

An aerial photograph of Baltimore, Maryland, showing a mix of modern and historic architecture along the waterfront. On the left, a tall, modern glass skyscraper stands prominently. Below it is a curved, historic-style building. The harbor is filled with numerous boats, including a large marina with many sailboats. In the background, industrial cranes and other city buildings are visible under a bright blue sky with scattered white clouds. A large, white, tent-like structure is partially visible in the lower right foreground.

BALTIMORE URBAN WATERS FLOOD SCIENCE AND POLICY WORKSHOP ACTION REPORT

SEPTEMBER 2021

EPA 840-R-21-004



INTRODUCTION

The Baltimore Urban Waters Partnership was formed in 2011 to improve community resilience and revitalization, especially in underserved parts of the greater Baltimore area, and reconnect these communities with their urban waters and with parks and green spaces.

The Partnership's Actionable Science Team brings scientists, environmental program managers and non-governmental organizations together to discuss

how recent scientific information can be used to guide environmental restoration efforts in the greater Baltimore area. Following the Ellicott City floods of 2016 and 2018 along with several flash flooding events in Baltimore City and the surrounding suburbs, the Actionable Science Team decided to create a periodic forum to foster greater collaboration among diverse experts and stakeholders aiming to tackle urban flooding.

THE WORKSHOP

That decision led to convening the Baltimore Urban Waters Partnership Flood Science and Policy Workshop on July 31, 2020. Eighty participants explored the relationship between current flood science and existing regulatory and policy frameworks, and generated ideas about how to address related gaps and hurdles moving forward. The workshop was organized around two objectives:

- Identify and address gaps between the science and the regulatory frameworks
- Produce recommendations that will guide future Partnership efforts, especially regarding social vulnerability and community resilience.

The Urban Waters Program hopes that all Federal Partnership locations and other communities can learn from this report. This report captures key takeaways and lessons learned from the workshop presentations and discussions. While the workshop discussions focused on the greater Baltimore region, the model and many of the lessons learned are transferable. The key takeaways are summarized into five themes in this report, each with a set of scientific and policy gaps along with recommendations. See Appendix A for the workshop agenda. A complete recording of all plenary sessions that provide greater context and specific references to academic literature cited in this document can be accessed [here](#).



WORKSHOP PARTICIPANTS

The Baltimore Partnership is very grateful to those who participated as presenters, planners and panelists:

Presentations:

- Mary Lynn Baeck, Princeton University; Presentation: Cloudbursts of the mid-Atlantic: the Ellicott City Storms and More
- Stewart Comstock, Maryland Department of the Environment; Presentation: Stormwater Program Stormwater Regulations to Control Flooding
- Dave Guignet, Maryland Department of the Environment; Presentation: What Does Our Regulatory/Policy Framework Accomplish
- Ming Li, University of Maryland Center for Environmental Science; Presentation: Impacts of Climate Change and Coastline Management on Inundation in Baltimore and Chesapeake Bay
- Andy Miller, University of Maryland Baltimore County; Presentation: Overview of Flooding in the Baltimore Metropolitan Region
- Bernice Rosenzweig, Sarah Lawrence College; Presentation: Street Flooding in Urban Areas
- Jim Smith, Princeton University; Presentation: Cloudbursts of the mid-Atlantic; Presentation: the Ellicott City Storms and More
- Kevin Wagner, Maryland Department of the Environment; Presentation: Critical Aspects of Flood Plain Regulations at Federal, State and Local Levels
- Claire Welty, University of Maryland Baltimore County; Presentation: Street Flooding in Urban Areas
- Radu Zamfirache, Baltimore County Department of Public Works: Local Government Approach to Runoff Management

Panelists:

- Jeanine Finley, Program Analyst, U.S. Environmental Protection Agency
- David Guignet, Water Resources Engineer in the Maryland Department of Environment
- Stephen Lafferty, Chief Sustainability Officer for Baltimore County
- Dr. Andrew Miller, Professor in the Department of Geography and Environmental Systems at the University of Maryland Baltimore County
- The Honorable Elizabeth Walsh, Vice-Chair of the County Council in Howard County, Maryland

Special thanks also go to the planning committee led by Bob Shedlock of the U.S. Geological Survey, as well as David Guignet and Kevin Wagner of the Maryland Department of the Environment, John Hammond, U.S. Geological Survey; Robert Summers, Ecologix Group; Andrew Miller and Claire Welty of the University of Maryland Baltimore County; Bernice Rosenzweig, Sarah Lawrence College; Dr. Mitchell Pavao-Zuckerman of the University of Maryland; and Radu Zamfirache, Baltimore County Department of Public Works.



