 2010, the Village of Downers Grove substantially increased the amount of stormwater storage in the neighborhood. Prior to the Village's investment in Washington Park, this area had six acre feet of stormwater storage.

need to incorporate stormwater management strategies into other types of public investments, including our streets, parks, and public building sites, as well as encourage retrofitting of private property. State agencies, counties, and municipalities that are making land development, and infrastructure decisions can play a critical role in ensuring that investments contribute to improved stormwater management.

Green infrastructure can be a cost effective way to increase stormwater management capacity, add redundancy to largely linear systems, and reap other co-benefits. Municipal and county investments in streets, park, and public buildings should be designed and constructed in coordination with stormwater management goals. For example, a recent partnership with Chicago Public Schools, MWRD, and Openlands, called Space to Grow, has led to the transformation of existing school campuses to meet both recreational and stormwater management goals.[77] Planned investments should be compared with existing studies at the county or municipal scale, such as MWRD's Detailed Watershed Plans or municipal stormwater management plans, to identify locations that are prone to flooding or could be contributing to flooding. Review of the regional flooding susceptibility indexes could help identify priority locations for stormwater retrofits that help reduce imperviousness and redirect runoff.

The Illinois EPA's Infrastructure Financial Assistance Section (IFAS) provides low interest loans to local governments through the State Revolving Fund (SRF). The SRF includes two loan programs: the Water Pollution Control Loan Program (WPCLP), which funds wastewater and stormwater projects, and the Public Water Supply Loan Program (PWSLP), which funds drinking water projects. Eligible projects under the WPCLP include infrastructure upgrades or rehabilitation and stormwater projects that benefit water quality, such as green infrastructure. Several communities have turned to the SRF program to fund drinking water or wastewater infrastructure projects. However, the program has only recently begun to accept stormwater projects. IEPA should promote the stormwater component of the program to Chicago region communities and assist interested applicants. CMAP can provide similar assistance by educating communities on the program.

Local flooding can be the result of specific issues on individual or a cluster of private properties. Engagement of private property owners in flooding solutions will be critical and can extend public dollars. Voluntary cost share programs, which provide technical and financial assistance and help pay for private improvements, are an important strategy to improve drainage and mitigate flooding for homeowners and businesses. Overhead sewers, backwater valves, sump pumps, and foundation crack repair are common improvements covered by cost share programs, however; some programs only cover overhead sewer installation.[78] Strategies to expand the effectiveness of cost share programs include targeting participation in flood-prone areas or by vulnerable populations, including green infrastructure improvements in addition to

[77] Space to Grow, http://www.spacetogrowchicago.org/

[78] Village of Glenview, Storm Water Task Force Cost Sharing Programs Overhead Sanitary Sewer Service Conversions factsheet, see https://glenview.il.us/Documents/overheadsewerinfo.pdf

grey infrastructure solutions, encouraging multi-property solutions where possible, and addressing infiltration and inflow (I/I) enforcement.[79] Infiltration and inflow of separate sewers occurs when aging pipes allow groundwater or stormwater to enter the sewer system, which can reduce sewer capacity and increase treatment costs. CMAP or other partners should investigate best practices across the region so that other counties and municipalities can continue to enhance their programs.

3.4 Establish dedicated revenue streams for stormwater management

Upkeep and expansion of grey and green infrastructure requires a dedicated revenue stream. While using the General Fund for stormwater infrastructure may work for some communities, establishing a dedicated revenue stream provides certainty that annual funding will be available. Sustainable streams of funding allow communities to carry out comprehensive planning and long-term projects, instead of isolated projects accomplished through grants. A stormwater utility allows a community to establish a user fee based on the demands property owners place on the drainage system. It provides a dedicated revenue stream for stormwater improvements and maintenance, as well as an incentive for property owners to reduce the amount of runoff they generate. Like other user-fee services, such as drinking water, electricity, and natural gas, a stormwater fee is a more equitable approach for paying for stormwater services. Stormwater utilities can also help raise awareness of the need for stormwater infrastructure and continued investment among the public who pay the fee. GO TO 2040 recommended the use of utilities and CMAP has provided additional guidance on establishing a utility fee.[80]

More recently, MPC has provided stakeholders with information on the benefits and options for dedicated funding as well as case studies of how communities have established successful programs in the region.[81] CMAP can help communities establish stormwater utilities by providing technical advice, via toolkits, municipal trainings, and stormwater planning. Stormwater plans often outline costs for improvements, which can be used as the basis for developing a stormwater utility. Understanding existing maintenance needs, as outlined in Strategy 3.1, can also inform the functions and budget of a stormwater utility.

The development of cost estimates is an element of some of CMAP's stormwater projects completed through the LTA program. Combining expertise in stormwater planning with capital improvement planning is a way in which CMAP can continue to assist communities that are

[79] Many cost share programs in Cook County build in infiltration and inflow (I/I) enforcement by requiring participants to cover the cost to disconnect illegal connections, like sump pumps connected to the sewer, or repair deteriorated laterals.

