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Stormwater Management in Response to Climate Change Impacts: Lessons from the Chesapeake Bay and Great Lakes Regions

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U.S. Environmental Protection Agency
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LIST OF ABBREVIATIONS

ACE	EPA’s Air, Climate, and Energy research program
ADA	Americans with Disabilities Act
ASAP	American Society of Adaptation Professionals
ASFPM	Association of State Floodplain Managers
CT NEMO	Connecticut Nonpoint Education for Municipal Officials
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GI	Green infrastructure
GIS	Geographic Information System
GLAA-C	Great Lakes Adaptation Assessment for Cities
GLISA	Great Lakes Integrated Sciences and Assessments Center
ICLUS	Integrated Climate and Land Use Scenarios
IHM	Immaculate Heart of Mary
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
ISC	Institute for Sustainable Communities
LID	low-impact development
LGAC	Local Government Advisory Committee
MS4	municipal separated storm sewer system
NCA	National Climate Assessment
NERR	National Estuarine Research Reserve
NOAA	National Oceanic Atmospheric Administration
ODNR	Ohio Department of Natural Resources
OW	Office of Water, USEPA
ROI	return on investment
SWC	EPA’s National Stormwater Calculator
SWMM-CAT	Storm Water Management Model Climate Adjustment Tool
TMDL	total maximum daily load
WICCI	Wisconsin Climate Change Impacts
WIP	Watershed Implementation Plan
YCPC	York County Planning Commission

PREFACE

This report was prepared by the U.S. Environmental Protection Agency's (EPA) Air, Climate, and Energy (ACE) research program, located within the Office of Research and Development, with support from ICF International. One of the goals of the ACE research program is to provide scientific information and tools to support EPA's strategic goal of taking action on climate change in a sustainable manner. This report supports that goal by providing insights gleaned from workshops and assessments EPA and National Oceanic Atmospheric Administration (NOAA) led with local planners on ways to further the adoption of climate change adaptation practices in stormwater management. Documentation from the workshops formed the basis for assessing common challenges and opportunities across the Chesapeake Bay and Great Lakes regions. The intended audiences for this report are local and state planners and managers engaged in the development and implementation of stormwater management policies and practices, and scientists (particularly those in EPA's Office of Water and regional offices) working on climate change adaptation specific to stormwater control.

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EXECUTIVE SUMMARY

This report provides specific examples of tools, data, methods, and actions to help stormwater managers, community environmental decision makers, and land use planners incorporate climate change into their management plans. Climate changes (e.g., the amount, timing, and intensity of rain events, droughts, and other extreme events), along with land use changes (e.g., development), can affect the amount of stormwater runoff to be managed. Local decision makers have stated a need for more information on how they can adapt local stormwater management planning and stormwater control to account for these changes.

To address this need, recent workshops and other community-level efforts funded by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) were held across the Chesapeake Bay and the Great Lakes regions. These collaborations with local communities resulted in jointly derived insights into how climate change practitioners can most effectively work with communities to increase the resiliency (adaptation) of stormwater systems to the impacts of climate and land use change. In particular, discussions focused on opportunities to implement green infrastructure, such as rain gardens that collect and absorb runoff from rooftops, sidewalks, and streets, low-impact development, and other alternative management strategies.

The report includes a synopsis of themes that emerged that were common across these efforts to inform stormwater managers, planners, and climate change or sustainability coordinators, or anyone charged with implementing climate change adaptation plans. Challenges, potential near-term solutions, and long-term needs are organized into four topic areas:

Incorporating climate change into planning

Several challenges were encountered in trying to find and apply relevant climate change information into planning; they included issues of scale and uncertainty in climate and land use change projections. Near-term opportunities to overcome these challenges were identified, and included better use of existing historical data and exploration of climate change scenarios to plan for future uncertainty. Scenarios are plausible alternative futures that represent a range of potential changes in climate, in contrast to predictions or forecasts. In the longer term, efforts can be made to improve or enhance data collection to support future decision making.

Building local capacity

Local capacity to plan for, design, construct, and permit green infrastructure and other alternative management strategies to increase resilience is necessary. Planning and implementing these types of solutions in the near-term requires that local-level professionals have greater opportunities to expand their knowledge and greater ability to coordinate across agencies and jurisdictions. In the longer-term, more novel watershed-scale solutions will be needed such as regional stormwater model ordinances and federal- or state-level regulatory changes.

Identifying and communicating costs and benefits of green infrastructure

Stormwater managers and planners currently have limited economic information on implementing green infrastructure projects and find it challenging to both quantify the benefits and articulate them to others. Local-level decision makers need better and more accessible information on the costs and benefits of green infrastructure and other climate change adaptation strategies. There is a particular need for more guidance and protocols that account for the full time period of expected (direct) benefits, as well as ancillary benefits (co-benefits), such as provision of habitat, community beautification, and other quality-of-life factors. Near-term opportunities include better training on the full value of green infrastructure and how to integrate it into other projects, such as highway improvements; maintenance, retrofit, and redevelopment projects; and Americans with Disabilities Act (ADA)-compliant sidewalk access construction. Long-term needs include tools to help quantify costs and benefits and to document and collect data related to actual costs.

Implementation within current governance structure

Existing priorities and regulatory requirements can be a barrier to managers voluntarily including climate change into their planning and decision making.   A shift towards incorporating green infrastructure into site design can be spurred by market forces such as incentives that change business or residential demand (e.g., business or homeowner rebates), and regulatory changes. Implementing novel solutions may require proactive interagency or interjurisdictional coordination in both the near term and long term. Greater public awareness and acceptance of these new approaches also helps achieve project success.

1. INTRODUCTION

1.1. A Changing Climate

Climate stressors such as increasing temperatures, changing precipitation patterns, and extreme events are already affecting water resources. As the climate continues to change, water resources will be affected in different ways across the country. Some regions may experience periods of drought and water shortages, while others may experience more frequent heavy precipitation events (see Figure 1), and others may experience alternating drought and heavy precipitation events. In addition to the regional diversity of precipitation trends, significant seasonal differences in precipitation rates are expected (see Figure 2). While many areas anticipate an increase in precipitation in the spring and winter, if that is accompanied by a decrease in precipitation in the summer, the result could be a reduction in water availability when it is most needed and an abundance of water when it is least needed.

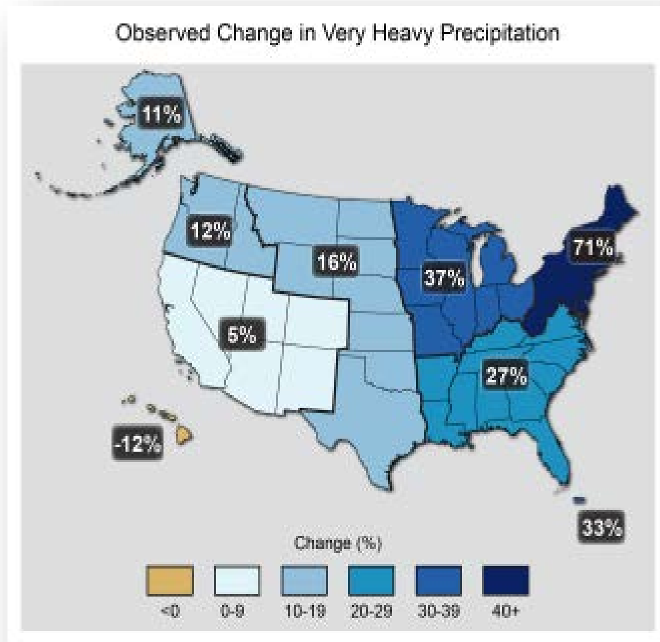

Figure 1. Percent changes in the amount of precipitation falling during very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region. Figure taken from Melillo et al., 2014.

Stormwater management is planned based on local weather and climate. However, climate changes, such as the amount, timing, and intensity of rain events, in combination with land development, can significantly affect the amount of stormwater runoff that needs to be managed. In some regions of the country, the combination of climate and land use change may make existing stormwater-related flooding worse, while other areas may be minimally affected. These interactions can also be additive or synergistic. These changing conditions have implications for stormwater management as local decision makers look to improve existing infrastructure and build new stormwater systems.

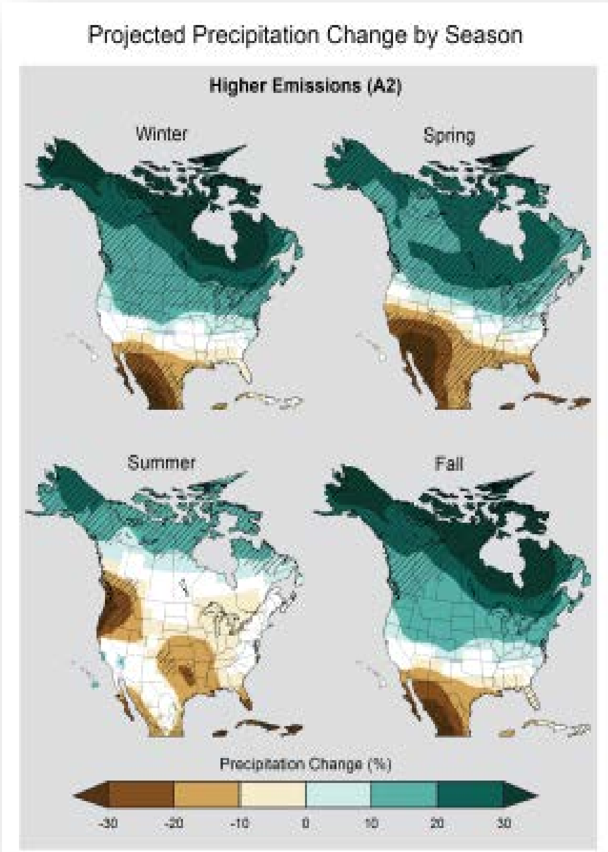

Figure 2. Projected change in seasonal precipitation for 2071-2099 (compared to 1970-1999) under an emissions scenario that assumes continued increases in emissions (A2). Figure taken from Melillo et al., 2014.

Addressing climate-driven changes in runoff can be done through altering or modifying stormwater practices and land use management decisions. Unfortunately, the process of incorporating climate change into existing planning processes can be difficult and daunting for local decision makers because of constrained budgets and staff availability, and an absence of climate change expertise. Better and more readily accessible information is needed on how to incorporate climate change into stormwater management planning. Effective management planning will require details on how and where impacts will be experienced, and information on costs and performance of stormwater management practices such as green infrastructure strategies. New and enhanced management practices hold promise for controlling climate change related events such as heavier downpours and oscillating drought-flood conditions.

1.2. Genesis of This Report

This report grew out of work done by the EPA to assess potential climate change impacts in the Chesapeake Bay region for the 2014 National Climate Assessment (NCA) (Melillo et al., 2014). After completing this assessment, the EPA conducted three local-level workshops in the Chesapeake Bay watershed on stormwater management and climate change adaptation to contribute to the NCA objective of promoting "an ongoing, sustainable national assessment of global change impacts and adaptation." The project team selected the sites for the workshops based on (1) the communities' level of concern about changing future precipitation (often informed by already observed changes) and (2) their willingness to engage in a dialogue regarding the impacts, adaptation options, and related challenges associated with climate and land-use change and the implications for water quality, precipitation-driven flooding, and stormwater management. Following the workshops, the EPA reached out to others conducting stormwater and climate change workshops, and to a National Oceanic and Atmospheric Administration (NOAA)-led needs assessment entitled *Planning for Climate Change in the Laurentian Great Lakes Basin* (Nelson et al., 2013), and other related efforts in the Great Lakes region to compare notes on lessons learned (see Figures 3 and 4). This report provides a compilation of the common ideas that emerged across all of these efforts.

Figure 3. Climate change workshop locations in the Chesapeake region. EPA and partners hosted workshops in York County, Pennsylvania; Baltimore, Maryland; and Stafford County, Virginia.

Figure 4. Climate change workshop locations in the Great Lakes region. NOAA and partners hosted workshops in Monroe and Ann Arbor, Michigan; Cleveland and Toledo, Ohio; Green Bay, Wisconsin; and Duluth, Saint Paul, and Minneapolis, Minnesota.

1.3. Roadmap to the Rest of This Report

The following sections provide brief descriptions of each of the EPA and NOAA workshops, assessments, and research collaborations (see Section 2); insights gained from these activities (see Section 3); a summary of resources identified in this report, compiled into a single table (see Appendix A); and listings of the project teams and participants involved in each of the workshops, assessments, and research collaborations (see Appendix B). The efforts described in this report (including associated tools, resources, and programs) are not intended to be comprehensive but rather illustrative of the types of resources and efforts available and underway; there are many other significant and successful efforts around the country that are not included in this report.

2. DESCRIPTION OF WORKSHOPS, ASSESSMENTS, AND RESEARCH COLLABORATIONS

Each workshop, assessment, and research collaboration was conducted in partnership with local decision makers and managers to learn together how climate change information can be made more helpful and useful in stormwater planning efforts. Lessons learned were assessed across these efforts and the primary topics discussed in Section 3 emerged from this assessment. These workshops, assessments, and research collaborations are summarized in Table 1 below, followed by longer descriptions of each.

