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ASFPM Foundation's 5th Gilbert F. White Flood Policy Forum

"Climate-Informed Science and Flood Risk Management: Opportunities and Challenges

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George Washington University

Following is a collection of background reading papers from the invited participants that focus on three categories: Policy and Budget, Practitioner Implementation and Research.

Policy and Budget

Challenge for TMAC and FEMA: Climate-informed science mapping should incorporate natural resource values and impacts

David Conrad, Consultant, Water Resources Policy

Since the earliest beginnings of the National Flood Insurance Program, there has always been some tension in the program between the level focus and attention placed on the provision, marketing and management of NFIP flood insurance products, and the attention levels given to risk mitigation and land use management aspects. Some of this tension has probably been driven by the need for risk maps to meet rigorous technical standards – partly because they are often subject to legal challenge. At the same time, communities today require much more information, well beyond the location of where insurance purchases will be required, for their long-term planning and development and in the face of changing flood risks and environmental conditions.

It is becoming increasingly clear from climate science that now and in the future, changing risks of flooding will also pose substantial, and in some cases, profound impacts on basic environments, which not only may affect buildings and property and their insurability, but also the very character and potential uses and productivity of lands and their affected floodplain ecosystems. Thus, a broad question is what adjustments are needed in the NFIP to help and support the thousands of affected communities that are and will be navigating the changes and uncertainties of climate change, rising sea levels, eroding shorelines, and how do those adjustments get made?

Focus on digital mapping systems

Ultimately, to make effective decisions, communities will increasingly need more easily-integrated information for planning (including for land use), decision making and policy setting. At least a substantial part of effective planning could be greatly facilitated through improved and integrated mapping systems, which should identify and characterize present and future hazards, as well as environmental values and assets and how their performance will be affected into the future.

The Biggert-Waters legislation authorized FEMA to (re)establish the Technical Mapping Advisory Council and – as to future conditions risk assessment and modelling – directed the Council “to develop recommendations on how to ensure that flood insurance rate maps incorporate the best available climate science to assess flood risks;” and “ensure that FEMA uses the best available methodology to consider the impact of – 1) the rise in sea level and 2) future development on flood risk.” The first two reports from the Council are expected to be delivered sometime this October. Biggert-Waters, in turn, authorizes and directs FEMA, in coordination with TMAC, to establish an ongoing, much enhanced national flood mapping program, including establishing standards for “use by state and local governments in managing development to reduce the risk of flooding,” and “any other relevant information as may be recommended by the [TMAC].”

Having observed the series of TMAC public meetings since the Council began work Sept. 30, 2014, I've developed the highest appreciation for the heroic efforts of this Council and for the daunting demands and scope of its charge, especially the difficult task of making recommendations for incorporating best available climate science into flood insurance rate maps – which, at this point, I believe the Council is ultimately focusing more on improving flood hazard risk identification and communication within the exploding field of digital-based formats, rather than the classic NFIP "rate maps." A basic first task for TMAC is to make recommendations to help direct the agency's flood risk mapping efforts to incorporate climate and future conditions, recognizing the many uncertainties, to meet needs of the insurance program.

The Biggert-Waters' direction, however, clearly presents a critically important opportunity to improve and expand the scope of GIS-based risk mapping beyond traditional boundaries and to employ an expanded range of disciplines, such as biology and ecology, that will become even more relevant to resiliency in the future.

Early on a substantial area of TMAC discussion focused on the mapping needs for the NFIP's "regulatory program" and the growing needs of communities and agencies at all levels for resource and hazard mapping for "non-regulatory" and planning purposes. Some of the greatest gains yet to be had may well be the expansion of what FEMA staff calls their "non-regulatory products."

Need to integrate critical environmental information with NFIP flood hazard identification to support improved community planning and decision making.