[80] "The Value of Stormwater Utilities for Local Governments in the Chicago region," Chicago Metropolitan Agency for Planning, 2013, www.cmap.illinois.gov/documents/10180/16791/stormwater_utilities_for_local_govts.pdf/866a64a4-ef11-47ce-b4ec-2293686d4a70

[81] Metropolitan Planning Council, "Steady streams: establishing dedicated funding for stormwater management," 2016, www.metroplanning.org/steadystreams/

interested in establishing a stormwater utility. CMAP can also integrate outreach and education into stormwater planning projects to garner public support for raising local revenue from a dedicated revenue stream, such as a stormwater utility. MWRD and county stormwater agencies should develop training programs and assistance for communities interested in developing a stormwater utility.

Non-home rule municipalities have the power to own and operate utilities under the Illinois Municipal Code. However, the majority of municipalities in Illinois that have established stormwater fees have done so under their home rule powers. To facilitate the process for all communities, CMAP should advocate that the Illinois General Assembly grant non-home rule municipalities and counties the power to establish stormwater utilities.

In the absence of a dedicated funding source, grants are important funding mechanisms that allow communities to demonstrate green stormwater infrastructure and garner public support for future investment. The grant landscape at the federal and state level is always changing. However, recent programs established by agencies, such as MWRD, demonstrate a local commitment to help communities address both riverine and urban flooding issues. CMAP should connect communities to grant and assistance opportunities through LTA projects and provide implementation assistance following plan adoption. Partners should also support initiatives that provide grant assistance through workshops or other activities. MWRD, county stormwater agencies, and other entities have a role to play by continuing or expanding assistance programs to assist floodprone communities, residents, businesses, and institutions. Flood studies performed by stormwater agencies, and/or CMAP's regional flooding susceptibility indexes and Economically Disconnected Areas layer should be utilized to target assistance to the highest-need areas. It should be recognized that grant funding is limited and often is only able to provide spot treatment for a particular flooding problem. Relying solely on grants is not a sustainable solution, but it can provided need funds to help communities, particularly low-capacity communities, implement and maintain green infrastructure.

4. Increase resiliency of transportation system

Current and future precipitation will continue to impact our transportation network. Modest flooding may only result in minor delays in our transportation network with light damages to infrastructure. However, severe flooding has the potential to lead to larger damages that reduce our ability to use key segments of our transportation network and increase maintenance costs as assets need to be repaired or reconstructed. In addition to the direct costs of delay and reduced access, road and transit closures can cause a cascade of indirect impacts, including declines in economic productivity and emergency service provision. Active forms of transportation, such as bicycling and walking, likely decline during storms and flooding and can affect mode choice and congestion. As the intensity and frequency of storm events increases with climate change, CMAP and partners should implement strategies that help protect our existing transportation assets, better integrate stormwater management into transportation planning and design, and improve operations and maintenance methods.

4.1 Conduct vulnerability assessments to inform transportation planning

The Fixing America's Surface Transportation (FAST) Act includes new requirements for state Departments of Transportation and Metropolitan Planning Organizations to integrate resilience into the transportation planning process.[82] Specific provisions require an assessment of capital investment and other strategies to reduce the vulnerability of the existing transportation infrastructure to natural disasters (23 CFR 450.324(f)(7)). MPOs should now coordinate with officials responsible for disaster risk reduction when developing the long-range transportation plan and the Transportation Improvement Program (TIP) (23 CFR 450.316(b)). IDOT is concluding an "All Hazards Transportation System Vulnerability Assessment and Response Plan," which determines the asset criticality of IDOT-owned assets (bridges, roadway corridors, railway corridors, and operational facilities) and the operational, socioeconomic, and health and safety impacts of different disasters. In addition, the Regional Transit Authority (RTA) is in the process of developing a "Flooding Resilience Plan for Bus Operations," which identifies key locations that are vulnerable to flooding that lead to Pace and CTA bus delays and re-routing.

As the new requirements go into effect in May 2018, CMAP and partners should explore different approaches and assist local communities in developing vulnerability assessments that reflect existing natural disasters, primarily flooding and storm events, and potential changes due to climate change. CMAP's work identifying populations who may be more vulnerable to climate change and/or economically disconnected populations should be a key component of the analysis. In addition, CMAP's Regional Flooding Susceptibility Index (Strategy 1.3) may provide additional information about flooding risk outside of regulatory floodplains. Through the LTA program, CMAP has recently been working to integrate climate change information into local planning processes. As a next step, the LTA program could assist communities in vulnerability assessments of their transportation system to help inform capital improvement plans and corresponding design considerations.

As new information on precipitation trends evolve and floodplain maps are updated, CMAP should explore conducting a regional vulnerability assessment that builds on the work of IDOT, RTA, and County DOTs. A system-wide assessment that takes into account which assets are most vulnerable and critical as well as the socioeconomic impacts can help the region prioritize investments. The effort should learn from existing state and MPO vulnerability assessments, many of which have been supported by FHWA. CMAP should involve local and county departments of transportation, emergency management agencies, and hazard mitigation specialists in the assessment process. Once complete, CMAP and partners should explore how the assessment can be integrated into local and county asset management plans, operational strategies, as well as the long-term transportation planning projects conducted by CMAP.