Table 1. Overview of workshops, assessments, and research collaborations

Identifier	Title	Sponsor	Types of Participants	Location	Date	Type of Effort
1	Stormwater Responses to Land Use and Climate Change in the Chesapeake Bay Watershed	USEPA	Federal and local government, academia, nonprofit	Stafford, VA; Baltimore, MD; York, PA	April–June, 2013	Workshop
2	Preparing Stormwater Systems for Climate Change—a workshop for Lake Erie basin communities	Michigan Sea Grant, Old Woman Creek NERR, GLA A-C, IHM	Federal and local government, academia, nonprofit	Monroe, MI	October 2013	Workshop
3	Planning for Climate Change in the Great Lakes Region	NOAA	State and federal agencies, academia, nonprofit	Cleveland, OH; Green Bay, WI; Duluth, MN	August–September, 2011	Needs Assessment and Workshops

Table1. Overview of workshops, assessments, and research collaborations (continued)

Identifier	Title	Sponsor	Types of Participants	Location	Date	Type of Effort
4	Supporting Climate and Coastal Resilience Planning in the Western Lake Erie Basin	NOAA	Local government, state and federal agencies, nonprofit, academia	Toledo, OH	June, 2013	Workshop
5	Evaluating Stormwater Solutions for Ohio Collaborative Research Project	Chagrin River Watershed Partners, Inc.	State and federal agencies, academia	Ohio	2011-2015	Collaborative Research
6	Economic Assessment of Green Infrastructure Strategies for Climate	NOAA	Federal agencies, consultants, nonprofit, local government	Toledo, OH; Duluth, MN	2012-2014	Economic Assessment
7	Great Lakes Adaptation Assessment for Cities	U of Michigan, Kresge Foundation, GLISA	Local government, nonprofit, academia	St. Paul, MN; Minneapolis, MN; Ann Arbor, MI	May–September 2013	Workshops
8	Forwarding Adaptation in the Great Lakes Region	ISC, GLAA-C, Kresge Foundation	Local government, nonprofits, academia	Ann Arbor, MI	November 2012	Workshop

NERR = National Estuarine Research Reserve, IHM = Immaculate Heart of Mary, GLISA = Great Lakes Integrated Sciences and Assessments Center, GLAA-C = Great Lakes Adaptation Assessment for Cities

2.1. Stormwater Responses to Land Use and Climate Change in the Chesapeake Bay Watershed (Workshops)

Stafford County, Virginia: April 25, 2013

City of Baltimore, Maryland: May 20, 2013

York County, Pennsylvania: June 20, 2013

The EPA's Office of Research and Development collaborated with the Chesapeake Bay Program's Local Government Advisory Committee (LGAC) and Scientific and Technical Advisory Committee to host three one-day workshops to assist local planners and stormwater managers in considering climate change impacts. The workshops followed the development of a case study of climate change impacts in the Chesapeake Bay developed for the 2014 NCA and contributed to the NCA objective to promote "an ongoing, sustainable national assessment of global change impacts and adaptation."

Figure 5. Communities in Chesapeake Bay watershed that hosted stormwater responses to land use and climate change workshops: Stafford County, Virginia; Baltimore, Maryland; and York County, Pennsylvania.

Workshop participants included local (county or city) staff and decision makers (e.g., land use planners, engineers, water managers, stormwater managers); local researchers investigating the impacts of climate and land use changes; representatives from nonprofit organizations and associations; and representatives of selected state and federal programs related to water quality.

2.1.1. Workshop Goals

1. Explore the impacts of climate and land use change in the Chesapeake Bay watershed and the implications for water quality, precipitation-driven flooding, and stormwater management.

2. Explore stormwater management adaptations to climate and land use changes in the Chesapeake Bay watershed, particularly green infrastructure or other LID strategies.

3. Identify information gaps and other barriers preventing local consideration and implementation of green infrastructure or other LID strategies to help control stormwater (see Appendix C for a discussion of these approaches).

2.1.2. Main Topics Addressed and/or Activities Undertaken

The interactive workshop included presentations and mapping exercises that provided participants with the opportunity to begin identifying concerns and solutions specific to neighborhoods within their city or county. Historic and observed changes in the precipitation patterns were presented for each city based on data that had been collected at a nearby airport. The data were used to initiate a conversation about local conditions in the region and how they might change under climate change. The workshop sessions covered a discussion of the existing planning context, constraints, and opportunities; presentations on projected land use change and climate change; participatory mapping exercises to pinpoint the areas with challenges (in terms of water quantity, flooding, and degraded water quality under current and projected conditions); and an exploration of green infrastructure and LID solutions as well as barriers to more widespread adoptions of these approaches.

Figure 6. Workshop participants in Baltimore discuss the potential impacts of increased precipitation-driven flooding in the Cherry Hill neighborhood.

2.1.3. Contribution

The facilitated workshop discussions were valuable on two levels: (1) participants identified some specific constraints and opportunities they face in day-to-day management of stormwater and the adoption of green infrastructure and LID solutions and (2) the project team observed how information on future climate and land use changes could be made most useful to local planners.

2.2. Preparing Stormwater Systems for Climate Change—A Workshop for Lake Erie Basin Communities (Workshop)

Monroe, Michigan: October 10, 2013

The Immaculate Heart of Mary (IHM) Sisters hosted a workshop for communities in the Lake Erie basin to explore how to prepare stormwater systems for climate change. The workshop was hosted and developed in collaboration with Michigan Sea Grant, Old Woman Creek National Estuarine Research Reserve (NERR), and Great Lakes Adaptation Assessment for Cities (GLAA-C). The workshop brought together technical staff that assist or work for municipalities and utility providers in the Lake Erie basin.

Figure 7. Preparing stormwater systems for climate change workshop in Monroe, Michigan.

2.2.1. *Goals*

The purpose of this workshop was twofold: (1) to increase the level of understanding about anticipated changes in precipitation patterns, and (2) to disseminate information about potential strategies to increase stormwater system resilience to the predicted impacts of climate change. The workshop invited participation from regional technical staff.

2.2.2. *Main Topics Addressed and/or Activities Undertaken*

The workshop provided an overview of the existing regional climate and anticipated changes in temperature, precipitation patterns, and storms in the Great Lakes region. The Great Lakes Integrated Sciences and Assessments Center (GLISA) delivered climate information tailored specifically for decision making in the western Lake Erie basin. Experts in stormwater management from regional planning authorities, consultancies, utility companies, and watershed groups provided case study presentations on their work, successes, and challenges. Presentations highlighted green, gray, and blue infrastructure approaches to stormwater management. Break-out sessions included panel discussions on innovative financing for stormwater upgrades and improvements, how to take advantage of regulations to incentivize action, and how to integrate new stormwater management approaches into everyday practice.

2.2.3. *Contribution*

The workshop provided opportunities for attendees to learn emerging approaches to addressing stormwater management and flooding through green, gray, and blue infrastructure[1]; how to assess the value of green infrastructure projects; and how to finance green and gray infrastructure improvements. Additionally, participants had an opportunity to meet with peers from communities throughout the region and share ideas and experiences on this pressing challenge.

2.3. Planning for Climate Change in the Great Lakes Region (Needs Assessment and Workshops)

Cleveland, Ohio: August 10, 2011

Green Bay, Wisconsin: September 13, 2011

Duluth, Minnesota: September 22, 2011

Figure 8. Planning for climate change in the Great Lakes region workshop locations: Cleveland, Ohio; Green Bay, Wisconsin; and Duluth, Minnesota.

The NOAA Great Lakes Regional Team, Old Woman Creek NERR, Lake Superior NERR, University of Wisconsin Environmental Resources Center, and Great Lakes Sea Grant Network worked collaboratively with a diverse partner network to assess, evaluate, and implement strategies for increasing Great Lakes coastal communities' ability to respond to climate change (Nelson et al., 2011; Nelson et al., 2013). The formative research stage for this effort involved a regional needs assessment that identified community-based needs related to climate adaptation. The assessment examined a multitude of factors including perceptions and attitudes regarding climate change, perceived barriers and benefits to climate adaptation planning, the need for training, and preferred training formats. The research was conducted in two phases with funding from the NOAA Sea Grant Climate Engagement Project and the Great Lakes Restoration Initiative.

[1]Green infrastructure is natural land- and plant-based ecological treatment systems that manage rainwater runoff. Gray infrastructure is the conventional piped drainage systems most typically used for rainwater control. Blue infrastructure is high efficiency technologies installed and retrofitted within existing gray or green infrastructure.

The needs assessment informed the development of three regional climate adaptation workshops funded through the Great Lakes Restoration Initiative. The Planning for Climate Impacts workshops presented the latest scientific research and forecast models regarding the impacts a changing climate could have on communities and ecosystems in the Great Lakes region. The workshops focused on actions communities can take today to prepare and adapt to the impacts of a changing climate. Based on a successful national model developed by the NERR System through its Coastal Training Program, the workshops were informed by the needs assessment and tailored to the Great Lakes region with extensive input from local planning teams. Based upon this input, the workshop curriculum was customized to address issues and the needs of planners and other professionals addressing land use, public health, stormwater, emergency preparedness, and natural resource management issues across the Great Lakes region.

2.3.1. Goals

The goal of the needs assessment was to collect sufficient information about the knowledge, skills, interest, attitudes, and/or abilities of Great Lakes coastal community planners, stormwater managers, and natural resource managers to design effective training that increases the ability of these groups to confront and adapt to the impacts of climate change.

The goal of the workshops was to build local and regional climate planning capacity in the Great Lakes region. Specifically, the workshops were intended to (1) increase participant understanding of climate science, local and regional climate projections and likely impacts, benefits of planning for changes in climate, and tools to assist with framing and overcoming barriers to adaptation planning; (2) create opportunities for networking and dialogue related to potential climate change adaptation strategies and regional examples of climate-integrated planning and adaptation; and (3) gather participant input on additional training and information related to climate change.

2.3.2. Main Topics Addressed and/or Activities Undertaken

To ensure that training meets priority needs and provides accessible and applicable tools and resources, the organizations involved conducted a needs assessment (a comprehensive front-end evaluation of the climate change adaptation training and information needs of the Great Lakes coastal communities). The needs assessment engaged nearly 700 stakeholders across the basin through interviews, focus groups, and an online survey.

At the workshops, experts provided an overview of the latest climate science, information about climate planning processes and strategies, and examples of available planning tools and resources. The workshops included an interactive session that offered an introduction to assessing climate vulnerabilities locally. Post-workshop surveys indicated that

87% of respondents agreed or strongly agreed that participating in the workshop was a good use of their time; furthermore, 91% reported some, a lot, or a great deal of climate adaptation knowledge gain from attending the workshop.

2.3.3. Contribution

The needs assessment and specialized training increased the knowledge base of Great Lakes coastal communities to adapt to the impacts of climate change. The project and workshops also serve as a replicable model for the Great Lakes region and beyond.

2.4. Supporting Climate and Coastal Resilience Planning in the Western Lake Erie Basin (Workshop)

Toledo, Ohio: June 19-20, 2013

This workshop sought to increase coastal climate adaptation capacity and resilience in the western Lake Erie basin. It was convened by the Great Lakes Restoration Initiative, Ohio Department of Natural Resources (ODNR), Old Woman Creek NERR, ODNR Division of Wildlife, ODNR Office of Coastal Management, NOAA, University of Wisconsin Environmental Resources Center, Association of State Floodplain Managers (ASFPM), Friends of Old Woman Creek, Ohio State University, Ohio Sea Grant College Program, The Nature Conservancy, and Michigan Sea Grant. Workshop participants included professionals interested in enhancing their community's or agency's ability to plan for coastal hazards and improve coastal resilience. Individuals involved in local, state, and tribal planning and decision making related to land use, public health, stormwater, community and economic development, emergency preparedness, and natural resource management attended the event. Key collaborators included the Lucas County Soil and Water Conservation District, Toledo-Lucas County Sustainability Commission, City of Toledo, American Planning Association, Coastal States Organization, National Association of Counties, Midwest Regional Climate Center, Illinois-Indiana Sea Grant, American Rivers, National States Geographic Information Council, University of Michigan Graham Sustainability Institute, and GLISA. In addition, the City of Toledo, Old Woman Creek NERR, University of Michigan Graham Sustainability Institute, University of

Figure 9. Supporting climate and coastal resilience planning in the western Lake Erie basin—Coastal Climate Adaptation and Resilience Workshop in Toledo, Ohio.

Wisconsin-Extension, and NOAA Coastal Services Center cohosted a workshop on June 20 related to climate change adaptation and potential next steps for Toledo.

2.4.1. Goals

1. Create opportunities for networking and dialogue among professionals from Toledo, OH with others from the western Great Lakes region who focus on coastal hazards.

2. Increase the ability of participants to effectively address coastal hazards through the use of online tools.

3. Improve awareness of climatic variability, understanding of climatic uncertainty, and methods for dealing with climatic uncertainty.

4. Provide an opportunity for participants to learn about and interact with the online Great Lakes Coastal Resilience Planning Guide (www.greatlakesresilience.org).

5. Gather participant feedback regarding applicability and effectiveness of the Great Lakes Coastal Resilience Planning Guide.

6. Gather participant input on additional coastal planning issues that participants would like addressed and relevant case studies for inclusion in the planning guide.

2.4.2. Main Topics Addressed and/or Activities Undertaken

The workshop on June 19 included plenary presentations related to the Great Lakes Coastal Resilience Planning Guide, climate trends in the western Lake Erie basin, potential regional climate change impacts, and strategies and tools for adapting to climate change. Breakout sessions covered topics in four tracks: (1) adaptation planning in the western Lake Erie basin; (2) developing western Lake Erie case studies for the Great Lakes Coastal Resilience Planning Guide; (3) climate change adaptation tools and resources; and (4) climate change communication, engagement, and action.