A major piece that should not be left out of an overall approach is the geographically-identified range of natural resource values and functions and conditions that are needed to maintain environmental health within floodplains and watersheds and that are being impacted by climate change, sea-level rise and other changes in watersheds, including urbanization. Such information must be sourced from a wide variety of disciplines and agencies. As part of reforming risk and impact data systems for the future, TMAC and FEMA should work to assure critical environmental planning data needed by communities can be accessed and analyzed in the context of its digital flood and erosion hazard maps. While the challenges of climate change and its potential impacts on the *built* environment are of enormous importance, we also must plan for *environmental and natural resources* impacts and changes, which often will bear heavily on the quality of life of our communities and health of our citizens and economies.

While the array of such resources is broad, just one example of such resources that should be identified and evaluated for future impacts would be the nation's coastal estuaries and primary nursery habitats that support the nation's fisheries. The planning problems may be how will these resources remain productive as ocean levels and shorelines advance landward and as public agencies and landowners construct more and more hardened shoreline structures and floodwalls in response, which in turn often reduce critically important shallow water fisheries' habitats. Identifying where these resources are located and characterizing the likely impacts on their survival or productivity as conditions are changing or are likely to change will be key information communities will need for wise land use, hazard management and other decision making. A further dimension of this natural resource array would include “natural infrastructure” and areas capable of establishing “nature-based measures” as part of flood risk reduction strategies.

As we currently find ourselves in the midst of an explosion of new technologies for identifying and estimating flood and other hazards, many of these same technologies should be brought together for communities’ improved environmental planning, fundamentally to support greater overall resiliency and sustainability. I would hope that ultimately FEMA’s flood mapping, working with the full range of other partners, will result in major steps forward in providing key tools for climate-informed, wise floodplain planning for community environmental management as well as for the built environment.

Key Questions for Flood Policy

Jeff Peterson; Senior Policy Advisor, Office of Water; Environmental Protection Agency

The policy questions below are provided in response to the request of the Association of State Floodplain Managers for a workshop on Sept. 17, 2015. The material in this document represents the views of the author and not the Environmental Protection Agency.

Questions Related to Inundation of Public Clean Water and Drinking Water Facilities

1) **Implementation of Federal Flood Risk Management Standard: New Facilities:** New Federal Flood Risk Management Standard offer a new level of flood protection for select facilities receiving federal grant assistance. What incentives can be offered to encourage adoption of FFRMS into design codes related to new or substantially renovated water facilities not now covered by the FFRMS?

2) **Implementation of FFRMS: Existing Facilities:** How should flood risks existing water facilities be addressed?

3) **Water Facility Inundation Risk Criteria**: Is there a need for water facility flood risk assessment more refined than the 100-year flood zone (e.g. 10 year flood zone or sliding scale)? How might facility service size, location and storm surge risk be accounted for in flood risk assessment? Should separate risk criteria apply to sea level rise?

4) **Risk Reduction Other than Elevation Standard:** Should new or existing water facilities implement flood risk reduction practices in addition to an elevation standard? What are examples of such practices (e.g.; WARN networks, chemical storage protection, back-up power)?

5) **Planning Horizon:** Does the conventional capital planning horizon for water facilities (i.e.; 20-40 years) need to be longer (e.g.; 50 or 100 years) to account for longer-term changes in flood risk as a result of climate change and sea level rise?

6) **Water Facility Relocation Real Estate Acquisition:** Should water facilities facing inundation risks from sea level rise be encouraged to identify and acquire real estate in anticipation of future relocation of treatment, pumping, office or related core operational units?

7) **FFRMS/Elevation Protection vs Relocation:** Should water facilities be encouraged to evaluate long-term costs/benefits of elevation protection investments (e.g.; berm) compared to relocation of facilities to less risky locations?

General Policy Questions

8) **Inundation Protection Policy for Conventional Flooding vs Sea Level Rise:** Should flood policy developed in response to conventional flooding risks be adapted to account for flood risks from sea level rise or is a wholly new policy approach needed to account for sea level rise driven inundation?