[82] Federal Register Vol. 81 No. 103, May 27, 2016, Statewide and Nonmetropolitan Transportation Planning; Metropolitan Transportation Planning: A rule by the Federal Highway Administration and the Federal Transit Administration, https://www.gpo.gov/fdsys/pkg/FR-2016-05-27/pdf/2016-11964.pdf

While the vulnerability assessment will help the region understand impacts on existing transportation systems; CMAP should also explore how flooding and storm events could impact planned investments. CMAP should explore whether additional design criteria are needed for regionally significant transportation projects in flood-prone areas.

4.2 Integrate stormwater management in transportation planning and investments

To reduce flooding vulnerability of our network, improved stormwater management techniques will be needed in existing and new transportation assets. These measures often include drainage improvements that increase detention capacity or promote infiltration, as well as a series of protective measures to reduce exposure to flood waters. Recently, the FAST Act expanded the scope of the statewide and metropolitan transportation planning process to reduce or mitigate stormwater impacts of surface transportation (23 U.S.C. 135 (d)(I) and 23 CFR 450.306 (b)(9)). This provision could enhance how stormwater management is addressed in surface transportation projects as well as overall planning efforts. Given the array of co-benefits from site-scale green infrastructure, CMAP recommends incorporating green infrastructure into road construction, rehabilitation, and retrofits to capture and infiltrate stormwater.

Currently, local street design and reconstruction requirements are not under the purview of the region's existing county stormwater management standards. Local streets follow design guidelines established by IDOT, which call for designs to follow the 10-year flood frequency or the 5-year flood frequency in combined sewer areas in the City of Chicago.[83, 84] There are no retention requirements connected with these standards. IDOT should reevaluate existing standards to better incorporate green infrastructure techniques into new and existing roadways. Partners in the region should participate in this process, particularly those who have gained experience through specific green infrastructure street projects. The City of Chicago, building on experience gained on projects like the Blue Island/Cermak Sustainable Streetscape project in Pilsen as well as their green alleys program, has developed a set of sustainable urban infrastructure guidelines to integrate green infrastructure interventions in street reconstruction projects.[85]

At the same time, many of our existing streets experience flooding due to conditions in the surrounding area. This is particularly true in locations where development occurred before stormwater management standards. Excess stormwater volumes that would ideally be handled on site flow to nearby streets and overwhelm the drainage capacity. Street flooding could be addressed through infrastructure retrofits in surrounding neighborhoods instead of within

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[83] "Illinois Department of Transportation Drainage Manual," July 2011, Illinois Department of Transportation," http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Bridges/Hydraulics/IDOT%20DRAINAGE%20MANUAL.pdf

[84] "Bureau of Local Roads and Streets Manual," Illinois Department of Transportation, 2008, http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Local-Roads-and-Streets/Local%20Roads%20and%20Streets%20Manual.pdf

[85] "Sustainable Urban Infrastructure, Policies and Guidelines," Chicago Department of Transportation, https://www.cityofchicago.org/city/en/depts/cdot/supp_info/sustainable_urbaninfrastuctureguidelines.html

constrained right-of-ways. Stormwater management planning efforts that focus on retaining stormwater can also assist in reducing the vulnerability of our streets to flooding. CMAP and partners should support continued efforts to integrate stormwater management into land use and transportation planning projects.

4.3 Develop and enhance operational strategies to maintain performance

Flooding can lead to a number of disruptions that reduce local and regional mobility on our streets, highways, and rail lines. While continuing land use and transportation planning efforts that expand transportation options are critical, further improvements in how we manage our existing transportation network are needed. Currently, operating agencies already use road closures and re-routing to prevent cars and buses from entering flooded streets. In addition, agencies pump water from flooded locations, including underground assets such as subways and viaducts.

CMAP has recommended a series of strategies to improve highway operations, including enhancements to weather responsive traffic management using Intelligent Transportation System (ITS) devices.[86] Work underway at the Midwest Regional Climate Center for the National Weather Service to better understand when weather events could lead to flash flooding could be integrated with management strategies. Improvements in stormwater monitoring technology may also alert operating agencies of future facility flooding, allowing them to better deploy traffic management strategies. CMAP has also recommended the creation of a regional pavement flooding reporting system to help plan for future flood events. This information could help inform a range of stakeholders, including stormwater modelers. Local and regional vulnerability assessments (4.1) can identify critical locations for management and operation changes and to plan for needed detours and traffic management activities. The RTA's "Flooding Resilience Plan for Bus Operations" currently under development, will outline strategies to maintain transit service during extreme events; operating agencies should undertake similar projects to ensure that the region's freight and transit system can maintain transportation access during storm events. CMAP should support these and other similar efforts through data sharing and coordination.