The June 20 workshop discussed ways the City of Toledo can adapt to climate change. The discussion included debriefing related to the content shared during the June 19 Climate Adaptation and Coastal Resilience workshop breakout sessions, learning how several communities are acting to implement climate change adaptation, and beginning a discussion to determine how Toledo can move forward to implement adaptation actions.

2.4.3. Contribution

The workshops launched a regional dialogue on the cross-disciplinary impacts of climate change and furthered City of Toledo dialogue related to integrating adaptation strategies into its internal policies and programs. The project also increased familiarity with online tools and resources that can assist with adaptation planning and enhancing coastal resilience. Participant input was used to further refine and develop resources available through the planning guide.

2.5. Evaluating Stormwater Solutions for Ohio Collaborative Research Project

2011-2015

This project is developing science-based tools to promote the implementation of LID stormwater control measures that reduce the impacts of stormwater runoff on Ohio's coastal communities and Lake Erie. This has been accomplished through design, construction, monitoring, and modeling of stormwater control measures with input from a group of stormwater professionals to ensure the research conducted is relevant to manager, planner, and policy maker needs. The project team includes the Chagrin River Watershed Partners, Old Woman Creek NERR, Ohio Department of Natural Resources Division of Soil and Water Resources, Erie Soil and Water Conservation District, the Consensus Building Institute, and North Carolina State University. The project is funded by the NERR Science Collaborative.

2.5.1. Goals

This project is quantifying the runoff reduction performance of LID systems on poorly draining soils typical of conditions in northern Ohio and working to develop credits and incentives to support effective LID implementation. Project activities are designed to provide concrete answers to questions about design, construction, and maintenance of LID practices that are preventing designers, contractors, and municipal officials from adopting LID practices in Ohio.

2.5.2. Main Topics Addressed and/or Activities Undertaken

A group of stormwater engineers, regulators, utility program managers, and watershed organizations has provided feedback to help guide design, construction, and monitoring of pervious pavement and bioretention systems at six sites in northern Ohio. Monitoring results are being used to assess hydrologic performance and validate models to predict LID system effectiveness under current and projected future climate conditions. The project is developing tools to promote effective LID implementation, including case studies of LID design, construction, maintenance and performance; model codes; design standards and guidance; and training to help engineers, reviewers, and permitting agencies determine whether LID stormwater systems are appropriate for site conditions, meet state and local requirements, and can be used as a climate adaptation strategy.

2.5.3. Contribution

This project is providing information about what can be expected from green infrastructure performance on poorly draining soils typical of northern Ohio under current and future climate conditions, identifying future research needs related to LID performance in Ohio, and promoting dialogue among diverse stormwater professionals.

2.6. Economic Assessment of Green Infrastructure Strategies for Climate (Assessment)

Toledo, Ohio and Duluth, Minnesota: 2012-2014

The project team worked closely with the communities of Toledo, Ohio and Duluth, Minnesota, to characterize existing flooding damage associated with extreme precipitation events, and to consider land use policy options and green infrastructure methods for reducing damages from these events. Based on preferred options identified by each community, the team modeled and assessed the benefits of reducing flooding through the implementation of green infrastructure.

Figure 10. Economic assessment of green infrastructure strategies for climate in Toledo, Ohio, and Duluth, Minnesota.

2.6.1. Goals

The purpose of this study was to assess the economic benefits of green infrastructure as a method of reducing the negative effects of flooding in Duluth, Minnesota and Toledo, Ohio. A secondary purpose of the study was to develop an analytical framework that can be applied in other communities to (1) estimate predicted changes in future precipitation; (2) assess how a community may be impacted by flooding with increased precipitation; (3) consider the range of available green infrastructure and land use policy options to reduce flooding; and (4) identify the benefits that can be realized by implementing green infrastructure.

2.6.2. Main Topics Addressed and/or Activities Undertaken

Two pilot projects were conducted to assess the benefits of green infrastructure in the 4,746-acre Silver Creek watershed in Toledo, Ohio, and the 4,275-acre Chester Creek watershed in Duluth, Minnesota (ERG, 2014). While both watersheds are of similar size and have a history of extreme flooding, they are very different in terms of population density, topography, land use, and the types of flood damages that occur. Thus, these two watersheds represent a range of flooding issues likely to occur within the Great Lakes region, and the methodology used here can be transferred to other communities facing similar challenges. Study steps included:

- Understanding the hydrology and hydraulics of the watershed.
- Considering potential future changes in climate and in land use and potential impacts of those changes on hydrology and hydraulics.
- Assessing damages associated with current and future flooding (baseline conditions).
- Considering challenges specific to the watershed and selecting green infrastructure options that can be implemented to reduce flooding over the study period (2012 to 2014).

2.6.3. Contribution

This project enabled two communities to identify green infrastructure as a viable option to reduce peak discharge from extreme events. It also provided a methodology for communities dealing with riverine flooding events that want to identify the costs and benefits of using green infrastructure to reduce the impacts of flooding.

2.7. Great Lakes Adaptation Assessment for Cities (GLAA-C) (Workshops)

Saint Paul, Minnesota: May 21, 2013

Minneapolis, Minnesota: May 23, 2013

Ann Arbor, Michigan: September 24, 2013

Through the support of the University of Michigan Graham Sustainability Institute and the Kresge Foundation, and in collaboration with GLISA, the GLAA-C project piloted a unique approach to urban adaptation premised on bringing together researchers and practitioners to develop actionable climate adaptation programs for cities in the Great Lakes

Figure 11. Great Lakes adaptation assessment for cities (GLAA-C) workshops in Ann Arbor, Michigan, and Saint Paul and Minneapolis, Minnesota.

region. Now a program within the University of Michigan Climate Center, GLAA-C project staff works with cities in the region to develop and implement climate adaptation strategies in these cities.

The work of GLAA-C is supported by six University of Michigan faculty members whose backgrounds include public health, public policy, governance, urban planning, and climate science. By incorporating research from all of these fields into climate adaptation solutions for cities, GLAA-C aims to create replicable programs to tackle the interconnected challenges that climate change presents.

The cities of Saint Paul, Minneapolis, and Ann Arbor hosted workshops for staff to begin identifying the highest priority community vulnerabilities related to climate change. Bringing together staff from various city departments—including Public Works, Health, Environmental Management, Emergency Preparedness, Water Resources, and Energy Management—helped to continue building support and cohesion across each city for climate adaptation efforts.

2.7.1. Goals

The purpose of these meetings was to begin identifying how the function of each city would be impacted by anticipated changes in climate. By introducing anticipated climate changes for each city, meeting participants were able to explore how those changes would affect their ability to perform their responsibilities, identify key resources that were needed to prepare for each anticipated change, and in some cases prioritize strategies and actions for climate adaptation. While each city developed its own unique set of workshop goals, in most cases, the goals generally included: (1) identifying where long-term expected changes (25, 50, 70 years) overlap with current infrastructure investments and (2) engaging in cross-unit discussions of likely impacts, existing strategies, and ideas on areas where to focus staff and fiscal investments.

2.7.2. Main Topics Addressed and/or Activities Undertaken

These workshops brought together staff from departments across the participating cities to identify areas of existing vulnerability to flooding, heat waves, and other climate impacts. Participants identified and prioritized strategies to address these vulnerabilities. The majority of the workshop time was used in small group discussions identifying how potential climate changes could lead to impacts to city service delivery and discussing how these impacts could be mitigated or avoided through the adoption of new adaptation strategies or expansion of existing strategies.

Throughout the series of workshops different tools were employed to foster small group discussions. Participants engaged in community mapping, wherein they used maps of the cities to identify where current threats to infrastructure and services exist; they used concentric circle activities which asked each group to place a selected impact in the center of a concentric circle and consider how this climate change might trigger a series of impacts across a city's service areas and infrastructure. Each layer of the circle should add onto the impact identified in the layer before. The concentric circle activity is an activity tool that helps participants see how the impacts that their service area may experience are related to other service areas in the city (see Figure 12). Finally, each community completed a worksheet of what strategies and resources they would need to deploy to cope with various impacts.

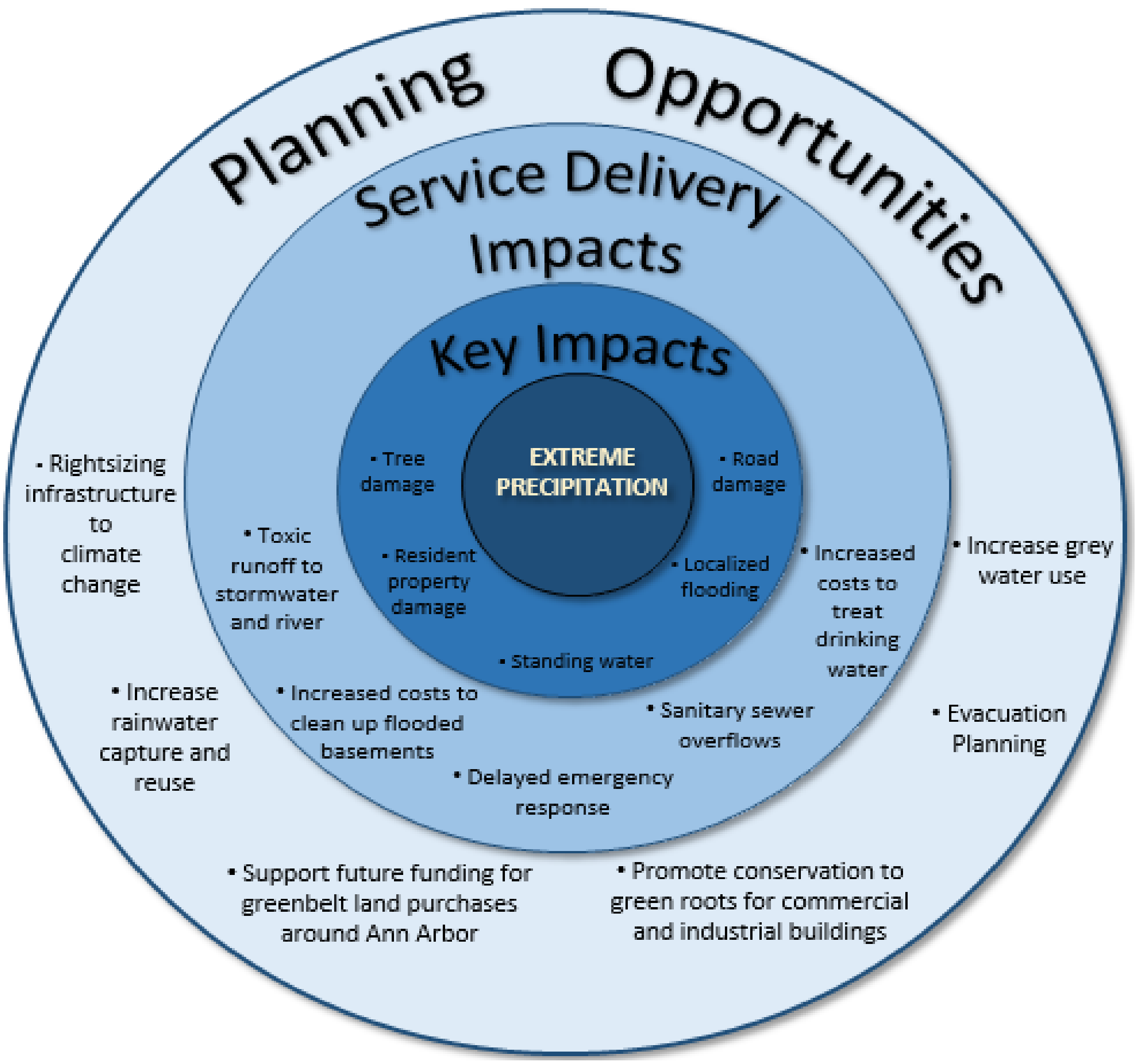

Figure 12. Climate change impacts and adaptation strategies: Extreme precipitation in the City of Ann Arbor (concentric circles activity example).

2.7.3. Contribution

Each of these workshops provided an opportunity for city staff to learn from one another and also to learn about ongoing climate adaptation efforts across the region. These workshops put the spotlight on the needs of the city itself. In addition, by dedicating time and resources to the development and networking of city staff, the workshops built a foundation for integrating climate adaptation efforts into the daily responsibilities of city staff within each community.

2.8. Forwarding Adaptation in the Great Lakes Region (Workshop)

Ann Arbor, Michigan: November 7-9, 2012

The purpose of this three-day workshop was to bring together practitioners from cities across the Great Lakes region, as teams, to discuss the potential impacts, available resources, and existing barriers posed by climate change in the region. This workshop employed a Sustainable Leadership Academy Model (ISC, 2015) used by the Institute for Sustainable Communities to build the capacity of communities to advance, accelerate, and scale up local solutions to the challenges of climate protection and sustainable development. This model offers participants a highly engaged team environment where they have opportunities throughout the conference to meet in "team huddles" and consider how to apply the lessons they are learning to their work.

Figure 13. Forwarding adaptation in the Great Lakes region—Workshop in Ann Arbor, Michigan.

2.8.1. Goals

- Build a community for municipal practitioners in the Great Lakes region.
- Introduce mid-sized and small communities to anticipated climate change impacts for the region.
- Provide a valuable experience to city staff members to encourage them to build a long-term engagement with the University of Michigan's Climate Center and the Graham Sustainability Institute's GLAA-C project.