9) **Coastal Flood/Sea Level Rise Impact on Municipal Finance/Property Taxes:** There is some macro-level assessment of the value of properties at risk from more severe coastal storms and sea level rise, but little assessment of the localized impact of declining property values on municipal property taxes and viability of municipal budgets. Should the impacts of long-term sea level rise on municipal finance be more closely evaluated? How should the costs and health/environmental risks associated with property abandonment be accounted for in assessing sea level rise impacts on municipal finance?

10) **Financing Mechanism to Avoid Sea Level Rise Stranded Assets:** Can a policy mechanism be developed that would offer an ownership alternative to private parties who own assets expected to depreciate in value and ultimately become stranded/abandoned as a result of sea level rise (e.g.: capacity for a public/private entity to purchase assets, lease-back to original owners for a period of years to recoup purchase costs, then manage asset and safely transition property to condition appropriate to a higher sea level)?

11) **Community Rating System Incentives:** What additional incentives (other than existing flood insurance rate reduction) might be offered to promote the expanded implementation of the flood protection measures promoted by the CRS? Should the development of flood protection strategies on a multi-community or watershed basis be recognized/rewarded within the CRS?

12) **Standards for Community Flood Prevention Planning:** Should there be national models or standards for community flood prevention planning? Should such standards address protection of natural and human systems? Should such standards address financial implications of flood prevention for municipal finance? Should such standards distinguish between conventional flooding and inundation as a result of sea level rise? What is the best geographic scale for such planning? Should community relocation be an element of a national flood/sea level rise protection planning approach?

Looking to tolerable risk in an uncertain future

Jessica Ludy, CFM, ARCADIS U.S., Inc.

Introduction. In 2004, this same forum posed the question, “Is the 1% chance standard sufficient?” The answer then was, no; the answer since then in Cedar Rapids, New Orleans, New York, Texas, and along the Mississippi to name a few, continues loudly--no. Executive Order 13960 improves our situation, for now, with additional freeboard, presumably keeping our communities safer from more extreme events. The new FFRMS is progress in that it acknowledges changing and uncertain conditions to which we must respond. However, the EO poses a challenge in that it could too easily promulgate the age-old approach focused on the base flood elevation, the design flood elevation, or some other “level of protection” if we use options (2) and (3) to establish the floodplain. Meanwhile, in 20, 30, or 50 years, mean higher high water is creeping up, and our more frequent or extreme base floods are lapping at the brand new floodwalls (presumably we built and maintained them to last). Now, we’re back in in 2004, questioning whether we’ve improved the “resilience of communities and federal assets against the impacts of flooding” at all.

The first method of establishing the floodplain, provides an opportunity to do things differently, however, and is arguably the best opportunity of the three to comply with the likely intent of the EO: to build resilience in our communities.

“The elevation and flood hazard area that result from using a climate informed, science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science. This approach will also include an emphasis on whether the action is a critical action as one of the factors to be considered when conducting the analysis.”

This text gives us the chance to change the discussion from the flood control to flood risk management. It offers the opportunity to make informed investments and land use decision that consider risk, changes, and uncertainty, and specifically, decisions that consider what level of risk is tolerable. I would argue that risk informed science is the best available and actionable science where resilience is a priority and the future is uncertain.

Tolerable risk vs. Level of protection. Risk, as typically defined, is the probability of an adverse consequence. It is impossible to completely eliminate risk. Tolerable risk, therefore, is level of risk that people are willing to live with in order to secure certain benefits. Tolerable risk is a range between every day, broadly acceptable risks like driving a car, to intolerable risks, like mass casualty. The main principle of tolerable risk when applied to flood management is that life safety is paramount.

We make decisions based on risk every day—for example, to wear your seatbelt (or not); what level or car insurance to purchase when you rent a car; or, based on how tech savvy you are, whether you want to front the $100 for AppleCare on your new iPhone. Yet in flood management, we have historically focused on the 1%, a probability-based “level of protection” approach. We’re not alone. In the Netherlands until recently, the Dutch have used a probability-based standard to guide their flood defenses; most well-known is the “10,000 year” level of protection for the Randstad, the region with the most people and a majority of Dutch GDP.