WORKSHOP SUMMARY: KEY FINDINGS

Photo courtesy of Baltimore City/[Baltimore Magazine](#)

Rich discussions were held throughout the event and discussions can be summarized around the five key themes that emerged:

FLOOD SCIENCE AND IMPACTS

DATA AND TECHNICAL RESOURCES

GOVERNMENT COORDINATION AND POLICY

EQUITY AND SOCIAL VULNERABILITY

OUTREACH AND EDUCATION



FLOOD SCIENCE AND IMPACTS

Photo courtesy of Alex Kruepy/[Baltimore Magazine](#)

- FINDINGS:**
- **Risk of flooding is increasingly imminent.**
 - Probabilistic flood mapping estimates and recent flood events show that places outside the 100-year floodplain line could be flooded at any time, and that a substantial strip along the margins of the 100-year floodplain is at some significant risk.
 - Street/pluvial flooding frequently results from cloudburst rain events and is projected to increase in frequency and magnitude in the coming decades in the absence of near-term, significant mitigation of global climate change.
 - As sea level rises the frequency and magnitude of both nuisance flooding and storm surge flooding will increase. Simulation studies show that regional mitigation actions will be required to reduce storm surge flooding in urban areas.
 - **The watershed-floodplain relationship needs to be better explained.**
 - Conveying water into the floodplain is an existing challenge, in addition the ability to convey water from the top of the watershed to the floodplain is becoming more limited. Some regulations end up squeezing conveyances in closed storm systems that cannot accommodate the excess storm flows, which makes upstream flooding worse.
 - **Urban streams are especially vulnerable.**
 - Urban streams are highly responsive to increases in the intensity and frequency of extreme precipitation, which is occurring in the US, particularly in the Northeast, as documented in the US National Climate Assessment report.
 - **Water quantity and water quality are inextricably linked.**
 - If the quantity is too high, erosion and sanitary sewer overflows are worsened making management of water quality more difficult too.

RECOMMENDATIONS

- **There is a need for scientists, regulators and policymakers to better understand flood risk and threats.**
 - The spectrum (e.g., from street flooding to riverine and tidal flooding) of flood risk and vulnerabilities related to financial consequences of property damage and public health threats must be considered. Scientists and policymakers need to work together on future flood scenarios to develop policies based on actionable science.
 - It is important to consider increases in cloudburst frequency and magnitude, and the impacts of climate change, to understand changes in the occurrence of street flooding.
 - Trackable cloudburst development features include wind, hail, water quantity and especially the development of strong updrafts and downdrafts. This capability is an important advancement in understanding how hydrometeorological phenomena impact urban flooding to monitor risk of floods.
- **Policy efforts should account for urban areas due to their increased susceptibility of extreme rain events.**
 - Extreme rainfall events are increasingly resulting in urban flooding; the problem is a growing source of significant economic loss, physical disruption and housing inequality for communities across the nation.



DATA AND TECHNICAL RESOURCES

FINDINGS: STREET/ PLUVIAL FLOODING

- **Research on street/pluvial flooding is lacking.**
 - There is no consistent terminology for street or pluvial flooding, flooding that happens when the rate of precipitation exceeds the rate of infiltration and engineered drainage.
 - This type of flooding presents a major challenge for many cities – despite the diversity of their land management practices and local climates – but remains poorly represented in the academic literature.
- **This type of flooding is misunderstood.**
 - Street and pluvial flooding is generally not mapped because it is often assumed that stormwater cannot accumulate at such depth to cause flooding and that the real problem is poor maintenance of existing storm drains. Research has shown examples that contradict both of those assumptions.
- **It is hard to find data on monetary losses that result from this type of flooding.**
 - Most data sets associated with monetary losses caused by flooding come from National Flood Insurance Program (NFIP) claims. Since street flooding is not mapped, people in street flood-prone areas are not required to carry flood insurance nor do they have the ability to research the vulnerability of their properties and must cover the damage and loss expenses on their own. Their losses are not recorded in a database.