5. Enhance coordination and information sharing

Stormwater crosses jurisdictional boundaries and improved management will require coordination across many aspects of land use and transportation. Throughout the above recommendations, opportunities for improved coordination are apparent, yet the forum for making those connections at the regional scale does not yet exist. As a member of the Calumet Stormwater Collaborative, CMAP has witnessed the value of bringing different government,

[86] "ON TO 2050 Highway Operations Strategy Paper," Chicago Metropolitan Agency for Planning, http://www.cmap.illinois.gov/documents/10180/470714/Highway%20Operations%20Strategy%20Paper/26cff0fc-876a-4843-9fe5-c9aedbf73ddd

nonprofit, and private stakeholders together to better define stormwater management needs and identify opportunities for collaboration.

Through the Climate Resilience strategy paper, CMAP identified the need to explore a platform for coordinating regional resilience initiatives. As a subset of a regional partnership focused on climate resilience, CMAP should explore how it can provide a regional forum for county stormwater agencies in order to share best practices and monitoring data, foster innovation, and address cross-jurisdictional issues. Such a committee could coordinate many of the strategies identified in this strategy paper, including efforts to advance watershed and sewer modeling efforts, update county stormwater management ordinances, and prioritize investments. In addition, such a group could speak in a coordinated way about Federal NFIP and disaster relief assistance reform at the state and national level.

Next steps

The policy framework presented in this document sets the direction for the improved stormwater management in ON TO 2050. Given that stormwater management activities are inherently linked to many aspects of planning, this framework presents many considerations for other planning topics in ON TO 2050. CMAP expects these recommendations to inform technical assistance projects, policy updates, research products, and data sharing. The recommendations of ON TO 2050 are expected to synthesize these strategies into a comprehensive vision for the region. Regional partners are critical to the implementation of many of the strategies discussed in this paper. Continued collaboration will be essential as the agency develops and then implements ON TO 2050.

Appendix: Regional Flooding Susceptibility Index

Purpose

CMAP has developed urban and riverine flooding susceptibility indexes to identify priority areas across the region for flooding mitigation activities. While riverine flooding risk continues to be best identified through updated floodplain modeling efforts, locations of urban flooding risk remain largely unknown outside of infrequent and individual modeling efforts often done by municipalities. These indexes are not intended to replace those more technical efforts, instead they are designed to identify larger scale priorities across the region for mitigation activities.

The regional flooding susceptibility indexes can help CMAP focus stormwater planning efforts within the region and may be helpful in coordinating the actions of partners. Other potential uses include referencing the indexes when setting both small and large scale open space preservation and restoration priorities. The indexes could also inform vulnerability assessments when combined with critical facilities and vulnerable populations.

CMAP developed the regional flooding susceptibility index with critical support from John D. and Catherine T. MacArthur Foundation. CMAP is currently using the index to integrate stormwater management strategies into CMAP Local Technical Assistance (LTA) projects with support from the Cook County Community Development Block Grant-Disaster Relief program.

Methodology

After a literature review of innovative spatial assessments, CMAP selected the frequency ratio approach to create flooding susceptibility indexes for the region.[87] The frequency ratio approach is a statistical method based on the observed relationship between the distribution of reported flood locations and flooding-related factors. Given the different causes and contributing factors for riverine and urban flooding, CMAP created two separate flooding susceptibility indexes. The two indexes use slightly different flooding-related factors and have distinct geographies. The riverine flooding susceptibility index pertains to those areas of the region within the FEMA 100-year floodplain or MWRD 100-year inundation layer within Cook County, while the urban flooding susceptibility index includes all areas of the region outside of that geography.[88]

[87] CMAP reviewed several approaches, including Saro Lee, Biswajeet Pradhan, "Landslide hazard mapping at Selangor, Malaysia using Frequency Ratio and Logistic Regression Models," Landslides, (2007) 4:33-41; Moung-Jin Lee, Jung-eun Kang, Seongwoo Jeon, "Application of frequency ratio model and validation for predictive flooded area susceptibility mapping using GIS," Geoscience and Remote Sensing Symposium, 2012 IEEE International 22-27 July 2012; and Arzu Erener, Suzanne LaCasse, Amir M. Kaynia, "Hazard Mapping by Frequency Ratio Approach using GIS," International Centre for Geohazards, 2015.

[88] The analysis focused on flooding of developed areas, so the geographies of both urban and riverine flooding have been further refined to exclude areas of water, open space, and agricultural production using data from the 2013 CMAP Land Use Inventory.

Floodplain mapping already identifies areas of risk in the region; the riverine flooding susceptibility index highlights areas within floodplains that have greater mitigation needs.

With input from experts and stakeholders in the field, [89] CMAP identified a number of flooding-related factors to include in the analysis. Each flooding-related factor was chosen due to their unique contribution to flooding risk. The following describes each factor and how it contributes to flooding:

- **Topographic Wetness Index (TWI):** The TWI identifies flat areas with high flow accumulation where water is likely to pond, especially if the existing storm sewer network has reached capacity. Streets and buildings within these areas could be more susceptible to surface ponding, overland flow, or water seepage. The TWI is calculated by evaluating the flow accumulation, slope, and various geometric functions through GIS.[90]

- **Combined sewer service areas:** Combined sewers have long been recognized as more susceptible to flooding given the combination of the storm and sanitary sewers. When the sewers reach capacity, areas of the region can experience basement backups and combined sewer overflows. CMAP identified those areas of the region currently being served by combined sewers with data assistance from MWRD and various communities.