The level of protection approach can be dangerous because it communicates that flood risk can be eliminated, and it focuses on the hazard while ignoring the consequence. In particular, it does not recognize the residual risk from larger-than-design floods and lends itself toward structural flood control measures that are less adaptable to changing conditions.

In the last couple of years, the Dutch have recognized that the uncertainty with climate change poses too high a risk to the people and the economy, and so have developed a risk-based safety standard whereby no single person in the Netherlands shall have a greater than one in one hundred thousand (1/100,000) chance of dying from a flood per year, and in areas where mass casualty are possible, posing a societal risk, the standard is higher because such consequences are generally considered unacceptable. In addition to the life safety threshold, the Dutch have developed what they call “economically efficient standards” where the standards they use are commensurate with the risk. After Hurricane Katrina, the US Army Corps of Engineers implemented a risk-based approach to managing their dams and levee portfolios, and have identified an individual tolerable risk threshold for those living in dam inundation zones of 1/10,000. The NFIP on the other hand, remains true to the 1%.

Risk-informed decision making. Risk-informed decision making compared to the level of protection approach changes the focus of the discussion from the hazard to the consequences. In doing so, it provides a better understanding of the real risk, including residual risk after measures have been implemented, and including the uncertainties. If residual risk or uncertainty is high, decision makers may consider additional risk reduction measures or higher standards. Using risk to inform decisions enables an evaluation of tradeoffs as well, and helps prioritize actions and allocate scarce resources toward the most urgent risks. Further, if tolerable risk thresholds are identified (as in the Netherlands and the Corps’ Dam Safety program), then risk reduction can aim to meet the threshold, or exceed it if practicable. Risk assessments can use scenarios to evaluate risk under changing conditions, and thereby reduce some of the uncertainties.

In light of changing future conditions and the uncertainty posed by climate change, it would be wise to take a risk-informed approach in making decisions. In the Bay Area, for example, communities are beginning to assess their vulnerability to sea level rise (SLR). At times, the process sticks on the conflict over “which scenario to use,” disagreeing on when the hazard (water level) will be at what elevation. The discussion loses sight of the fact that the low lying areas will eventually be inundated, whether it is in 2100 or later. Shifting the focus to risk has enabled stakeholders to think about what the consequences of temporary or permanent inundation of their waste water treatment plant or emergency room would be, for example, and whether or not those consequences are acceptable. With that in mind, the discussion is again moving, and moving toward action.

Given the uncertainty in climate science, and the certainty of future strained financial resources, we would be remiss if we did not take advantage of this opportunity presented in 13960 to expand the discussion on risk with our stakeholders, and to use it to make our communities more resilient from the impacts of floods.

Mainstreaming climate-change considerations: The New York State Community Risk and Resiliency Act

Mark Lowery, Office of Climate Change, New York State Department of Environmental Conservation, and **William Nechamen**, Division of Water, New York State Department of Environmental Conservation

New York state is one of the most weather-vulnerable states in the nation, and much of that vulnerability is related to flooding. The state has 70,000 miles of rivers and streams, 127 miles of Atlantic Ocean coastline, and 9,767 miles of total shoreline. Every inch of shoreline along the state's rivers, streams, coastlines and lakefronts is prone to flooding. Between 1960 and 2012, excluding Hurricane Sandy, New York suffered almost $4 billion in flooding losses. Sandy added about $30 billion to that total as it hit the most densely populated part of New York.