RECOMMENDATIONS

- **New flood tracking tools and long-term monitoring networks are necessary.**
 - Developing the observational tools for characterizing and quantifying flooding changes will be instrumental in assessing urban flooding in Baltimore and other settings.
 - Continuous and consistent commitment to long-term monitoring networks should be prioritized, as especially data from long-term gauges is necessary to understand how continuing climate change and land cover change are influencing flooding at a spectrum of durations and intensities.
- **Utilize terrain analysis.**
 - Terrain analysis helps identify areas at greater hazard from street flooding and should be prioritized for more rigorous modeling.
- **Criteria for stormwater drainage systems are outdated.**
 - Storm systems are aging, watersheds are being stressed by water quantity, and frequent clogging by debris further complicates those systems.
- **Cities should map street flooding to encourage flood insurance.**
 - The best available modeling resources to identify the flood hazard areas more precisely are not being used. For example, most cities do not map this type of flooding even though there are street flooding models that are approved for use for flood hazard mapping for the NFIP.



DATA AND TECHNICAL RESOURCES

FINDINGS: GREEN INFRASTRUCTURE

- **Connect science and policy to inform infrastructure decision-making especially on the effectiveness of mitigation measures such as GI.**
 - o Research on climate change (e.g., trajectory or predictive tools) that can result in specific regulatory and policy actions to inform decisions about where it is best to apply hard vs. green infrastructure (GI) is needed.
- **Research has found significant differences in future tidal range under hard shoreline versus soft shoreline scenarios.**
 - o Coastal management approaches include building a hard shoreline with seawalls and levees to protect houses and infrastructure or working with nature (soft shorelines) by taking advantage of salt marshes, living shorelines and potentially even retreat from the inundated areas. Hard shoreline modeling scenarios indicate a future increase in tidal range while soft shoreline scenarios show a decrease of tidal range in Maryland. Storm surge modeling scenarios show that we will experience higher storm tides throughout Chesapeake Bay as sea-level rises. However, the models also indicate that soft shoreline measures in sufficiently large areas of low population density can decrease the magnitude of future storm tides in urban areas protected with hard shoreline structures.
- **Environmental site design (ESD) does not manage large storms.**
 - o ESD is intended to manage the runoff from the one-year, 24-hour design storm which is helpful in reducing smaller, more frequent flows, but does not manage large storms unless specifically designed for them.

RECOMMENDATIONS

- **Conduct research that can provide updated tools for policy makers on:**
 - o Data and tools that support mitigation efforts such as GI, impervious cover disconnection and removal especially outside of designated Federal Emergency Management Agency (FEMA) floodplain boundaries.
 - o The effect of impervious surfaces on downstream flooding, pipes and storm drains
 - o The impacts, function, benefits and risks of GI at various watershed scales, on surface water flow regimes and under extreme event scenarios.
- **The impacts of coastal management infrastructure decisions are vital, as hard shorelines and soft shorelines will affect sea level and tidal range differently.**
 - o Tools that support improved infrastructure design and shoreline protection that focus on short duration, high intensity storm events are needed.
 - o The sea level and tidal effects of using a combination of low impact development and natural shoreline opportunities versus seawalls should be accounted for in policy decisions.
- **Policy must consider soil management practices.**
 - o Impacts to existing soils are not factored well into a calculation of climate change effects. For future stormwater management regulations, it is important to manage soil development and incorporate soil infiltration and understand the effects of runoff on water quality.
 - o Government should take a more active role in gathering data and information to challenge the design assumptions used by the development sector.