- **Elevation differential between property and nearest Base Flood Elevation (BFE):** Development near a floodplain with a surface elevation within 6 feet of the BFE have been identified as higher urban flooding risk. The Cook County Hazard Mitigation Plan identified that the majority of repetitive loss properties located outside of the floodplain had basements below the base flood elevation.[91] Using GIS, CMAP calculated the mean parcel elevation for properties within 1,500 feet of the nearest BFE and identified those whose elevation was within six feet.

- **Impervious cover:** Impervious cover prevents infiltration of rainwater and generates stormwater runoff. Areas with higher impervious cover generate more runoff and are more reliant on sewer drainage capacity. Development in these areas could experience

[89] CMAP worked directly with the Conservation Design Forum and Geosyntec on developing the approach, which had been informed by pervious work with Hey and Associates. In addition, CMAP consulted a number of stakeholders in the process, including representatives from the Metropolitan Water Reclamation District of Greater Chicago, DuPage County Stormwater Management Planning Committee, Lake County Stormwater Management Commission, Kane County Division of Environmental and Water Resources, Kendall County Stormwater Planning Committee, McHenry County Planning and Development, and Will County Stormwater Planning Committee, City of Chicago Department of Water Management, Illinois State Water Survey, and US Army Corps of Engineers.
[90] CMAP received assistance from the Illinois State Water Survey on the use of this flooding-related factor.
[91] The development of this flooding-related factor was also informed by FEMA Technical Bulletin 10: Ensuring that Structures Built on Fill in or Near Special Flood Hazard Areas are Reasonably Safe From Flooding, see https://www.fema.gov/media-library/assets/documents/3522.

flooding in the form of basement backups, due to overloaded sewers, and surface ponding. CMAP relied on the National Land Cover Dataset to identify the percent of impervious cover.

- **Impervious cover of watershed catchment:** Riverine flooding is related to the imperviousness of the contributing watershed catchment. More developed catchments have the potential to generate more stormwater runoff that increases the risk of flooding. CMAP relied on the National land Cover Dataset to identify the percent of impervious cover within catchment boundaries from the National Hydrography Dataset Plus.

- **Age of first development:** Nationally, floodplains began to be recognized in development regulations in 1968, while stormwater management ordinances were introduced in the region starting in 1972. However, large portions of the region were developed prior to these practices and may be more likely to experience flooding. In addition, older development may be more susceptible to flooding due to greater maintenance demands over time. CMAP utilized the USGS National Water-Quality Assessment (NAWQA) Wall-to-Wall Anthropogenic Land Use Trends (NWALT) 1974-2012 land cover datasets in order to conduct a comparison over time.

- **Precipitation variation:** Areas that typically receive higher amounts of precipitation within the region for specific storm events may be more likely to experience flooding. CMAP relied on the NOAA Atlas 14 10-year, 2-hour storm event to identify precipitation variation within the region that could contribute to urban flooding. This storm event was selected given its connection to common infrastructure design standards for local drainage systems.

With data assistance from FEMA, several counties, and the City of Chicago, CMAP created an address-level database of documented flood locations. **Table 1** provides a summary of each dataset used in the analysis. CMAP used unique locations for the analysis, which results in a total database of 165,919 locations. This total represents unique flood locations across all input datasets, as some locations were presented in multiple datasets.

Table 1. Reported flood locations

Source	Time period	Unique locations		
		Riverine	Urban	Total
FEMA National Flood Insurance Program Claims[a]	1978-2016	5,809	7,551	13,360
FEMA Individual Assistance Grants[a]	2007-2013	2,541	135,055	137,596
FEMA Discovery Data	2013-2015	77	725	802
City of Chicago 311 Standing Water Locations[b]	2010-2017	1	1,236	1,237
MWRD Detailed Watershed Plans	2009-2011	199	688	887
DuPage County[c]	2013	51	354	405
Kendall County Department of Planning	2008-2013	29	238	267
Lake County Stormwater Management Commission	2013	3,324	12,016	15,340

a All FEMA claims or reports were include regardless of payment.
b CMAP is using point-data 311 calls for standing water related to mosquito abatement, obtained from the City of Chicago in June 2017. This dataset does not include calls to report basement back-ups or other building flooding. The majority of the calls (~93%) correspond with flooding in the street.
c Associated with the April 2013 floods that were recognized in a presidentially declared disaster (DR-1416)
Source: CMAP

Categorical flooding-related factors were split into classes to determine which characteristics of the factor are more highly correlated with reported flood locations. For example, age of development was split into six classes based on the year the area was first developed: pre-1974, 1975-1982, 1983-1992, 1993-2002, 2003-2012, undeveloped/post-2012. Other flooding-related factors, such as percent impervious cover, were divided into intervals of roughly equal sizes. CMAP then compared the categories/percentiles of each flooding-related factor to reported flood locations to determine the strength of the relationship between the factor characteristics and flood occurrence.