Recognizing a trend of increasingly frequent heavy-precipitation events and associated flooding, as well as the risks of coastal storms enhanced by sea level rise, Gov. Andrew Cuomo signed the Community Risk and Resiliency Act into law September 2014. CRRA's purpose is to ensure that certain state monies, facility-siting regulations and permits include consideration of the effects of climate risk and extreme-weather events. CRRA includes five major provisions, listed below:

Official sea level rise projections. CRRA requires the Department of Environmental Conservation to adopt science-based sea level rise projections by regulation.

Consideration of climate hazards in facility siting, permitting and funding. CRRA requires applicants for permits or funding in several specified permitting and funding programs to demonstrate consideration of future physical climate risk due to sea level rise, storm surge and flooding. DEC is required to consider these hazards in updating certain facility-siting regulations. Affected permits include oil and natural gas well siting, streambed disturbance, wetlands and coastal erosion hazard area. Important funding programs affected include state revolving funds for water pollution control and drinking water facilities, and local waterfront revitalization.

Smart Growth Public Infrastructure Policy Act criteria. CRRA amends the state's Smart Growth Public Infrastructure Policy Act to add mitigation of risk due to sea level rise, storm surge and flooding to the list of smart-growth criteria that must be considered by any state agency when it undertakes, funds, approves or supports a public infrastructure project.

Model local laws. CRRA requires development of model local laws that include consideration of future risk due to sea level rise, storm surge and/or flooding to enhance community resiliency.

Guidance on natural resiliency measures. CRRA requires development of guidance on the use of natural resources and natural processes to enhance resiliency.

To ensure consistency in implementation across DEC and other state agencies, and to take advantage of relevant expertise in other agencies, DEC has organized the CRRA Interagency Work Group, consisting of the six agencies directly named in CRRA, including representatives from the affected DEC program divisions, as well as public infrastructure and other interested agencies. DEC has also organized several small drafting teams, led by staff that have accepted responsibility for development of specific guidance or other materials that will ultimately be incorporated into each relevant program.

Three of these teams will develop information in three topical areas specifically required by CRRA:

- Model local laws to enhance resiliency
- Smart Growth Public Infrastructure Policy Act guidance
- Use of natural resources to enhance resiliency

Two additional drafting teams have been organized to address needs identified during discussions with affected programs:

- Protection of Waters guidance
- State Flood Risk Management Standard

Among the permit programs affected by CRRA is DEC's Protection of Waters program, implemented under the authority of Environmental Conservation Law Article 15, which requires permits for disturbance of the bed or banks of a protected stream or other watercourse. DEC issues approximately 1,000 Article 15 permits each year for the replacement of culverts and bridges across New York state. Currently, there are no specific numeric regulatory standards or criteria contained within the Protection of Waters program as it applies to bridge and culvert replacement. Rather, narrative standards are used to determine if a project can be permitted. The CRRA Protection of Waters guidance team is developing more specific guidance to ensure that resiliency to current and future flood conditions is formally incorporated into this regulatory program.

The majority of permit programs and facility-siting regulations affected by CRRA include some provision for facilities or projects within the current 1-percent floodplain as mapped on FEMA flood insurance rate maps. One of the challenges presented by CRRA is to identify "future" floodplains, taking into account climate change so that review considerations in the current floodplain can be transposed to the future floodplain. The state flood risk management standard drafting team has been charged with developing such a standard reference for all programs in which future flooding must be considered.

One option under consideration by this team is to adopt the language describing the Federal Flood Risk Management Standard by Executive Order 13690 for federally-funded projects be adopted for regulatory purposes in New York state. The team recognizes, however, that staff and applicants will require additional guidance with respect to use of climate-informed science to establish the floodplain. DEC staff continue the process of examining applicable tools and data available from U.S.G.S. and other sources, as well as working with the academic research community to develop data and methods that can be brought to bear on this challenge.

Moving Forward: 21st Flood Risk Management Imperatives

Velma Smith, officer, government relations, The Pew Charitable Trusts

This paper must start with appreciation to the leaders of the Association of State Floodplain Managers who—as they have for many years prior—set the stage for an important dialogue on floodplain management. Once again, ASFPM has selected a timely and critical topic and framed the issues well – not only highlighting the technical challenges but also alluding to the enormous financial component of flood risk decisions.