GOVERNMENT COORDINATION AND POLICY

- FINDINGS:**
- **There is a disconnect between federal, state and local policy in flood management and regulating development.**
 - o Currently, there are flood-minimizing floodplain and waterway construction regulations at the state level, stormwater management regulations at the local level and regulations for storm drain design and construction managed by different departments.
 - o Management, mitigation, enforcement and mapping end up falling on the state. States should also work with counties to share the data which led to the development of the floodplain map, including the date the analysis was prepared.
 - o FEMA's NFIP tells the community to regulate development, which includes changes to structure, mining, dredging, filling, grading, paving and excavation. It is often controversial and difficult to put a flood plain review and permitting process in place locally.
 - **FEMA regulations are too siloed and regulations should not stop at the flood plain.**
 - o FEMA's regulations do not necessarily prevent more water from getting into floodplains. FEMA's regulations focus on development in and just outside the floodplain, creating regulations for building smarter and on higher elevation.
 - **500-year floodplain planning requires federal approval.**
 - o Baltimore City and other communities are starting to look at 500-year floodplains, but a shift to incorporate them is highly unlikely until there is approval at the federal level.
 - **Updates to stormwater management regulations are not easily made.**
 - o Current processes to update these regulations are complicated and bureaucratic. Current 10-year storm drain design includes a risk that these systems will fail from a 10% overtopping each year.

RECOMMENDATIONS

- **Flood management is extremely complex and silos need to be broken down between disciplines and at various levels of decision-making.**
 - o More interdisciplinary collaboration on water management is needed.
 - o Researchers, managers and policy makers must collaborate to improve comprehensive water management (especially water quality and quantity and social impacts).
 - o Scientists must also be familiar with current policies and regulations so their research can produce more actionable scientific information to bring about change to regulation and policy.
- **Policymaking needs to be more collaborative and multijurisdictional.**
 - o Collaborative forums, such as Urban Waters Partnerships, should be supported. These forums enable professionals to bridge jurisdictional silos and provide spaces for community-based organizations to engage and bring perspectives from impacted communities directly to decision-makers.



EQUITY AND SOCIAL VULNERABILITY

DEFINING EQUITY AND SOCIAL VULNERABILITY

EQUITY AND SOCIAL VULNERABILITY ARE OFTEN MISUNDERSTOOD WITHIN THE HAZARD MITIGATION COMMUNITY.

EXECUTIVE ORDER 13985 ON ADVANCING RACIAL EQUITY AND SUPPORT FOR UNDERSERVED COMMUNITIES THROUGH THE FEDERAL GOVERNMENT

“ The term “equity” means the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality. ”

FEMA BUILDING ALLIANCES FOR EQUITABLE RESILIENCE

“ Equity acknowledges that people are diverse and have different needs, and therefore does not seek one solution as an answer to the needs of many. Achieving equity requires understanding that everyone is not starting in the same place, everyone doesn't have access to the same resources, and everyone doesn't have the same life experiences. Therefore, one solution cannot address everyone's needs.

Social vulnerability is a framework that helps planners assess the risks and needs of various groups based on individual circumstances and historic social, cultural and economic inequality. These circumstances may make it harder for people with diverse needs to adapt to, cope with and recover from a disaster when everyone's needs are not taken into consideration in hazard mitigation planning and disaster recovery. ”

FINDINGS:

- **Social vulnerability is not a static state nor is it a circumstance that only impacts certain people.**
 - o Anyone can move in and out of different types of vulnerability throughout life depending on how individual circumstances change over time. Climate change has caused geographic risk to shift significantly and those who may not have been vulnerable in the past are now vulnerable. However, certain groups that have been subject to historic inequality may find themselves at higher risk due to where they live or experience reduced ability to recover due to lack of insurance coverage or recovery programs that create higher barriers to access support. These circumstances can be avoided when risk assessment and planning take social vulnerability into account. This enables planners to better understand everyone that may be vulnerable, the factors that contribute to vulnerability and how to respond.
- **Currently, GIS mapping is the main method utilized to carry out social vulnerability analysis.**
 - o Although social vulnerability has been discussed in academic literature for decades, approaches and methods to assess social vulnerability are still developing. Current methods include the use of GIS mapping to assess vulnerability screen by layering social and demographic data with natural hazards data. Additional methods of assessment are needed to help planners make better decisions.