Tables 2 and 3 provide the frequency ratios for each flooding-related factor for both urban and riverine flooding study areas respectively. The table also presents two contextual data points that are used to derive the frequency ratio: the percent of the study area that corresponds with each factor category, and the percent of flood locations that occurred within each factor category. In the analysis, the frequency ratio is the ratio of the percent of flood locations in each category to the percent of the study area in each category. A value of one indicates equal occurrence of reported flood locations within a category as compared to the amount of that category within the study area; so if a category within a flooding-related factor reveals a value greater than one, it indicates a higher correlation. Frequency ratios above one are highlighted in Tables 2 and 3 in yellow. Additional factors were tested but revealed lower correlations or noisy results and were removed from the analysis.[92]

[92] The following factors were initially included but revealed low or noisy correlation with reported flood locations: potential Wetland Soils Landscapes, sandy soils, and precipitation amounts for the 100-yr, 24-hr event.

Table 2. Flooding-related factors, categories, and frequency ratios for the urban flooding susceptibility index

Flooding-related factor	Data input	Description	Urban[93]			
			Categories	Percent of Study Area	Percent of Flooding Locations	Frequency Ratio
Topographic Wetness Index (TWI), Urban Only	CMAP derived from 5-ft resolution Digital Elevation Model (DEM).	Potential risk of flooding within drainage depressions where water is likely to pond.	0 to 0.17	7.70%	1.15%	0.15
			0.17 to 0.19	12.07%	4.48%	0.37
			0.19 to 0.2	9.47%	6.06%	0.64
			0.2 to 0.21	9.99%	8.84%	0.89
			0.21 to 0.23	10.79%	12.14%	1.13
			0.23 to 0.25	9.92%	12.87%	1.30
			0.25 to 0.28	10.01%	15.49%	1.55
			0.28 to 0.37	11.32%	12.08%	1.07
			0.37 to 0.56	9.77%	11.45%	1.17
			0.56 to 1	8.97%	15.40%	1.72
Combined sewer service area	Combined Sewer Service Area boundaries, received from MWRD and municipalities.	Potential risk of flooding caused by a connection to a combined sewer system.	Present	15.75%	69.55%	4.41
			Absent	84.25%	30.43%	0.36
Elevation differential between property and nearest FEMA Base Flood Elevation (BFE), Urban only	Difference in mean parcel elevation calculated from 5-ft regional DEM and BFE from FEMA for parcels within 1,500 feet of the nearest BFE.	Potential risk of flooding caused by a sewer connection to a nearby waterway and an elevation at or near the BFE.	Not within 1,500 feet / Non-Parcel	80.01%	86.76%	1.08
			<-6	0.12%	0.04%	0.33
			-4 to -6	0.07%	0.03%	0.49
			-2 to -4	0.23%	0.25%	1.06
			-2 to 0	0.75%	1.16%	1.56
			0 to 2	1.67%	3.16%	1.89
			2 to 4	2.15%	2.37%	1.10
			4 to 6	2.03%	1.57%	0.77
			>6	12.96%	4.63%	0.36
Impervious cover	Percent Impervious Cover from 2011 National Land Cover Dataset	Potential risk for flooding where greater impervious cover generates more runoff; can contribute to a greater likelihood of flooding in the form of basement backups, due to overloaded sewers, and surface ponding.	No IC	15.52%	0.60%	0.04
			1-16%	8.91%	1.65%	0.19
			17-24%	8.82%	3.32%	0.38
			25-30%	7.95%	5.15%	0.65
			31-36%	8.33%	8.74%	1.05
			37-43%	9.36%	12.74%	1.36
			44-49%	7.35%	13.63%	1.85
			50-58%	9.03%	21.76%	2.41
			59-69%	8.10%	20.20%	2.49
			70-85%	8.60%	10.29%	1.20
			86-100%	8.01%	1.90%	0.24

[93] The study area includes all land uses outside of the 100-yr floodplain boundary (MWRD inundation layer in Cook County) except those portions that include water, open space, or agricultural lands as identified in the 2013 CMAP Land Use Inventory.

Table 2 (cont). Flooding-related factors, categories, and frequency ratios for the urban flooding susceptibility index

Flooding-related factor	Data input	Description	Urban[94]			
			Categories	Percent of Study Area	Percent of Flooding Locations	Frequency Ratio
Age of first development	Age of first development from USGS 1974-2012 land use trends dataset, using developed land classes.[95]	Potential risk for flooding where presence of development pre-dates floodplain and stormwater management standards.	Prior to 1974	41.16%	84.66%	2.06
			1982	5.43%	2.92%	0.54
			1992	3.34%	0.89%	0.27
			2002	4.95%	1.05%	0.21
			2012	4.55%	0.99%	0.22
			Undeveloped/ post-2012	40.58%	9.48%	0.23
Precipitation variation	Precipitation amounts (inches) for the 10-year, 2-hour storm from NOAA Atlas 14.	Identifies variation in precipitation for this specific frequency storm	2.26 to 2.29	9.88%	2.19%	0.22
			2.29 to 2.32	10.42%	3.08%	0.30
			2.32 to 2.35	10.06%	3.40%	0.34
			2.35 to 2.39	10.14%	4.73%	0.47
			2.39 to 2.41	10.18%	2.06%	0.20
			2.41 to 2.42	10.75%	0.92%	0.09
			2.42 to 2.44	10.90%	2.75%	0.25
			2.44 to 2.47	10.20%	14.38%	1.41
			2.47 to 2.49	10.37%	33.99%	3.28
			2.49 to 2.55	7.08%	32.46%	4.58