As a relative newcomer to this policy arena, I have spent some time looking back at previous forum papers and at the many paths that have led to the current state of floodplain management. From that perspective, I offer this view: Today's challenge of making reasonable flood risk estimates with incomplete data and knowledge is not new.

We know and have known that hurricanes and nor'easters will hit, rivers will overflow with spring rains, and flash floods will send dangerous torrents across parched lands. But we don't know where or when those things will occur, so we struggle to outline the future flood footprint, to predict the where, the how far, how high and how bad. This has always been the challenge, and scientists have always struggled to make reasonable predictions without as much knowledge as they would like.

The challenge is not new. It is the level of urgency that is perhaps unprecedented and growing.

The tragic flood stories that we revisit around this 10th anniversary of Katrina, the deep debt of the federal flood insurance program, the economic disruption felt when New York City staggered under Sandy, and the increasing frequency of big price-tag storms, all of these tell us we must do better. With a rapidly growing population and that long-enduring desire to be near the water, flood management– as difficult as it has been for decades – will only get harder in the years ahead and more expensive.

As this group discusses how we might do better, I would suggest two central imperatives to consider.

- First and foremost is the need for the science to look ahead, assuring that flood risk planning is planning and acting for the future, not just for yesterday's storms or even today's storms.
- The second imperative, very much related to the first: to integrate the science with the public policies and spending priorities that can impact how flood-resilient the nation becomes. On this, it seems, we have a long way to travel.

It is true –as the forum invitation conveyed – that hydrologists and coastal scientists have looked backwards, observing and recording information about the past to make their maps. Of course, it can be argued that even from this historical perspective climate science has quietly informed this work, since it draws on the study of flow rates, peak discharges and storm intensities that subtly and ever so slowly morph from weather patterns to manifestations of a changing climate.

I am encouraged that the statisticians, the hydrologists, and the modelers have hungrily gathered as much of this data as they could and sharpened their methods from crude approximations on paper maps to robust and informed digital depictions of flooding. As forecasting techniques and models have been peer-reviewed, validated, and calibrated, the science has been honed—now accounting for previously missed dimensions like erosion and wave velocity.

As a non-scientist, I am impressed with these advancements, but offer a caution to those who labor to understand even more clearly the details of what has happened with water and why: Keep your eyes on the road ahead. Don't focus solely on the rear view mirror.

This is perhaps where imperative one meets imperative two.

If we want flood maps – as accurate as they can be – to be put to good use and to chart the course to a flood-resilient future, we must be up front about their fleeting nature. Scientists must convey to the users that these are statistical approximations based largely on the past, not precise and immutable predictions. Be the 10-year flood maps, or 100, or 500, or any other variation, they are averages that will change. And while it may help to share information about confidence levels along with recurrence intervals, the more important information to share could be that each map is likely outdated at the very moment it is completed.

That doesn't mean the maps are useless, that the scientists have failed. Not at all.

Even after nearly half a century of underpriced flood insurance rates that have lulled much of the public into a deep denial about real flood risk, today's maps can guide us forward—if we use them in context and with caution, remembering that the lines on a flood insurance rate map cannot tell the whole story.

Flood maps should be the starting point, not the end point, for sensible decisions about where localities should direct growth and development, about how robustly to build, about where to restore wetlands and vegetated dunes, and about how federal and state governments can make public investments that will last.

Unfortunately, however, because these maps have been the linchpins in the determination of who must buy federal flood insurance, the process of adopting maps has become an adversarial exercise, fraught with politics and distrust. Hence, many of the pitfalls and missteps in flood risk management.