2.8.2. Main Topics Addressed and/or Activities Undertaken

This conference covered a range of topics from addressing public health to managing urban tree canopies and preparing ports and marinas for more severe storms. A major impact from climate change in the Great Lakes region is increased precipitation, and issues with water quality from erosion, combined sewer overflow events, and contaminated water sources are of major concern. These issues took up a significant amount of time at the conference.

2.8.3. Contribution

This conference provided many communities in the region with a baseline understanding of climate change impacts and provided an opportunity to identify regional colleagues who are struggling with similar challenges. For the GLAA-C project, this event was a building block for the next two years of work. This event confirmed the need to focus on mid-sized to small cities.

3. PRIMARY MESSAGES

The common ideas emerging from these varied efforts are discussed below. They have been grouped into the following topic areas:

- Incorporating climate change into planning
- Building local capacity
- Identifying and communicating costs and benefits of green infrastructure
- Implementing changes within the current governance structure

Within each of these topic areas, specific challenges related to stormwater management in response to climate change impacts are presented along with observations drawn from discussions with local-level participants. Potential near-term solutions and long-term needs are also presented. A summary table of the example tools and resources mentioned throughout this report is available in Appendix A. Numbers provided in brackets refer to the particular workshops, assessments, and research collaborations (described and numbered in Table 1 and Section 2) from which the observations emerged. Participants and partners shared their observations at the local level and identified potential solutions during the EPA- and NOAA-led efforts. The observations and potential solutions were then grouped under common challenges that support the fundamental ideas described in this section.

3.1. Incorporating Climate Change into Planning

Local decision makers readily identified a need for better and more accessible climate change information to incorporate changing future conditions into their planning efforts. Project teams encountered several expected challenges in trying to find and apply relevant information to planning efforts (e.g., issues of scale and uncertainty in climate and land use change projections). It is apparent, however, that historical data can be more effectively mined and utilized in the near term than it is currently, such as using heavy precipitation events or extreme storm events in the past as analogues for potential future changes (e.g., 100 year storm events in the past that become 10 year events in the future or 500 year events in the past that become 50 year events). Planning for climate change can also be approached by planning for relevant endpoints (e.g., changes in the hydrologic cycle, such as heavier precipitation events, earlier snowmelt, and so forth). In the longer term, data collection efforts that start now can help inform future planning. Additionally, new planning approaches and mindsets may be needed to take action in the face of uncertainties. Major challenges, local-level observations, potential near-term solutions, and long-term needs are outlined below.

Challenge	Climate change data often are not available at the desired geographic and/or temporal scale and may be relevant to endpoints of greatest concern to decision makers.
Observations from the Local Level	**Planners and stormwater managers perceive a need for better projections of local precipitation patterns**. Rainfall varies based on local conditions and microclimates. For example, Peach-Bottom Township in York County, Pennsylvania, often receives significantly more rainfall than other neighboring townships in the county. A municipal water infrastructure manager participating in a focus group conducted under the Nelson et al. (2013) effort noted that "…in our little tiny area we put up three rain gauges. So in 5 square miles… we might have three distinct weather patterns." Spatially, regional climate projections do not provide precise, downscaled data for rainfall shifts at the level of particular townships. Temporally, climate change projections are often generated for annual or seasonal changes while stormwater managers frequently make decisions based on 24-hour precipitation events. Seasonal projections provide more fine-scaled information than annual averages, which can be valuable to ensure sufficient water supply. However, seasonal projections do not inform decision makers about the intensity of specific events. Additionally, managers may be underutilizing climate change data that can be found in tools such as the EPA's National Stormwater Calculator (SWC) (U.S. EPA, 2014a, b), and Storm Water Management Model Climate Adjustment Tool (SWMM-CAT) (U.S. EPA, 2014c, d), as well as available information that could serve as a reasonable alternative to precise downscaled projections (e.g., analogue storm events, proximities to thresholds, system sensitivities to weather patterns). See Brown and Wilby (2012) for a discussion of alternatives. (Workshops 1, 3, and 5; Projects 6 and 7) **Local conditions and concerns vary regarding which events result in the greatest impediment to effective stormwater management**. In Baltimore, MD, heavy rain events cause flooding in areas with back-logged stormwater maintenance. In York County, 15-minute squalls or intense downpours overload the stormwater systems that were built for 24-hour storms. Several communities expressed concern that flash floods are viewed as a management failure rather than an act of nature such as a hurricane or 20-year flood. (Workshop 1)

Observations from the Local Level (continued)	**Long-term climate projections are relevant to short-term infrastructure decisions; making this link is necessary to affect local action**. Climate change projections are typically on the 20-100 year timescale while decisions about infrastructure are made on the 1-20 year time frame. However, although infrastructure may be intended for a 20-year life span, it often exceeds the intended life span by decades. (Workshops 1 and 3; Project 6) **Stormwater codes have been created based on historical data.** Infrastructure is built for stormwater detention, with the ability to handle the 2-year 24-hour event. County engineers are not ready to change the codes to address changing precipitation patterns (e.g., assuming more frequent rainfall, or based on analysis using continuous flow models) or the impacts of intense brief storms without evidence that such changes are established sufficiently to be reflected in the long term historical record. (Workshops 1, 3, and 4; Project 5)
Potential Near-Term Solutions	**Mine existing data sources to ensure that decisions are based on the best available data.** (Workshops 1, 3, and 7; Projects 5 and 6) • Local decision makers are often working with old data. Simply updating storm standards to match *current* precipitation patterns can result in a marked improvement. • Accurate historical climate information can help serve as a bridge to discussions regarding future climate projections (which are less certain and may be less readily received by skeptical planners and decision makers). NOAA's National Climatic Data Center provides historical climate information. • To understand future climate changes, techniques that use historic data, such as analogue events or other sensitivity and threshold information in the historic record, can be used as illustrations (e.g., see the IPCC [Intergovernmental Panel on Climate Change] report *Climate Change 2001: Working Group II: Impacts, Adaptation, and Vulnerability*, Section 3.5 (https://www.ipcc.ch/ipccreports/tar/wg2/). The EPA's SWC and SWMM-CAT provide regional downscaled climate projections. The EPA is also developing a web application for visualizing and downloading climate model output (the Global Change Explorer will be available at http://globalchange.epa.gov). • There are resources that show historical and future trend lines (e.g., via GLISA at http://glisa.umich.edu/resources). Sometimes the visual that results from combining historical and future trends (i.e., the gradual increase) can motivate action.

Potential Near-Term Solutions (continued)	• Land use changes, including retrofits, have tremendous effects on climate change impacts on stormwater management; managers can incorporate land use change maps into planning discussions. The EPA's Integrated Climate and Land Use Scenarios (ICLUS) project can serve as a resource (http://www.epa.gov/ncea/global/iclus/). **Consider what decision makers are planning for as a starting point to the discussion (rather than starting with a discussion of climate change projections).** Then, engage decision makers, including stormwater managers and planners, to seek agreement on a threshold (e.g., the community will prepare for *X* storm) that is informed by historic data and reflects the risk tolerance of the community (e.g., what level of damage or disruption the community can tolerate at different costs). (Workshops 1, 3, and 7; Projects 5 and 6) **Communicate the overlap of "short-term" infrastructure lifetimes with longer term climate changes.** If better understood, it may motivate local planners to consider climate change when making decisions on infrastructure retrofit or design and maintenance. (Workshops 1 and 3; Project 6) **Use scenarios to develop a set of possible futures, rather than seeking consensus on a particular projection.** In addressing future precipitation changes in stormwater management, decision makers may need assistance determining which climate change scenarios to evaluate, where to get appropriate climate data, and assessing whether the climate projections coincide with locally driven concerns. For example, Grand Rapids, Michigan conducted a study that evaluated a range of future climate scenarios in order to inform rainfall-based design criteria (http://grcity.us/enterprise-services/Environment-Services/SOC%20Resources/GrandRapidsFutureIDF%20June%202015.pdf). (Workshops 1, 3, and 7; Projects 5 and 6) **Demonstrate the use of dynamical downscaling on research projects at the site scale.** Decision makers can use local resources for climate change data from researchers at organizations within the area, such as universities, state meteorological agencies, and other organizations that may be involved in downscaling of climate change scenarios. (Workshops 1, 3, and 7; Projects 5 and 6)

Long-Term Needs	**Stormwater managers and geographic information system (GIS) staff can develop a "wish-list" of data that should be collected to improve understanding of changes** (e.g., data at small and consistent intervals such as 10- or 15-minute increments). Begin now to collect needed local data (e.g., establish and maintain more local weather gauges and monitoring stations). Partners in the community or neighboring jurisdictions may also be interested in pooling resources to develop or improve data sets. Working with federal partners also may help with data collection and processing (Workshop 1) **Consider the role that regulation at the state level can play in spurring action.** If appropriate, seek to encourage or shape the development of such regulations. (Workshops 1, 3, and 4; Project 5)

Challenge	**Projections of future climate change and land use change are uncertain.**
Observations from the Local Level	**Stormwater managers want to know with certainty what they are planning for and perceive uncertainty as a barrier to action.** A stormwater manager participating in a focus group conducted under the Nelson et al. (2013) effort noted that "What's hard is that people are going to ask the inevitable question, 'what am I planning for? More rain? Less rain? More snow? Less snow?'" In a survey conducted under the same effort, "85% of the Great Lakes benchmark group indicated that the level of uncertainty about the impacts of climate change was a barrier to climate planning" (Nelson et al., 2013). (Workshops 1 and 3) **Climate models are complex; numerous variable inputs can produce a range of projections**. Climate models typically use the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (Nakicenovic and Swart, 2000) as inputs. More recently, these scenarios have been updated and are referred to as Representative Concentration Pathways (RCPs) (Van Vuuren et al., 2011). These scenarios reflect different levels of greenhouse gas emissions and result in a range of climate model outputs. These complexities can be daunting to decision makers seeking information about what to plan for in the future. (Workshops 1, 3, and 4; Project 5) **Different regions face similar challenges but varying sources of uncertainty due to unique conditions**. For example: • There is uncertainty in regional annual precipitation projections for the Chesapeake Bay region, likely due to the bay's location (positioned between subtropical areas expected to become drier and higher-latitude regions expected to become wetter) (Najjar et al., 2010). (Workshop 1)

Observations from the Local Level (continued)	• In the Great Lakes region, the climate is driven by large regional weather patterns and the Great Lakes themselves. In most cases, lake-land climate interactions are not well understood (and global and regional models do not fully account for the effects of the Great Lakes). Direct application of climate projections is difficult and discussions of uncertainty can be complicated. (Workshop 7) **Climate change will interact with other existing stressors.** Future land use, in particular, will significantly impact the effectiveness of stormwater management. The economy, cultural preferences, transportation decisions, and other factors drive development patterns. It is difficult to project changes in land use and climate change; both are highly uncertain. (Workshops 1, 3, and 4; Project 6)
Potential Near-Term Solutions	**Assemble existing data sets with information such as historic land use, planned retrofits and development, topography, and location of floodplains**. They are often sufficient to support a near-term conversation about how stormwater management may need to change to accommodate changes in climate. (Workshops 1, 3, and 4; Project 6) **Use land use build-out models** (projections of the amount and location of development that may occur in a specified area as permitted by current land development ordinances) to understand the maximum allowable use which will inform stormwater managers regarding projected changes in impervious surfaces and evapotranspiration, and the associated stormwater management needs. (Workshops 1, 3, and 4; Project 6)
Long-Term Needs	**Seek partnerships that can contribute to the field of knowledge.** For example, the U.S. Army Corps of Engineers has been helping communities better understand hydrologic modeling (U.S. ACE, 2015) and Federal Emergency Management Agency (FEMA) helps with preparedness planning for extreme events (FEMA, 2015). Communities can work with universities to make sure that research is applicable to local needs. Such partnerships can be fruitful when there are several crucial players working with the data to identify solutions (check local university websites for potential resources and partnering opportunities). (Workshops 1, 3, and 4; Project 5)

Long-Term Needs (continued)	**Develop regional scenarios** (complete with uncertainty bounds) that can be used by communities across a region, minimizing the need for individual communities to spend limited resources to determine which climate model results are appropriate to their planning needs (see SFWMD, 2011 for example of regional climate and sea level rise scenarios produced for south Florida counties and municipalities by the South Florida Water Management District). (Workshops 1, 3, and 7) **Address the likely need to facilitate a change in thinking to enable action in the face of uncertainties that have not been traditionally considered in decision making but now should be.** There will likely never be a tool to predict storm events with precision. Communities will need to develop new ways of thinking and planning, such as analyzing decisions by their robustness over a range of potential changes, employing risk management techniques, using principles that maximize minimum losses or minimize maximum losses, and other approaches for decision making under uncertainty. For example, although design and selection of vegetation for long-term survivability under changing climate conditions is complex, adjustments to vegetative cover is ripe for experimentation in the face of uncertainty because it does not have large upfront costs and is highly adaptive. (Workshops 1 and 3)

Challenge	Reliable and up-to-date land use data is critical to understanding how changes in precipitation-driven flooding will impact stormwater management.
Observations from the Local Level	**Existing land use data used for planning may be outdated or incomplete**. Land use projections are typically grounded in an understanding of the existing and planned development. The format, availability and quality of data varies widely across communities. (Workshop 1) • Stafford County, VA recently updated the impervious surface layer that was last updated in 2000. Prior to the update, the best available data had been 14-years old and did not reflect the 35% population growth the county had experienced. • Each of the 72 jurisdictions in York County, PA define development zones independently and thus it is a challenge to amalgamate zoning for the County and make collective decisions.