[94] The study area includes all land uses outside of the 100-yr floodplain boundary (MWRD inundation layer in Cook County) except those portions that include water, open space, or agricultural lands as identified in the 2013 CMAP Land Use Inventory.

[95] Developed USGS classes: Major transportation, commercial/services, industrial/military, high density residential, and low-medium density residential.

Table 3. Flooding-related factors, categories, and frequency ratios for the riverine flooding susceptibility index

Flooding-related factor	Data input	Description	Riverine[96]			
			Categories	Percent of Study Area	Percent of Flooding Locations	Frequency Ratio
Combined sewer service area	Combined Sewer Service Area boundaries, received from MWRD and municipalities.	Potential risk of flooding caused by a connection to a combined sewer system.	Present	3.47%	16.01%	4.62
			Absent	96.53%	83.62%	0.87
Impervious cover	Percent Impervious Cover from 2011 National Land Cover Dataset	Potential risk for flooding where greater impervious cover generates more runoff; can contribute to a greater likelihood of flooding in the form of basement backups, due to overloaded sewers, and surface ponding.	No IC	46.36%	8.51%	0.18
			1-10%	5.60%	3.75%	0.67
			11-15%	5.56%	3.70%	0.67
			16-19%	4.85%	4.93%	1.02
			20-24%	5.87%	8.43%	1.44
			25-29%	5.12%	9.46%	1.85
			30-36%	5.75%	12.69%	2.21
			37-44%	5.15%	14.59%	2.83
			45-55%	5.03%	16.71%	3.32
			56-75%	5.48%	13.38%	2.44
			76-100%	5.25%	3.49%	0.67
Impervious cover of watershed catchment, Riverine only	Percent Impervious Cover from 2011 National Land Cover Dataset; summarized by catchments using National Hydrography Dataset Plus	Riverine flooding is related to the imperviousness of the contributing watershed.	0-4%	10.01%	1.38%	0.14
			4-8%	10.13%	4.84%	0.48
			8-13%	9.99%	5.56%	0.56
			13-17%	10.02%	13.26%	1.32
			17-22%	10.01%	4.15%	0.41
			22-27%	10.05%	6.24%	0.62
			27-32%	10.01%	6.28%	0.63
			32-39%	9.94%	10.76%	1.08
			39-46%	10.00%	20.73%	2.07
			46-84%	9.84%	26.43%	2.69
Age of first development	Age of first development from USGS 1974-2012 land use trends dataset, using developed land classes.[97]	Potential risk for flooding where presence of development pre-dates floodplain and stormwater management standards.	1974	23.43%	55.58%	2.37
			1982	3.05%	4.28%	1.41
			1992	2.08%	4.01%	1.92
			2002	2.62%	2.48%	0.94
			2012	3.04%	0.93%	0.31
			Undeveloped/ post-2012	65.78%	32.35%	0.49

[96] The study area includes all land uses within the 100-yr floodplain boundary (MWRD inundation layer in Cook County) except those portions that include water, open space, or agricultural lands as identified in the 2013 CMAP Land Use Inventory.

[97] Developed USGS classes: Major transportation, commercial/services, industrial/military, high density residential, and low-medium density residential.

CMAP then added the frequency ratios of all the relevant flooding-related factors to create a flooding susceptibility index, which highlights areas more or less likely to experience flooding.[98] The flooding susceptibility value represents the relative hazard to flooding; the greater the value, the higher the hazard to flooding. The resulting flooding susceptibility index was mapped for urban flooding (**Figure 1**) and riverine flooding (**Figure 2**).[99] The spatial resolution of the index is determined by the variable with the highest resolution; in this case, the urban index is defined by the TWI's 5-foot resolution while the riverine index is defined by the NLCD's 30-meter resolution. For reference, CMAP also produced separate maps of each flooding-related factor as they relate to the urban and riverine flooding susceptibility indexes.

CMAP tested the results of the flooding susceptibility indexes against a random sample of reported flood locations that were set aside for this validation exercise.[100] Preliminary accuracy assessment was performed by counting the number of validation flood locations within each of the five index levels. **Table 4** displays the total acreage of each index level and the count/percentage of flood locations within each index level. The results show a strong correlation between the validation flooding locations and the highest index levels.