EQUITY AND SOCIAL VULNERABILITY

RECOMMENDATIONS

- **Improve openness to a range of analytical approaches for assessing risk.**
 - Assess our capacity to carry out social vulnerability assessments, within our own organizations and at scales consistent with the impact of flood hazards.
 - Water managers should develop increased openness to working with social scientists to develop new analytical approaches and with participatory methods of data collection to help risk assessments better reflect the reality of impacted communities. GIS mapping should not be the only approach to assessing risk to these populations.
- **Establish social vulnerability indicators and metrics.**
 - Work to share lessons related to flooding vulnerability (e.g., geography, income, risk tolerances) that are tied to regulations to determine their usefulness in flood management regulation and policy.
 - Work to include flood risks/vulnerability with other environmental justice concerns in developing regulations and policy.
- **Establish accessible databases and Integrate input from impacted communities.**
 - Allow for transparent tracking of cost, benefits and risks after flooding events and use this information to improve science, regulation and policy.
 - Develop applications that allow citizens to better understand and contribute to science that supports policy decisions.
- **Improve and expand networks of citizen scientists.**
 - Take advantage of existing NGOs, community-based organizations and other programs that work with communities to build trust and get an appraisal of the knowledge-base and support related to flooding issues.
 - Enhance communication tools and opportunities that allow citizen scientists to interact with scientists, regulators and policymakers.
- **Work to create innovative partnerships that bring new voices to the table.**
 - Improving civic education through better understanding of, access to and accuracy of existing tools such as FEMA maps and better communication and partnerships with the real estate community.
 - Develop more partnerships among all stakeholders (scientists, regulators, policy makers and laypeople) to develop sustainable funding mechanisms for research and coordination.

ADDITIONAL QUESTIONS FOR WORKING TOWARD EQUITABLE RESILIENCE:

- How do we transform governance structures to create more public participation?
- How do we make planning processes more inclusive?
- How do we work toward planning processes that are inclusive and co-created with impacted communities?
- How do we build more spaces that enable trust and long-term relationship building with impacted communities?
- How do we create more meaningful collaboration (across academia, social scientists, community-based organizations, public health officials, etc.) that breaks down silos?



OUTREACH AND EDUCATION

FINDINGS:

- **There is a lack of understanding of flood risks, mitigation and research.**
 - o Policymakers and the public are not keenly aware of the imminent flooding threats to which many communities across the nation are increasingly susceptible.
 - o The public and policy makers perceive flood events as rare occurrences, while they are actually more common than previously thought. 30-year, 60-year, 100-year and 1,000-year floods can happen more frequently than their names suggest, indicating a problematic misunderstanding and underestimation of their frequency.

RECOMMENDATIONS

- **Education on the need to appreciate trend data and act under uncertainty.**
 - o With respect to flood predictions and risks, acting under uncertainty, or without the 100% guarantee of scientific data assurance, should be normalized. Although uncertainties exist, the science shows trends that should not be ignored.
- **New partners (e.g., realtors, NGOs, community organizations) need to be incorporated into policy making using better communication tools that relay flood issues and relevant science.**
 - o Publicly available tools such as FEMA maps and better communication and partnerships with the real estate community should be promoted.
- **Common language for flooding terms is necessary.**
 - o There is no consistent terminology for street or pluvial flooding – flooding that happens when the rate of precipitation exceeds the rate of infiltration and engineered drainage.
- **Stakeholder awareness of flood science and mitigation needs to be enhanced.**
 - o Stakeholders need to be made aware of actionable science, vulnerabilities and risks, and risk-reduction and mitigation alternatives to give them a better voice in supporting change in regulation and policy.
 - o Property owners often prefer weaker regulations on building and property management and generally regard regulation from an individual perspective of protecting individual interests. They express preference toward mitigating and controlling the flooding of their property, not toward increasing the overall resiliency of the area in which they are located.
- **All at-risk homeowners should be educated about flood insurance.**
 - o Education on risk to homeowners in and just outside the floodplain should be prioritized. The value of property covered by the NFIP in the state is known but studies need to be conducted to determine how much property is at risk (either in or just outside the floodplain) and not covered by flood insurance.