Potential Near-Term Solutions	**Use land use build-out models to understand the maximum likely development in a region.** This can help planners and stormwater managers consider the potential needs associated with projected increases in impervious surfaces. In addition, evaluate existing impervious surfaces and take advantage of retrofit opportunities to green existing parcels. Example resources include the EPA's Integrated Climate and Land Use Scenarios (ICLUS) project and the EPA's Impervious Surface Growth Model (ISGM). (Workshops 1, 3, and 4; Project 6) **Routinely re-evaluate accuracy of land use maps** (especially in areas experiencing rapid development) to make sure the best available data about the extent and location of impervious surfaces is used. (Workshop 1)
Long-Term Needs	**Consider updates to data management practices to facilitate use of the best and most recent data.** (Workshop 1) **Expand staff expertise in GIS or other data management processes** (via training, new hires, or sharing of staff across the county or a group of municipalities). (Workshop 1)

Challenge	Communication, Coordination, and Education
Observations from the Local Level	**There is a need for greater interdepartmental cooperation at the municipal level.** During workshops in Green Bay, Wisconsin; Duluth, Saint Paul, and Minneapolis, Minnesota; Ann Arbor, Michigan; and Baltimore, Maryland, participants discussed how climate change is a cross-sector issue that affects all aspects of government work. However, in many communities, staff is focused on the needs of their department (e.g., zoning, stormwater management, wastewater management, land use planning) and may miss opportunities to work across departments to find solutions. This challenge was identified as a major finding in the needs assessment described in Nelson et al. (2013) and echoed both in interviews and during the workshops. (Workshops 1, 4, and 7; Project 6)

Observations from the Local Level (continued)	**One-off meetings can serve as a launching point for continued collaboration.** Across all of the efforts described in this report, participants cited the convening of people from different departments, agencies, and organizations (and the associated conversations that ensued) as one of the greatest benefits. The connections made at a single meeting can extend beyond that event. For example, some of the Toledo, Ohio workshop participants later formed the Northeast Ohio Climate Change Adaptation Workgroup. The group is seeking to jointly pursue grants and coordinate in other ways. (Workshops 1, 2, 3, 4, 7, and 8; Projects 5 and 6) **Sharing and communicating positive examples of adaptation strategies, especially at the local level, can help leverage successes.** In many communities, local examples may not be readily available. Organizers at the Duluth and Green Bay workshops offered examples from other areas (e.g., Philadelphia, Virginia) to provide inspiration for local action. The Wisconsin Climate Change Impacts (WICCI) developed a manual for adaptation strategies that was distributed to all of the participants from Wisconsin and Minnesota. (Workshop 4; Project 6) **There is a need for additional adaptation training at the local level.** Nelson et al. (2013) identified decision-maker training as one of the top 10 needs that emerged from the needs assessment that engaged nearly 700 professional planners, stormwater managers, natural resource managers, public health officials, and emergency managers across the region. In response to a survey "45% of Great Lakes benchmark respondents were 'very interested' in obtaining climate change knowledge and planning skills in a fact sheet format, 44% through one day intermediate training workshops, and 40% through websites. The format for which the highest percentage of respondents were 'not interested at all' was multiday advanced training courses (29%)" (Nelson et al., 2013). This need for training was repeated during the Toledo and Monroe, Michigan workshops. (Workshop 3; Project 6)
Potential Near-Term Solutions	**Create opportunities for staff to exchange experiences and ideas for programs** (e.g., interdepartmental meetings, workshops, webinars, online forums). For example, maintenance staff may have detailed knowledge about issues that arise during extreme weather events and sharing the information with planners and engineers can help design more resilient programs under changing climate conditions. Ensure that senior management is on-board and that the administrative and fiscal mechanisms of the city enable interdepartmental collaboration. (Workshops 1, 4, and 7; Project 6)

Potential Near-Term Solutions (continued)	**Engage in existing peer-to-peer networks** that connect communities at varying stages of implementation such as the GLAA-C, Urban Sustainability Directors Network (USDN), American Society of Adaptation Professionals (ASAP), Great Lakes Saint Lawrence Cities Initiative, and the American Society of Civil Engineers' Environmental & Water Resources Institute (EWRI). (Workshop 4; Project 6) **Take advantage of already available resources that promote information sharing.** For example, at the regional level, the *Great Lakes Coastal Resilience Planning Guide* is an online tool that filled some of the data needs identified during the Great Lakes workshops (ASFPM, 2013). At the national level, ICLEI Local Governments for Sustainability (ICLEI) and NOAA are just two entities participants identified as providing useful online resources (ICLEI, 2014; NOAA, 2015a). Other examples are the EPA tools, guides, and case studies of green infrastructure projects conducted with a large number of communities across the country. Project descriptions and products from these efforts are available on-line (see Appendix A: Summary of Resources Identified in This Report). (Workshop 4; Project 6)
Long-Term Needs	**Nelson et al. (2013) identified increasing climate literacy as a top 10 need.** The survey and interviews suggested that this could be achieved through "research that addresses decision-maker needs, comprehensive science education throughout all grade levels, community outreach, ensuring ecological awareness through youth programs as well as training students in scientific field methods, tribal engagement, increased communication with stakeholders, and end-user/public participation" (Nelson et al., 2013). Long-term efforts to increase climate literacy of stormwater managers and planners may involve both (Workshop 3; Project 6): • Building awareness and increasing knowledge via curriculum taught at educational institutions and • On-the-job training and continuing education opportunities, which can help to increase the climate literacy of existing staff and ensure timely application of research designed to address decision-maker needs.

3.2. Building Local Capacity

Local capacity to plan for, design, construct, and permit green infrastructure and LID projects is necessary to effectively integrate these solutions into regional stormwater management practices. Limited local knowledge can be a barrier to overcoming competing priorities and continuing with the status quo. However as climate change presents new challenges for stormwater management, increasing professional knowledge of alternative solutions, learning how to incorporate climate projections into plans, and collaborating across jurisdictions can enhance a community's ability to adapt existing management strategies.

Challenge	Stormwater managers, engineers, planners, and contractors may have limited experience or expertise with relatively newer solutions such as green infrastructure.
Observations from the Local Level	**Stormwater managers have only recently started to more broadly accept green infrastructure.** While conventional infrastructure is largely based on engineered solutions with hard infrastructure, green infrastructure is reliant on natural systems-oriented solutions requiring landscape and site design expertise (e.g., proper site design is needed for the success of green infrastructure from the perspective of environmental outcomes). The role of a stormwater manager and the requisite expertise may shift as communities increase the application of green infrastructure (Workshop 1; Project 6). **Green infrastructure may require different construction and maintenance methods, such as deep soil tillage.** For example, pavement installation often requires mass grading and compacting soils during construction. However, compacted soils are not beneficial for designing a system that encourages infiltration (Project 5). **There is limited information about the performance of green infrastructure techniques on poorly draining soil.** The majority of the available technical literature focuses on studies in areas with well-draining soils. However, many areas have poorly draining soil and thus managers may not be able to adequately assess the projected effectiveness of green infrastructure and LID as stormwater control and resiliency measures (Project 5).
Potential Near-Term Solutions	**Provide training for municipal staff on green infrastructure to better equip staff to assess green infrastructure proposals and technical approaches.** For example, the EPA offers a Green Infrastructure Webcast Series (http://www.epa.gov/green-infrastructure/green-infrastructure-webcast-series). The EPA and other federal agencies and nongovernmental organizations have formed the Green Infrastructure Collaborative, a network to help communities more easily implement green infrastructure (http://www.epa.gov/green-infrastructure/green-infrastructure-collaborative). (Workshop 1; Project 6)

Potential Near-Term Solutions (continued)	**Publicize a list of green infrastructure contractors and engineers who are certified and credentialed to help connect experienced professionals with potential projects that could benefit from alternative design solutions.** For example, the RainScapes program in Montgomery County, Maryland regularly updates a public list of professionals who have taken training courses on landscaping techniques to reduce stormwater runoff (http://www.montgomerycountymd.gov/DEP/water/rainscapes.html). (Workshop 1; Projects 5 and 6) **Offer incentives to encourage innovation and use of green infrastructure designs by engineers or contractors, rather than relying on pipe-based systems.** (Project 5)
Long-Term Needs	**Consider using or developing a stormwater model ordinance for local jurisdictions seeking to incorporate climate change projections or green infrastructure incentives into local legislation.** For example, the City of Seattle developed a citywide model ordinance for stormwater management using green infrastructure (http://www.sustainablecitiesinstitute.org/topics/water-and-green-infrastructure/stormwater-management/model-ordinance-for-establishing-citywide-green-stormwater-infrastructure). (Workshop 1; Projects 5 and 6) **Conduct pilot studies and publish the results and lessons learned to increase awareness and provide specific examples of how alternative stormwater management solutions perform.** One specific need is additional examples that quantify infiltration and evapotranspiration rates in different areas to supplement existing knowledge. (Project 5) **Hire new staff that has experience with green infrastructure design and implementation to complement existing staff knowledge and expertise.** (Workshop 1; Projects 5 and 6) **Modify designs and maintenance plans and monitor results to determine whether performance can be enhanced for projects in the region** (particularly in areas with poorly draining soils). (Project 5)

Challenge	Competing priorities (e.g., attracting development to a local area) are a barrier to establishing stringent local policies that benefit stormwater management.
Observations from the Local Level	**Implementing stormwater fees or strict development standards to limit impervious surfaces may be beneficial for managing stormwater in a community but can also be a disincentive for developers to work in that community**. Most communities are looking to encourage growth and development and minimize disincentives to developers. State and federal regulations can help to "level the playing field" by minimizing community-by-community variance in development incentives or disincentives. (Workshop 1) **"Home-Rule" style governance (in which decisions are made at a very local level) can be an obstacle to cooperation and coordinated decision making within counties.** Counties with highly decentralized decision making and authority may find it more difficult to coordinate at the watershed or subwatershed scale when it would be beneficial from the standpoint of stormwater management. In some cases, however, voluntary participation in regional efforts is successful. The York County Planning Commission (YCPC) invited all 72 municipalities in the county to participate in the Regional Chesapeake Bay Pollution Reduction Plan. Forty-five municipalities participated, including the 33 regulated municipal separate storm sewer systems (MS4) municipalities that are required to participate and 12 nonregulated municipalities. (YCPC, 2014) (Workshop 1)
Potential Near-Term Solutions	**Coordinate regional policies to minimize the impact on individual communities.** Since development may be deterred when individual communities change local standards independently, potentially negative impacts could be avoided if surrounding municipalities agree to adopt similar policies. Such creative collaboration across communities may also help leverage state and federal funding for development and facilitate pollution control cost sharing. (Workshop 1)

Potential Near-Term Solutions (continued)	**Incorporate green infrastructure and LID into existing plans, such as maintenance plans for retrofits, integrated municipal stormwater and wastewater plans, and watershed implementation plans (WIPs).** (Workshop 1) • The EPA's Integrated Municipal Stormwater and Wastewater Planning Approach Framework (http://www.epa.gov/sites/production/files/2015-10/documents/integrated_planning_framework.pdf) provides a way that innovative technologies, including green infrastructure, may become fundamental components of municipalities' plans for integrated solutions. • WIPs are used by the Chesapeake Bay watershed jurisdictions to meet the bay total maximum daily load (TMDL) goals. A TMDL is the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. The York County Coalition for Clean Waters incorporated green infrastructure and LID into the York County WIP as a stormwater management strategy. The recently completed plan has been endorsed by the county commissioners, and coalition members are now promoting the plan to municipalities and other stakeholders as an important tool to improve the county's waters. **Consider offering alternative incentives such as fast-track permitting for projects that adhere to a more strict set of requirements** (e.g., projects that manage 80% of runoff onsite or incorporate a green roof). (Workshop 1) **Assess whether green infrastructure could be included as a control measure in Municipal Separate Storm Sewer Systems (MS4s), and how to best implement those measures.** MS4s transport stormwater runoff that is often discharged into water bodies. Since 1999, even small MS4s within and outside urbanized areas have been required to obtain National Pollutant Discharge Elimination System permit coverage. Jurisdictions with MS4s can include green infrastructure as a control measure. The EPA published a factsheet that discusses how green infrastructure can be integrated into stormwater permits and provides examples of communities that have done so (http://water.epa.gov/infrastructure/greeninfrastructure/gi_regulatory.cfm). (Workshop 1)
Long-Term Needs	**Consider regulatory changes at the federal or state level to minimize variance regarding stormwater infrastructure guidance and regulations among communities.** (Workshop 1)

Challenge	Planning, construction, and management of a geographically dispersed network of green infrastructure may require a different management approach than that used for conventional systems.
Observations from the Local Level	**Green infrastructure is often geographically dispersed.** Conventional stormwater management is typically comprised of a series of large systems that are publically owned and operated. Green infrastructure projects can span land holdings of several different individuals, entities, or even jurisdictions. (Workshop 1; Project 6) **Green infrastructure relies on a network of landscape-scale solutions,** many of which are on private property, and the responsibility for maintenance costs may not be clearly defined. (Workshop 1; Project 6) **It may be difficult to identify which department(s) should cover the upfront and ongoing maintenance costs for a green infrastructure project.** In some communities, the parks department may have more qualified staff to install and maintain a green infrastructure project, but the optimal site may be located on land that is maintained by the public utilities department. (Workshop 1)
Potential Near-Term Solutions	**Provide individual homeowners and businesses with information about how to correctly maintain green infrastructure design elements** (e.g., rain gardens, vegetated swales, and other installations). (Workshop 1; Project 6) **Develop a methodology and schedule for maintenance that includes details about who is responsible for maintenance and new protocols that provide for adjustments and updates in response to changes in climate.** Establish this protocol early in the project planning phase to avoid future confusion or mismanagement. For example, Washington, DC's *Stormwater Management Guidebook* (CWP, 2013), provides for a stormwater retention credit program for certification. To be eligible for certification, a best management practice must, among other criteria, provide a contract or agreement for ongoing maintenance and pass ongoing maintenance inspections. (Workshop 1; Project 6) **In places where individual homeowners may be responsible for installation and maintenance, offer financial incentives to help individuals pay for the maintenance of this public good.** (Workshop 1; Project 6)