Table 4. Correlation by Index Level for both Urban and Riverine Flooding Susceptibility Indexes

Index Level	Urban Flooding Susceptibility Index		Riverine Flooding Susceptibility Index	
	Count of Flooding Locations[1]	Flood Occurrence (%)	Count of Flooding Locations[1]	Flood Occurrence (%)
1 (lowest)	406	0.9%	43	1.4%
2	625	1.3%	94	3.0%
3	896	1.9%	57	1.8%
4	1113	2.4%	170	5.5%
5	1360	2.9%	240	7.7%
6	1602	3.4%	238	7.6%
7	2504	5.4%	288	9.2%
8	4945	10.6%	378	12.1%
9	8719	18.7%	487	15.6%
10	24460	52.5%	1124	36.0%

[1] The flooding locations used are from the validation dataset that were set aside for the accuracy assessment.

[98] All frequency ratio scores are included in the flooding susceptibility index, including those that are less than one.
[99] While percentiles or unique classes were used to symbolize most variables, CMAP used the geometrical interval classification to symbolize the susceptibility indexes. For more details, see http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Geometrical_interval
[100] Separate validation samples of known flooding locations were retained for the urban and riverine flooding susceptibility indexes. The validation sample consisted of 30 percent of known flooding locations.

Figure 1. Urban flooding susceptibility index

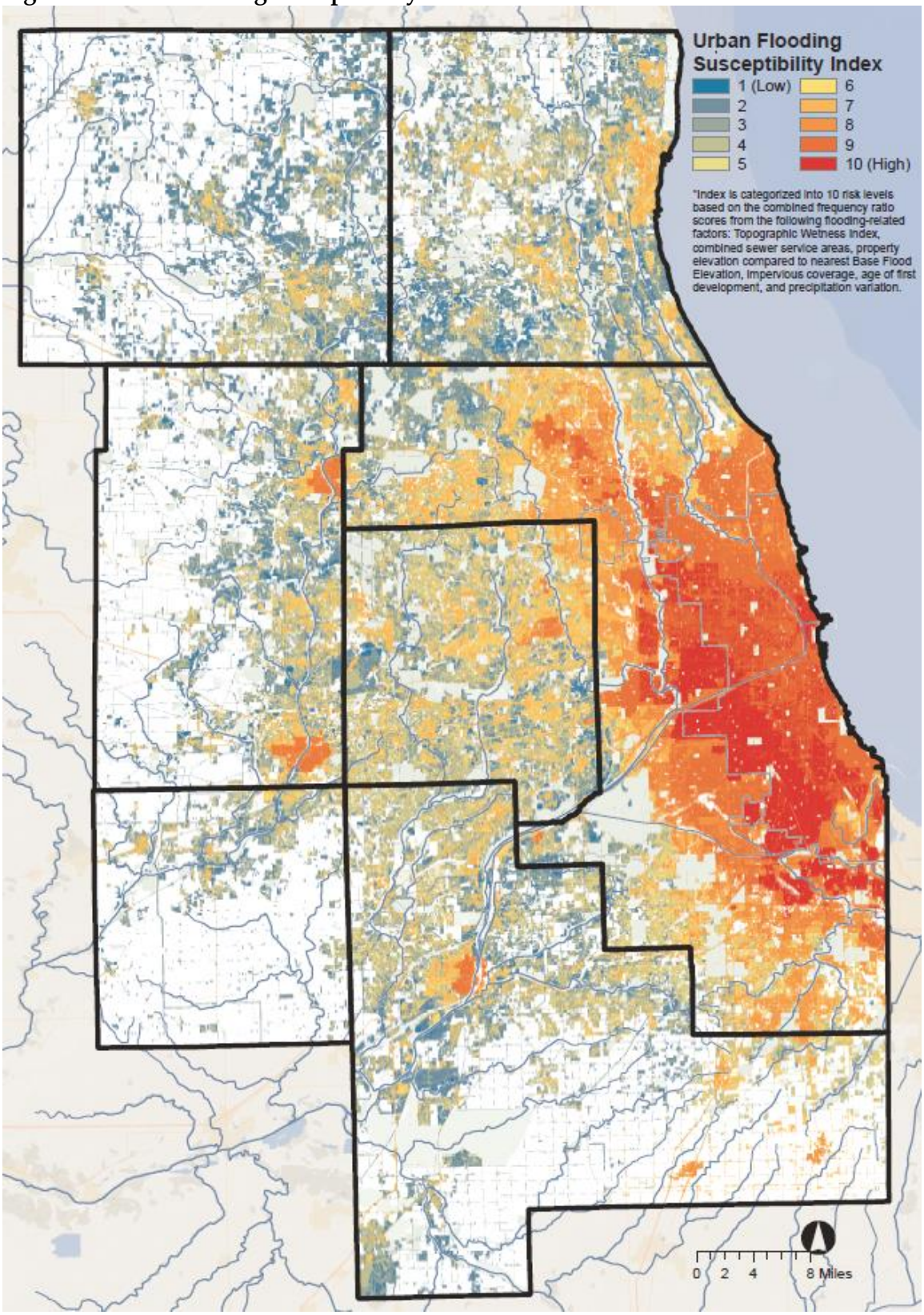

Figure 2. Riverine flooding susceptibility index