Some communities and some individuals do not want to see anything beyond the delineation of the so-called 100-year floodplain. Some simply want to see the boundaries of the perceived risky areas shrink on paper or on screen, with little regard for what that might mean in the real world. Some are outraged that federal agencies might scrutinize federal investments in an area beyond the traditional floodplain. As one practitioner noted, we seem to be more concerned with mitigating against buying insurance than we are with mitigating against future flood risk.

Thankfully, in some places, the evolving science is being put to good use. Some local planners are looking closely at multiple sea level rise scenarios; many localities and states have adopted freeboard requirements for new construction—an essential margin of safety to guard against uncertainty and change; federal dollars are being leveraged to buy out the most at-risk properties in flood-ravaged communities. The Administration has updated the long-standing but narrowly focused flood risk management standard. The Department of Transportation is working with multiple communities and states to foster consideration of future flood risk in highway and other transportation planning. FEMA has called for state hazard mitigation plans to consider climate risks, and NOAA and other agencies are making sea level rise scenario tools widely available. This is good news, but we must have more of it.

Though neither science nor magic can give us the flood risk equivalent of Harry Potter's Marauders Map with its real-time adjustments, all communities should have maps that suggest the direction of change that may come. All coastal maps should incorporate consideration of sea level rise scenarios; communities guarded by levees—accredited or not—should get a sense of the risk shadow that could fall if maintenance of those structures is neglected or, conversely, what might be possible, if such levees were moved back to allow for natural dissipation of floodwaters.

What's more, these forward-looking maps must be used. Community zoning and subdivisions ordinances should derive from flood maps, not just to specify the most hazardous current floodways where new construction cannot occur but to enhance local protections and build communities that can withstand and bounce back from future storms. Maps should link to capital investment plans and inform how and where to build new roads, public utilities, schools, and hospitals. Each community should use its flood maps in concert with its land use plans and contemplate the flood risk of a future at full build-out.

Where localities cannot move in this direction, states must step in. And states and localities that seek over and over again to have the federal government help them rebuild their vulnerable infrastructure but refuse to change how they deal with flood risk, must be compelled to act.

Such prescriptions have been suggested before, but have not been widely adopted. If we are to break the costly cycle of damage and repair, this is what must happen, however. We must look ahead and begin to make decisions about where to live, how to build, how to keep people safe and prosperous, and how to make sensible investments that will last.

Federal Flood Risk Management Standard: Opportunities for Reducing Flood Risks and Protecting and Restoring Floodplain Functions and Values

John McShane, CFM

The primary purpose for establishing the Federal Flood Risk Management Standard was to improve the nation's resilience to flooding and to better prepare for the impacts of climate change. These impacts will likely increase in the decades to come due to more intense precipitation events without a higher flood standard. Implementing the new FFRMS will reduce flood risks to federal facilities and other federal projects as well as reduce costs to taxpayers from the inevitable floods in the years to come. The higher vertical elevation and expanded floodplain will reduce flood risks, however, a challenge will be in ascertaining the best available climate data by decision-makers.

In the long term, the new FFRMS will clearly provide opportunities for reducing flood risks and will have significant economic and environmental benefits. However, for a variety of reasons, some organizations have expressed their opposition to implementing the FFRMS and the revised EO 11988 Implementing Guidelines. Therefore, it is recommended that a study be conducted to quantify the economic and environmental benefits of the FFRMS, as well as the costs, to verify and validate the value of implementing a higher flood standard. This analysis should include direct and indirect benefits, and costs of the FFRMS and a narrative explaining how it will assist in the on-going efforts to achieve the goals of floodplain management. Quantifying the benefits would provide the data needed to demonstrate that a new flood standard is a wise investment, as well as justify the underlying reasons for implementing zoning and building codes that are in the national interest. The challenge of regulating land use in hazardous areas has been an on-going issue in societies around the world for many years, independent research would assist the private and public sectors in finding common ground that will help ensure that communities are more resilient from flooding for generations to come.