Challenge	Watersheds are not confined to political boundaries.
Observations from the Local Level	**Flooding issues may be exacerbated by upstream development beyond jurisdictional boundaries**. Coordinating across jurisdictions can be contentious and costly (in terms of staff time to schedule, travel to, and participate in meetings). For example, severe rainfall in Duluth during the summer of 2012 resulted in significant damage caused by high-quantity and high-velocity runoff, which may have been amplified by upstream development of land that was previously wetlands (NOAA, 2015b) (Workshop 1; Project 6). **Cooperation among neighboring jurisdictions can help alleviate concerns and discrepancies in development requirements.** For example, Stafford County, VA is partnering with neighboring counties to address stormwater issues that are not confined to their county lines (Workshop 1). **Interactive sessions at workshops can provide opportunities to explore collaborative solutions that transcend political boundaries.** Strategizing across agencies or even sectors may reveal opportunities to incorporate climate change considerations into current strategies at no additional cost. A county agency director participating in an interview conducted under the Nelson et al. (2013) effort noted that "People have their missions, and they're just following it down without realizing that they can get more of their missions accomplished by helping other people to accomplish their missions, if we are all working together—whether it's federal, state, or local level" (Workshops 1 and 3; Project 6).
Potential Near-Term Solutions	**Convene relevant agencies, organizations, and individuals responsible for stormwater management decisions across watersheds to help address barriers presented by different regulations, budget limitations, and expectations for growth.** Representatives of water management, environmental, land use planning, public works, and transportation departments (among others) are important to include because each of these agencies plays a role in stormwater management. In Pennsylvania, for example, participants in the York County workshop also participate in the York County Coalition 4 Clean Waters (YCC4CW) that brings together "representatives of municipalities, engineering firms, waste water treatment plants, septic pumping businesses, water companies/authorities, attorneys, farmers, watershed association, York County Conservation District, York County Planning Commission, Chesapeake Bay Foundation, Stewards of the Lower Susquehanna, PA Department of Environmental Protection, and others," and could provide a model for other regions to follow in developing regional approaches to stormwater management (http://watershedalliance.tripod.com/ycc4cw.html). (Workshops 1 and 3; Project 6)

Potential Near-Term Solutions (continued)	**Look for opportunities to develop a regional or watershed-scale plan for stormwater management, and include new methods to apply in the planning process, such as continuous flow models.** This may be more cost effective than developing individual plans. (Workshops 1 and 3; Project 6) **Seek opportunities to incorporate climate change adaptation measures into existing plans, such as comprehensive plans or watershed-scale plans, which may be the best scale at which to address climate change.** (Workshops 1 and 3; Project 6)
Long-Term Needs	**Find ways that the state or county can provide incentives for regions to develop watershed-scale plans.** (Workshops 1 and 3; Project 6)

3.3. Identifying and Communicating Costs and Benefits of Green Infrastructure

Managers have limited information to provide economic justification for implementing green infrastructure projects, and that information becomes even scarcer when justifying these projects as adaptation to climate change impacts. Whether information is limited by a shortage in studies or because information is not reaching the local level, managers are not satisfied with their ability to address financial considerations associated with green infrastructure options (a critical concern for municipalities facing increasingly constrained budgets). Generating and increasing access to information on costs and benefits of green infrastructure under current climate conditions will become increasingly important in order to understand how future climate conditions may change those calculations.

Challenge	Municipalities need improved access to economic information on costs and benefits to support decisions regarding the use of green infrastructure.
Observations from the Local Level	**There is limited information about the costs and benefits of green infrastructure and other climate change adaptation strategies, which makes return on investment (ROI) calculations difficult**. Some green infrastructure solutions may be cost effective immediately, while others may cost more and require a longer rate of return (especially if a project requires changing existing infrastructure or provides benefits over gradual changes in climate). For example, it can be challenging to fully assess the potential flood mitigation benefits of green infrastructure solutions, especially considering how such solutions interact with existing infrastructure and alter regional hydrology (i.e., the cumulative and long-term impact on a watershed scale). Uncertain and extended return periods, especially resulting from in climate change projections, often cause green infrastructure and other climate change adaptation strategies to be shifted to the bottom of a list of priorities (effectively deterring local-level investment in such strategies). (Project 6) **Traditional economic assessments that span a typical local planning horizon do not fully capture benefits that extend beyond the time frame of the analysis nor cobenefits, which are difficult to quantify.** An economic assessment of green infrastructure conducted in Duluth, MN used a 20-year planning time frame (to align with the city's capital improvement planning). It became clear, however, that strategies such as wetland restoration and forest preservation provide water management and other benefits that extend far beyond that 20-year period. The value of green infrastructure may appreciate over time rather than depreciate (as is typically the case with conventional infrastructure options). There may also be cobenefits that are not factored into a traditional ROI assessment, such as ecosystem services (e.g., water quality protection, habitat maintenance, community beautification, recreational opportunities like birding) and human well-being (e.g., social, physical, and community). (Project 6) **Stormwater managers and their partners have limited access to or awareness of the information that does exist on the costs and benefits of green infrastructure.** Access may be limited by a lack of staff time and/or knowledge about how to efficiently find locally relevant and readily applicable information from within more general studies or specific case studies. (Project 6)

Potential Near-Term Solutions	**Ensure existing case studies (e.g., from Milwaukee, Wisconsin; Philadelphia, Pennsylvania; Toledo, Ohio; and Portland, Oregon) are readily available.** Examples that cover a range of municipalities with different budgets and populations are helpful for local practitioners to find and consult studies that are similar to their own communities. (Project 6) **Provide opportunities for information sharing that are specific to economic valuation.** Webinars, workshops, and tools can be used to disseminate existing knowledge and answer questions. (Project 6) **Conduct research and collect data (e.g., what a city spent on repairs and replacement of infrastructure following a storm; job and recreational losses due to damaged or destroyed infrastructure) to facilitate improved quantification of the costs and benefits of green infrastructure investments.** For example, the State of Indiana Department of Natural Resources conducted a statewide street tree benefit study using i-Tree Streets, an urban forestry analysis tool from the United States Forest Service. The Department used the tool to quantify the benefits related to stormwater management, energy costs, improved air quality, sequestered carbon dioxide, and aesthetics (https://www.itreetools.org/applications.php). (Workshop 1; Project 6) **Consider long-term benefits of green infrastructure in economic analysis of stormwater management plans.** For example, Toledo, OH estimated that they would reap about $38,000 in annual benefits over the next 20 years as measured only in damages avoided to buildings from flooding. This is an underestimate because other benefits of flood mitigation strategies under changing climate conditions are not included. (Project 6) **Train local appraisers/commissioners to capture the full value of green infrastructure.** Incorporate direct benefits (e.g., jobs) and cobenefits (e.g., ecosystem services, quality of life factors, real estate values) into ROI calculations. (Project 6) **Identify opportunities to integrate green infrastructure into other projects, as a co-benefit with little to no added cost** (e.g., providing Americans with Disabilities Act [ADA]-compliant sidewalk access, adding a swale for pedestrian protection that also collects rainwater). For example, the Green Streets, Green Jobs, Green Towns Initiative is a collaboration among EPA Region 3, Chesapeake Bay Trust, Maryland Department of Natural Resources, and others that provides a network and resources for integrating green infrastructure to streets (http://www.cbtrust.org/site/c.miJPKXPCJnH/b.7735695/k.5E92/Green_Streets_Green_Jobs_Green_Towns.htm). (Project 6)

Potential Near-Term Solutions (continued)	**Develop templates that can be used to assess how different green infrastructure methods and projects can work in an area and include cost estimation guidance.** (Project 6) **Use cost planning scenarios that are based on real projects for the state or region.** (Project 6)
Long-Term Needs	**Improve documentation** regarding project funding and actual costs. **Build a database to inform future projects.** Suggest funding organizations incorporate requirements for enhanced financial and impact tracking reporting in project selection. (Project 6) **Develop tools to assist with quantifying costs and benefits** (e.g., the Center for Neighborhood Technology's Green Values National Stormwater Management Calculator at http://greenvalues.cnt.org/national/calculator.php and *The Value of Green Infrastructure* guide at http://www.cnt.org/repository/gi-values-guide.pdf). Update existing tools (e.g., the ASFPM flood tool that is under development for Toledo at http://floodatlas.org/toledo/) to include cost and benefit information. (Project 6) **Collaborate across departments to coordinate collection of data on the costs and benefits of green infrastructure.** For example, work with the financial departments to establish an easy tracking and reporting protocol to collect data related to costs and savings of implemented green infrastructure projects. (Project 6)

Challenge	Municipalities need cost-benefit information to communicate the value of green infrastructure.
Observations from the Local Level	**Practitioners need to be able to evaluate and discuss the costs and benefits of green infrastructure and other climate change adaptation strategies with citizens, elected officials, and colleagues**. Increasing the capability and fluency with which practitioners can both assess the costs *and* the benefits of green infrastructure, and present the findings of those assessments clearly and compellingly to others will facilitate more serious dialogue about green infrastructure options. (Project 6)

Potential Near-Term Solutions	**Share existing information about how natural systems can be cost effective and efficient methods of stormwater control, flood mitigation, and climate adaptation** (e.g., through videos or other readily accessible modes of communication). (Project 6) **Present cost statistics in formats that can be shared with colleagues, elected officials, and the public.** Develop communication materials that can be used in conversations with different audiences (e.g., use common terminology to help nontechnical stakeholders better understand the value of green infrastructure). (Project 6) **Incorporate cost and benefit information into tools** (e.g., visualization tools) that can support project planning and assist in communications with multiple audiences, such as the Connecticut Nonpoint Education for Municipal Officials (CT NEMO) Rain Garden App; provide information about the multiple ecosystem services provided by green infrastructure, such as the U.S. Forest Service's i-Tree tool that estimates ecosystem services from trees used for urban stormwater runoff control that also provide local cooling services and habitat for species; provide guidance on estimating the economic benefits of green infrastructure, such as through technical assistance grants and services such as the technical assistance provided to Lancaster, Pennsylvania). (Project 6)
Long-Term Needs	**Share information about the current status and the actual costs and values of projects that were implemented 10 or 20 years ago.** Show how benefits and ROI have been realized. (Project 6)

3.4. Implementation within Current Governance Structure

Existing priorities and regulatory requirements as well as political sensitivities can be barriers to voluntarily incorporating climate change into planning and decision making. A shift towards managing stormwater onsite or incorporating climate change projections into decision making can be driven by available market solutions, residential demand (as both voters and consumers), or by regulation (e.g., from a state or federal agency). In all cases, more proactive interagency or interjurisdictional coordination may be necessary, and greater awareness and acceptance by the public is conducive to achieving project success.

Challenge	Novel and/or watershed-scale solutions may necessitate proactive interagency or interjurisdictional coordination.
Observations from the Local Level	**As climate change adaptation becomes an increasing priority for federal agencies, local governments need to understand how to engage those agencies and leverage resources.** An increasing number of federal agencies are engaging in climate change adaptation programs as a result of EO 13653 (*Preparing the United States for the Impacts of Climate Change*). However, local water resource managers still struggle to understand how to effectively partner with federal agencies and who to turn to for assistance and advice. Resources such as the Sustainable Facilities Tool help users understand definitions and identify strategies and to put policy into action (https://sftool.gov/learn/annotation/427/executive-order-13653-preparing-united-states-impacts-climate-change). (Project 6) **Numerous agencies and regulatory schedules are involved in stormwater management and planning**. It is difficult for municipalities to act strategically when they are responding to a constant rotation of different (and sometimes competing) reporting requirements (e.g., MS4 permits and others). (Workshop 1) **Interagency or interjurisdictional coordination may be needed to secure funds and support to implement novel and/or watershed-scale solutions**. Conflicting interests can make this kind of coordination difficult. For example, roads and the associated rights-of-way comprise a large portion of public lands, but transportation agencies often do not coordinate with local jurisdictions to assess potential stormwater management impacts and solutions for flooding caused by road surfaces. Green infrastructure solutions could be prominently featured on land managed by transportation agencies; however, such strategies must not impede efforts to ensure traffic safety (a primary concern of departments of transportation). (Workshop 1) **State or federal-level resources or requirements may not fully account for more nuanced local-level observations and needs.** For example, state or federal resources to map floodplains often do not dive into detailed granularity to account for site-specific contexts. (Workshop 1; Project 6)