NEXT STEPS

Review and discussion of the 2020 Baltimore Flood workshop proceedings have led to a few important general conclusions and areas of future work. One significant need is to consider flood mitigation and stormwater management actions in the context of a whole watershed approach. Sources of flood water in the entire watershed should be considered. It is not reasonable to only target actions in and near the floodplain. Another important issue is that stormwater management is typically designed to achieve water quality goals and only weakly considers how storm flows will be affected. Furthermore, because different communities employ different stormwater management

strategies, there is no standard way to analyze the efficacy of local stormwater management systems on the overall flooding characteristics of a watershed. Dovetailed with a whole watershed approach is the need to address social equity and social vulnerability from holistic approaches within the watershed. The Baltimore Urban Waters Partnership will work collaboratively to identify and fill research and policy gaps to produce actionable science, promote a holistic watershed approach, and continue to serve as a nexus for managers, researchers, and community members engaging in flooding issues in Baltimore.



APPENDIX A: BALTIMORE FLOOD SCIENCE AND POLICY WORKSHOP, JULY 31, 2020

BRIDGING THE GAPS BETWEEN SCIENCE AND REGULATION

	Agenda Item	Topic	Speakers
9:00	Introduction	Welcome, Goals of Workshop, Acknowledgments	Robert Shedlock, USGS
9:15	Plenary	Does existing stormwater and floodplain management policy respond to present and future risks? Where are the gaps?	Dr. Robert Summers, Ecologix Group
	Session 1	Flood Science	
9:30	Talk 1.	Overview of flooding in Baltimore Region	Dr. Andrew Miller, University of Maryland Baltimore County
9:50	Talk 2.	Cloudbursts of the Mid-Atlantic: The Ellicott City Storms and more	Drs. Jim Smith and Mary Lynn Baeck, Princeton University
10:10	Talk 3.	Street Flooding in Urban Areas	Dr. Ming Li, University of Maryland Center for Environmental Science
10:30	Talk 4.	Impacts of climate change and coastline management on inundation in Baltimore and Chesapeake Bay	Laura Kuhn, Baltimore Mayoral Fellow, Anna Brackett and Linah Sedeek, Maryland Institute College of Art
10:50	Technical Briefs	Rain Harvesting Flood Glossary for General Public	Laura Kuhn, Baltimore Mayoral Fellow, Anna Brackett and Linah Sedeek, Maryland Institute College of Art
11:05	Morning Break		

Agenda Item		Topic	Speakers
Session 2		Flood Regulations and Policies	
11:20	Talk 1.	What does our regulatory/policy framework accomplish?	David Guignet, MD Dept of Environment, National Flood Insurance Coordinator
11:30	Talk 2.	Critical aspects of flood plain regulations at Federal, State, and Local levels	Kevin Wagner, MD Dept of Environment, Community Assistance Program
11:45	Talk 3.	Stormwater regulations to control flooding	Stewart Comstock, MD Dept of Environment Stormwater Program
12:05	Talk 4.	Local government approach to runoff management	Radu Zamfirache, Baltimore County DPW
12:25	Discussion	What are the gaps in our regulatory policy framework?	David Guignet, MDE, National Flood Insurance Coordinator
12:40	Lunch Break		
Session 3		Panel on What We Learned	
1:10	Panel Discussion	Councilwoman Elizabeth Walsh, Howard County, Stephen Lafferty, Baltimore County Chief Sustainability Officer, Jeanine Finley, EPA, Andrew Miller, UMBC, David Guignet, MDE	Moderated by Radu Zamfirache
Session 4		Breakout Sessions	
2:00	Breakout charges	Identify gaps, Eureka moments, possible changes in policy framework, lessons on vulnerability and resilience, topics for future forums	Bernice Rosenzweig
2:10	Breakouts meet	Critical aspects of flood plain regulations at Federal, State, and Local levels	Moderators and Facilitators
3:10	Reconvene everyone and report out	Stormwater regulations to control flooding	Stewart Comstock, MD Dept of Environment Stormwater Program
3:50	Wrap-up	Local government approach to runoff management	Robert Shedlock
4:00	Adjourn	Local government approach to runoff management	Radu Zamfirache, Baltimore County DPW