Potential Near-Term Solutions	**Seek schedule variances for some reporting requirements (e.g., MS4, others), as needed, within a given community.** (Workshop 1) **Engage the full suite of agencies and departments, and the private sector that affect or could be affected by solutions to address changing climate conditions in stormwater management.** Coordination across relevant institutions and sectors is particularly important in response to climate change since impacts and solutions may be cross-cutting. Consider involving, for example, FEMA, the Army Corps of Engineers, Departments of Transportation, Parks and Recreation, and State Departments of Ecology or Natural Resources. For example, the Silver Jackets program brings together multiple federal, state, and tribal and local agencies to collaboratively address flood risk (Silver Jackets, 2015). (Workshop 1; Project 6) **Coordinate across agencies, particularly at the federal level, and encourage a "no wrong door policy"** (i.e., that data and information is shared across web portals and resources are shared across agencies). Seven federal agencies have come together with nongovernmental organizations and private-sector entities to support the Green Infrastructure Collaborative, a network to help communities more easily implement green infrastructure (http://www.epa.gov/green-infrastructure/green-infrastructure-collaborative). Look for opportunities to act flexibly across different levels of governance to accommodate new green infrastructure practices and techniques. Flexibility, a key characteristic of adaptive management, is important because future climate conditions are highly uncertain. (Workshop 1; Project 6)
Long-Term Needs	**Use pilot projects or those with minimal barriers to explore collaboration among agencies.** (Workshop 1; Project 6) **Request modifications to reporting requirements (e.g., MS4, others) so that schedules are complimentary to efforts and the same/complimentary goals are being targeted for different projects.** (Workshop 1) **Coordinate and expand federal guidance and planning on incorporating climate change projections into decision making around stormwater management and removing local barriers.** (Project 6)

Challenge	Limited public support or awareness of the benefits and value of green infrastructure, LID, or other climate change adaptation solutions.
Observations from the Local Level	**Interest and willingness to commit to addressing climate change or to even discuss it varies among communities.** In some communities, even mentioning the terms "climate change" may shut down a discussion of anticipated challenges and possible solutions. (Workshop 1) **Less well-known alternative stormwater management strategies may be met with more resistance than known conventional strategies.** More information about the benefits and value of green infrastructure and a public that is better educated on green infrastructure options and their benefits under changing climate conditions help achieve project success. (Workshop 1; Project 6)
Potential Near-Term Solutions	**Adopt more stringent policies such as stormwater fees and requirements for developers to manage water onsite to the maximum extent feasible.** Similarly, require developers to make decisions informed by future climate, and local governments to incorporate climate change into decision-making processes. (Workshop 1) **Developers can demonstrate attractive, cost-effective, marketable solutions** (e.g., see an EPA technical assistance report in which a developer uses green infrastructure in Portland, OR (U.S. EPA, 2012)). If the market offers innovative stormwater solutions or climate resilient developments that are attractive and effective, the public will more likely favor these best available options. A developer-driven solution may be most effective in an area that is rapidly changing. For instance, the recently developed Celebrate Senior Center in Fredericksburg, Virginia, is using 65 bioretention areas and 15 water quality swales to treat 43 acres of manicured landscape. Stafford County anticipates that this project will demonstrate that green infrastructure solutions can offer amenities that increase the value of the landscape while managing stormwater onsite (see Appendix B for additional information). (Workshop 1; Project 6) **Showcase green infrastructure as adaptation to climate change by using redevelopment projects as onsite demonstrations of ways to adapt to climate change using LID, green streets, or environmental site design.** Such demonstrations will make these approaches highly visible to the public, politicians, decision makers, and project partners. (Workshop 1)

Potential Near-Term Solutions (continued)	**Use educational projects in schools or at community centers as opportunities to disseminate climate change information to the public.** (Workshop 1) **Collaborate with community groups through activities such as tree planting or installing rain gardens that can be effective adaptation measures and that require hands-on work by volunteers.** (Workshop 1) **In all work with individuals and community groups, be sensitive to hot-button topics that may distract from the purpose of the conversation and the issues that the work intends to address.** For example, if climate change is a highly political issue, it may be useful to steer the conversation towards observed and projected changes for specific endpoints of concern (e.g., changes in 25-year storm event or the intensity of brief downpours) or green infrastructure's cobenefits to a community's livability and economic vitality. Focusing on issues of vulnerability and future weather changes can help to move discussions forward and avoid some of the potential barriers that arise when using the term "climate change." (Workshop 1)

3.5. Conclusions

Despite uncertainties in how global climate change will be manifested locally and the shortages in resources and information that local communities often experience, there are still concrete steps decision makers can take to begin adaptation planning for climate change impacts. The insights derived from the workshops in the Chesapeake Bay and Great Lakes regions provide concrete ways that climate change practitioners, stormwater managers, planners, and engineers can work together to advance adaptation planning. One way that was discussed across all of the workshops was greater implementation of green infrastructure and LID to deal with anticipated changes in precipitation, stormwater runoff, and flood events. The workshops demonstrated that providing local communities with opportunities to learn about climate change, green infrastructure, and LID can be the catalyst for shifting communities toward climate-adapted planning and implementation. A cycle begins with increasing community members' knowledge and skills that leads directly to greater action to address climate change, which continues beyond the workshops and projects themselves.

The suggested actions in this report provide communities with specific ideas to incorporate climate change into current planning, enhance capacity to more effectively and completely address climate change in the future, assess and effectively communicate costs and benefits of green infrastructure to the larger community, and implement adaptation strategies within current governance structures. Potential near-term solutions include mining existing historical data to plan for future uncertainty using relevant endpoints. Communities can also expand the expertise and knowledge of local-level professionals and look for opportunities to increase coordination across agencies and jurisdictions in order to effectively integrate alternative stormwater solutions. Near-term opportunities to enhance assessment of costs and benefits include better access to, and training on the full value of green infrastructure. Finally, implementing novel solutions may require proactive interagency or interjurisdictional coordination.

The workshops also identified long-term needs that communities can begin to tackle in order to better manage stormwater in the face of a changing climate. Several long-term needs concern providing additional information on climate change, such as developing regional scenarios of climate change and sea level rise that can be incorporated into decision making. Sharing a variety of knowledge related to stormwater management issues, including climate change information, GIS land use applications, and GI best practices, was also identified as a long-term need. Suggestions for how to accomplish this include developing partnerships with other organizations and documenting lessons learned from GI implementation. Another important information gap identified concerns costs, benefits, and return-on-investment (ROI) from past GI projects. Sharing this information can inform future projects and can be used to develop tools to assist quantification of costs and benefits. Identification of additional data gaps also can inform future data collection to improve the overall understanding of the impacts of GI projects. A better understanding of costs, benefits, and best practices of GI also can assist planners at the state and county level to incentivize the development of watershed-scale plans and assist with the development of model ordinances to incorporate climate change projections into the stormwater planning and management process.

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Appendix A: Summary of Resources Identified in This Report

This listing is not intended to be comprehensive; rather it provides a quick reference for the links listed throughout the report as examples of available resources. It is thus organized according to the sections of the report where the links appear. The resources focus on those produced by federal agencies. Many other resources are available on the topic, including journal articles (e.g., American Society of Civil Engineering, Water Environment Federation), manuals, or other technical publications. The technical practice of stormwater management in response to climate change is continually changing and is not captured here but is also available and may be instructive.

Resource	Description	Link
Efforts Already Underway to Address Climate Change		
EPA's National Stormwater Calculator (SWC)	Stormwater tool that estimates runoff based on historical weather and future climate	http://www2.epa.gov/water-research/national-stormwater-calculator
EPA's Storm Water Management Model and Climate Adjustment Tool (SWMM-CAT)	Stormwater tool that can process regional downscaled climate projections	http://www2.epa.gov/water-research/storm-water-management-model-swmm
EPA's Climate Resilience Evaluation & Awareness Tool (CREAT)	Tool that assists drinking water and wastewater utility owners and operators in understanding potential climate change threats and risks to their individual utilities, and aids in evaluating various adaptation options	http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm
NOAA's Stormwater Runoff Modeling (SWARM) system	Stormwater tool that quantifies runoff using climate change and development scenarios	http://www.coastalscience.noaa.gov/projects/detail?key=1
EPA Technical Assistance for Green Infrastructure	The EPA Office of Water provides technical assistance to support green infrastructure in communities	http://water.epa.gov/infrastructure/greeninfrastructure/gi_support.cfm#TechnicalAssistance

Resource	Description	Link
Greening of America's Capitals (GAC) and Building Blocks for Sustainable Communities	The EPA Office of Sustainable Communities offers green infrastructure technical assistance through the GAC and Building Blocks for Sustainable Communities programs	http://www.epa.gov/smartgrowth/greencapitals.htm and http://www.epa.gov/smartgrowth/buildingblocks.htm
Incorporating Climate Change into Planning		
Climate change data often are not available at the desired geographic and/or temporal scale and may not inform on the endpoints of greatest concern to decision makers.		
NOAA's National Climatic Data Center	Resource for historical climate information	https://www.ncdc.noaa.gov/cdo-web/
City of Grand Rapids, Michigan's *Hydrologic Design Standards under Future Climate for Grand Rapids, Michigan*	Example of a study that uses a range of scenarios to develop a set of possible rainfall futures	http://grcity.us/enterprise-services/Environment-Services/SOC%20Resources/GrandRapidsFutureIDF%20June%202015.pdf
Incorporating Climate Change into Planning		
EPA's National Stormwater Calculator (SWC)	Stormwater tool that estimates runoff based on historical weather and future climate	http://www2.epa.gov/water-research/national-stormwater-calculator
EPA's Storm Water Management Model and Climate Adjustment Tool (SWMM-CAT)	Stormwater tool that can process regional downscaled climate projections	http://www2.epa.gov/water-research/storm-water-management-model-swmm
An Alternate Approach to Assessing Climate Risks	Discussion of alternatives to precise downscaled projections (e.g., analogue storm events, proximities to thresholds, system sensitivities to weather patterns).	http://www.value-cost.eu/sites/default/files/BrownWilby2012EO410001_rga.pdf
IPCC's *Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability*	Section 3.5 (Climate Scenarios) provides information on analog approaches and other methods for utilizing historical and projected climate data	https://www.ipcc.ch/ipccreports/tar/wg2/

Resource	Description	Link
Global Change Explorer	Web application for visualizing and downloading climate model output	http://globalchange.epa.gov
Great Lakes Integrated Sciences + Assessments (GLISA)	Resource that provides historical and future climate trend lines	http://glisa.umich.edu/resources
EPA's Impervious Surface Growth Model (ISGM)	Land use model to help understand the maximum likely development in a region and potential needs associated with projected increases in impervious surfaces	http://www2.epa.gov/smart-growth/impervious-surface-growth-model
EPA's Integrated Climate and Land Use Scenarios (ICLUS)	Resource to help integrate land use to address climate change impacts on stormwater management	http://www.epa.gov/global-adaptation/iclus/index.html
Projections of future climate change and land use change are uncertain		
FEMA Public Assistance: Preliminary Damage Assessment	Federal assistance with damage assessments	https://www.fema.gov/public-assistance-preliminary-damage-assessment
FEMA Hydrologic Engineering Center	Provides hydrologic technical assistance, training, and resources to communities	http://www.hec.usace.army.mil/
FEMA preparedness grants	Helps with preparedness planning for extreme events	https://www.fema.gov/grants
South Florida Water Management District's *Past and Projected Trends in Climate and Sea Level for South Florida*	Regional climate and sea level rise scenarios produced for south Florida counties and municipalities	http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/ccireport_publicationversion_14jul11.pdf
Communication, Coordination, and Education		
Wisconsin's Changing Climate: Impacts and Adaptation	Manual for adaptation strategies	http://www.wicci.wisc.edu/publications.php

Resource	Description	Link
Great Lakes Adaptation Assessment for Cities (GLAA-C)	Peer-to-peer network that connects communities at varying stages of implementation	http://graham.umich.edu/glaac
Urban Sustainability Directors Network (USDN)	Peer-to-peer network that connects communities at varying stages of implementation	http://usdn.org/home.html
American Society of Adaptation Professionals (ASAP)	Peer-to-peer network that connects communities at varying stages of implementation	https://adaptationprofessionals.org/
Great Lakes Saint Lawrence Cities Initiative	Peer-to-peer network that connects communities at varying stages of implementation	http://www.glslcities.org/
Great Lakes Coastal Resilience Planning Guide	Planning guide that filled some of the data needs identified during the Great Lakes workshops	http://www.greatlakesresilience.org/
Building Local Capacity		
Stormwater managers, engineers, and contractors may have limited experience or expertise with relatively newer solutions such as green infrastructure.		
EPA Green Infrastructure webcast series	Training on green infrastructure	http://www.epa.gov/green-infrastructure/green-infrastructure-webcast-series
Montgomery County, Maryland's RainScapes program	Example of a publicized list of certified green infrastructure contractors and engineers to help connect experienced professionals with potential projects that could benefit from alternative design solutions	http://www.montgomerycountymd.gov/DEP/water/rainscapes.html

Resource	Description	Link
Building Local Capacity		
City of Seattle's citywide model ordinance	Example of a model ordinance for stormwater management using green infrastructure	http://www.sustainablecitiesinstitute.org/topics/water-and-green-infrastructure/stormwater-management/model-ordinance-for-establishing-citywide-green-stormwater-infrastructure
Competing priorities (e.g., attracting development to a local area) are a barrier to establishing stringent local policies that benefit stormwater management.		
EPA factsheet: *Stormwater*	Factsheet that discusses how green infrastructure can be integrated into stormwater permits	http://water.epa.gov/infrastructure/greeninfrastructure/upload/EPA-Green-Infrastructure-Factsheet-4-061212-PJ.pdf
EPA's Integrated Municipal Stormwater and Wastewater Planning Approach Framework	Framework for integrated planning approaches for stormwater and wastewater and management	http://www.epa.gov/sites/production/files/2015-10/documents/integrated_planning_framework.pdf
Planning, construction, and management of a geographically dispersed network of green infrastructure may require a different management approach than that used for conventional systems.		
EPA's *Getting to Green: Paying for Green Infrastructure—Financing Options and Resources for Local Decision Makers*	Guide with examples of green infrastructure incentives, such as Washington, DC's Stormwater Management stormwater retention credit program	http://www2.epa.gov/sites/production/files/2015-02/documents/gi_financing_options_12-2014_4.pdf
Watersheds are not confined to political boundaries.		

Resource	Description	Link
York County Coalition 4 Clean Waters (YCC4CW)	Example of group in Pennsylvania able to take a regional approach to stormwater management.	http://watershedalliance.tripod.com/ycc4cw.html
Identifying and Communicating Costs and Benefits of Green Infrastructure		
Municipalities need improved access to economic information on costs and benefits to support decisions regarding the use of green infrastructure		
EPA's *Stormwater to Street Trees—Engineering Urban Forests for Stormwater Management*	Guidance on urban forestry for stormwater management, including an example of how the State of Indiana Department of Natural Resources conducted a statewide street tree benefit study	http://water.epa.gov/polwaste/green/upload/stormwater2streettrees.pdf
Identifying and Communicating Costs and Benefits of Green Infrastructure		
Green Streets, Green Jobs, Green Towns Initiative	Collaboration among EPA Region 3, Chesapeake Bay Trust, Maryland Department of Natural Resources, and others that provides a network and resources for integrating green infrastructure to streets	http://g3partnership.org/
Center for Neighborhood Technology's Green Values National Stormwater Management Calculator	Tool to assist with quantifying costs and benefits of green infrastructure	http://greenvalues.cnt.org/national/calculator.php
Center for Neighborhood Technology's *The Value of Green Infrastructure*	Guide to assist with quantifying costs and benefits of green infrastructure	http://www.cnt.org/repository/gi-values-guide.pdf
ASFPM flood tool for Toledo	Example of an existing tool that has been updated to include cost and benefit information	http://floodatlas.org/toledo/
Municipalities need resources to help them articulate the costs and benefits of green infrastructure.		

Resource	Description	Link
CT NEMO Rain Garden App	Example of a visualization tool that can support project planning	http://nemo.uconn.edu/tools/app/raingarden.htm
U.S. Forest Service's i-Tree tool	Tool with information about the ecosystem services provided by trees for urban stormwater management	https://www.itreetools.org/applications.php
EPA's *The Economic Benefits of Green Infrastructure: A Case Study of Lancaster, PA*	Resource on the economic benefits of green infrastructure	http://water.epa.gov/infrastructure/greeninfrastructure/upload/CNT-Lancaster-Report-508.pdf
Implementation within Current Governance Structure		
Novel and/or watershed-scale solutions may necessitate proactive interagency or interjurisdictional coordination.		
Sustainable Facilities tool	Tool to help users identify strategies to put policy into action	https://sftool.gov/learn/annotation/427/executive-order-13653-preparing-united-states-impacts-climate-change
Implementation within Current Governance Structure		
Silver Jackets program	Program that brings together multiple federal, state, and tribal and local agencies to collaboratively address flood risk	http://www.nfrmp.us/state/
Green Infrastructure Collaborative	Network to help communities more easily implement green infrastructure	http://www.epa.gov/green-infrastructure/green-infrastructure-collaborative
Limited public support or awareness of the benefits and value of green infrastructure, LID, or other climate change adaptation solutions.		
District-Scale Green Infrastructure Scenarios for the Zidell	Example of a developer using green infrastructure in Portland, OR	http://water.epa.gov/infrastructure/greeninfrastructure/upload/Portland_Zidell_Report.pdf

Resource	Description	Link
Development Site, City of Portland		

Appendix B: Project Teams and Participants

B.1. Stormwater Responses to Land Use and Climate Change in the Chesapeake Bay Watershed (Workshops)

B.1.1. For More Information

Contact Susan Julius, U.S. EPA, ***Julius.Susan@epa.gov***, 703-347-8619

B.1.2. Acknowledgements

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- *Norm Goulet,* Northern Virginia Regional Commission
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- *David Sample,* Virginia Institute of Technology
- *Pam Shellenberger,* York County
- *Beth Strommen,* City of Baltimore

B.2. Preparing Stormwater Systems for Climate Change—A Workshop for Lake Erie Basin Communities (Workshop)

B.2.1. For More Information

http://graham.umich.edu/climate/workshops

B.2.2. Acknowledgments

- *Michigan Sea Grant (*workshop sponsor*)*
- *GLAA-C*
- *Old Woman Creek NERR*
- *Ohio Sea Grant*

B.3. Planning for Climate Change in the Great Lakes Region (Needs Assessment and Workshops)

B.3.1. For More Information

http://nerrs.noaa.gov/CTPIndex.aspx?ID=663

http://www.glerl.noaa.gov/pubs/brochures/GLRI_climate.pdf

B.3.2. Acknowledgments

Cleveland, OH Workshop Planning Team:

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- *Yetty Alley,* Ohio Coastal Management Program—Ohio DNR Office of Coastal Management
- *Anne Baird,* Ohio State University Extension Climate Team—Great Lakes Regional Water Program
- *Dan Bogoevski,* Ohio EPA—Northeast Ohio Stormwater Training Council
- *Amy Brennan,* Chagrin River Watershed Partners
- *Kirby Date,* Ohio Planning Conference Northeast Chapter
- *Michael Davidson*, ICLEI Local Governments for Sustainability USA
- *Stephanie Fauver,* NOAA Coastal Services Center
- *Linda Feix,* Friends of Old Woman Creek
- *Cathi Lehn,* Cleveland Museum of Natural History
- *Frank Lichtkoppler,* Ohio Sea Grant College Program
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- *John McLeod,* Cuyahoga County Board of Health
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- *Anand Natarajan,* City of Cleveland Mayor's Office of Sustainability
- *Dawn Nelson,* University of Michigan School of Environment and Natural Resources
- *Kellie Rotunno*, Northeast Ohio Regional Sewer District
- *Leslie Sadowski,* Old Woman Creek NERR—Ohio DNR Division of Wildlife
- *Gwen Shaughnessy,* NOAA Coastal Services Center
- *Daila Shimek,* Cleveland State University—Great Lakes Environmental Finance Center
- *Bill Stanley,* The Nature Conservancy

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- *Stephanie Fauver,* NOAA Coastal Services Center
- *Mike Friis,* Wisconsin Coastal Management Program
- *Kim Hall,* The Nature Conservancy
- *Bud Harris, University of Wisconsin-Green Bay*
- *Vicky Harris,* University of Wisconsin Sea Grant Institute
- *Katie Kahl,* The Nature Conservancy
- *Sally Kefer,* Wisconsin Department of Natural Resources
- *David Liebl,* University of Wisconsin-Extension
- *Paul Linzmeyer,* New North and Sustainable Green Bay
- *Vicki Medland,* University of Wisconsin-Green Bay
- *Jay Mohnihan,* University of Wisconsin-Extension
- *Angela Pierce,* Bay-Lake Regional Planning Commission
- *Becky Sapper,* University of Wisconsin-Extension

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- *Becky Sapper (co-chair),* University of Wisconsin-Extension
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- *Peter Ciborowski,* Minnesota Pollution Control Agency
- *Gene Clark,* University of Wisconsin Sea Grant Institute
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- *Travis Olson,* Wisconsin Coastal Management Program
- *Jesse Schomberg,* Minnesota Sea Grant
- *Cathy Techtmann,* University of Wisconsin-Extension
- *Amber Westerbur,* Minnesota Coastal Program

B.4. Supporting Climate and Coastal Resilience Planning in the Western Lake Erie Basin (Workshop)

B.4.1. For More Information

http://graham.umich.edu/climate/workshops

B.4.2. Acknowledgements

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B.5. Evaluating Stormwater Solutions for Ohio Collaborative Research Project

B.5.1. For More Information

http://nerrs.noaa.gov/NSCIndex.aspx?ID=690

B.5.2. Acknowledgements

Project Coordinator and Fiscal Agent:

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- *Keely Davidson-Bennett,* Chagrin River Watershed Partners, Inc.

Collaboration Leads:

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- *Ona Ferguson,* Consensus Building Institute providing technical assistance

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- *Frank Lopez and Cheryl Wolfe-Cragin,* Old Woman Creek NERR, ODNR Division of Wildlife
- *Ryan Winston,* North Carolina State University
- *Bill Hunt,* North Carolina State University
- University of New Hampshire TIDES Interns
- *Will Brown,* University of New Hampshire
- *Rebecca Jacobson,* University of New Hampshire

B.6. Economic Assessment of Green Infrastructure Strategies for Climate (Assessment)

B.6.1. For More Information

http://coast.noaa.gov/digitalcoast/publications/climate-change-adaptation-pilot

B.6.2. Project Team

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- *Lori Cary-Kothera,* NOAA's Coastal Service Center
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- *Tashya Allen,* NOAA's Coastal Service Center
- *Brandon Krumwiede,* NOAA's Coastal Service Center
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- *Ellie Codding,* Eastern Research Group, Inc.
- *Lauren Scott,* Eastern Research Group, Inc.
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- *Vince Moody,* USACE Institute of Water Resources
- *Jeff Stone*, Association of State Floodplain Managers (ASFPM)

B.6.3. City Partners

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- *Shawna Callaghan,* City of Toledo
- *Chuck Campbell,* City of Toledo
- *Scott Sibley,* City of Toledo
- *Kelly DeBruyn,* City of Toledo
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- *Steven Robertson,* City of Duluth
- *Hilarie Sorensen,* Minnesota Sea Grant
- *Brent Schleck,* Minnesota Sea Grant
- *Jesse Schomberg,* Minnesota Sea Grant

B.7. Great Lakes Adaptation Assessment for Cities (GLAA-C) (Workshops)

B.7.1. For More Information

http://graham.umich.edu/glaac

B.7.2. Acknowledgements

City of Saint Paul Workshop:

- *Anne Hunt, City of Saint Paul Environmental Policy Director*
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- *Brendan Slotterbock, City of Minneapolis, Sustainability Program Coordinator*
- *Gayle Prest, City of Minneapolis Sustainability Director*

City of Ann Arbor Workshop:

- *Matthew Naud,* City of Ann Arbor Environmental Coordinator
- *Jamie Kidwell-Brix,* City of Ann Arbor Sustainability Associate
- *Rebecca Esselman,* Huron River Watershed Council Watershed Planner
- *Melissa Stults,* University of Michigan Dow Sustainability Fellow

B.8. Forwarding Adaptation in the Great Lakes Region (Workshop)

B.8.1. For More Information

http://sustainability.umich.edu/events/forwarding-adaptation-great-lakes-region

B.8.2. Acknowledgements

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Appendix C: Novel Adaptation Approaches: Green Infrastructure and Low-Impact Development

Many efforts are underway to explore the potential for alternative stormwater management solutions to help communities adapt to a changing climate. Historically, stormwater infrastructure was designed to move rainwater offsite quickly. This type of development created hardened riverbanks and disconnected the rivers and streams from the floodplain, interrupting the natural flows. While this hardened approach usually protects developments, there is little room for error, resiliency, or adaptation to accommodate shifts in storm patterns. Existing systems may already be underperforming or undersized. Increased demands from growth in surrounding areas place additional pressure on existing systems and can lead to costly upgrades.

Figure 14. Permeable pavements reduce runoff.

Figure 15. Street planters collect and absorb runoff.

Green infrastructure, such as rain gardens that collect and absorb runoff from rooftops, sidewalks, and streets, and Low Impact Development (LID) are two closely related (and sometimes overlapping) development approaches that are gaining attention as potential strategies for managing stormwater under changing climate conditions. Green infrastructure refers to systems and practices that utilize or mimic natural processes to manage stormwater onsite throughout an area. LID refers to a specific type of construction that seeks to minimize development impacts on nature and water resources. These stormwater management options can improve resiliency to changing stormwater conditions by increasing the flexibility and capacity of drainage. The options also provide broader benefits to communities, including reduced energy use, recharged aquifers, and cleaner air and water. Forms of green infrastructure and LID include green roofs, green spaces, rain barrels, bioretention areas, bioswales, permeable pavements (see Figure 14), and street planters (see Figure 15). Some aspects of green infrastructure such as selection of vegetative cover still will need to consider climate uncertainty (e.g., changes in precipitation in drought, seasonality, invasive species, etc.).

Green infrastructure and LID are being implemented across the country. The EPA's Office of Water (OW) provides technical assistance to support green infrastructure in communities (U.S. EPA, 2015a). For example, OW's Green Infrastructure program evaluated local codes and ordinances for Dallas, TX, and provided them guidance that identified barriers and presented opportunities for using green infrastructure in Dallas. The EPA Office of Sustainable Communities also offers green infrastructure technical assistance through the Greening of America's Capitals (GAC) program (U.S. EPA, 2015b) and the Building Blocks for Sustainable Communities program (U.S. EPA, 2015c). Stafford County, Virginia, implemented ordinances and stormwater management guidelines to encourage LID and developed bioretention areas throughout the county (e.g., in parking lot islands and edges, a public school, hospital, and residential area). The District of Columbia Water and Sewer Authority is designing and constructing measures such as green roofs, rain gardens, rain barrels, and pervious pavement. While these innovative practices are attractive as means to adapt to climate-driven changes in precipitation, many communities are not considering them for many reasons.

C.1. References for Appendix C

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