One of the most significant provisions of EO 13690 was to amend section 2(a)(2) of EO 11988 with the addition of this requirement: "Where possible, an agency shall use natural systems, ecosystem processes, and nature-based approaches when developing alternatives for consideration. "Requiring agencies to use nonstructural or "green infrastructure" approaches to reducing flood losses, especially in light of climate change, will have long-lasting benefits to the floodplain environment. As structural measures, such as levees and concrete channels, have had a significant adverse impact on the water quality and ecological integrity of the waters of the United States, especially to highly productive wetlands and riparian areas, this new provision will facilitate the restoration of the natural functions and values of floodplains. A key to implementing nonstructural measures is a comprehensive accounting of all the costs of structural measures. In fact, if all the costs of structural measures and all the benefits of nonstructural measures were taken into account, it is likely that nonstructural approaches would be the best alternative. This approach would also help to achieve one on the goals of floodplain management—protecting and restoring the natural functions and values of floodplains. Floods will continue to occur, but flood disasters are not inevitable. Implementing FFRMS will enhance flood risk management efforts, and save taxpayer dollars, through the 21st Century and beyond.

The Need for Guidance to Industry on Parameters that Define the Range of Climate Projections to Use in Climate Adaptation Planning

Laurens van der Tak, CH2M

Utility managers are increasingly including climate risk in their long term facility planning, be they water, transportation, electric, gas or other infrastructure that have distributed systems that are at risk of flooding or drought or excessive heat. For example, water and wastewater utilities are realizing that they need to plan for more extreme weather conditions that has the potential to cause system service interruptions within the service life of existing assets. Numerous large and small water and wastewater utilities have already prepared such plans (e.g. New York City DEP, Boston Water and Sewer, Denver Water, Wilmington NC, and LA County Sanitation), and others are in the process of updating their facility plans to account for climate change (e.g. Miami-Dade Water and Sewer, Hampton Roads Sanitation District, and Washington Suburban Sanitary Commission).

Many resources are available to these entities to guide their climate resilience planning based on climate informed science, such as those tools and resources from US EPA's Climate Ready Water Utilities program. However, a common issue that comes up when planning climate resilience for facilities with long-term service life, (e.g. 50 years or more), is how to plan for uncertainty given the range of projections. Many facilities are given a bewildering range of choices that define the range of projections from available science. For example, which greenhouse gas scenario to use (RCP8.5, or 6.0, or 4.5 or 2.6), and which set of GCMs or ensemble of GCMs to use, and which statistics to use to define the reasonable range (e.g. 50, 67 or 90 percent non-exceedance of GCMs), and what planning horizon to use. Increasingly utilities are being guided by consultants to pick two values that reflect their risk tolerance, such as 50 percent central estimate, and a precautionary estimate (NYC picked 67 percent non-exceedance, and Miami-Dade is leaning towards selecting 90 percent non-exceedance). In picking these ranges, a very common question is "what is the industry recommendation?" At present, none of the professional societies or U.S. government guidance documents give recommendations on which range of projections to use. So utilities are making use of the climate-informed science, but need help with the policy choices needed to move forward with implementation planning for climate adaptation measures. While the larger utilities are prepared to evaluate the tradeoffs of cost vs risk in making these choices, smaller utilities with fewer resources would benefit from having a fixed set of recommended assumptions to use in defining the range of climate projections that affect their facilities.

The need for multiple-benefit floodplain management in a changing climate

Eileen Shader, American Rivers

Wise floodplain management should achieve two goals- flood loss reduction and the conservation and protection of the natural and beneficial functions of floodplains. These goals can be entirely complimentary. We know that giving rivers more room to safely accommodate flood water is the best way to keep people and communities safe from flooding. We also know that giving rivers room to accommodate flood water allows water to flow onto floodplains and maximize natural and beneficial floodplain functions. As communities deal with climate change impacts from both ends of the water spectrum- more frequent and extreme floods and droughts utilizing multiple-benefit floodplain management approaches that give rivers more room to access their floodplains will be essential. Likewise, climate-informed science should be utilized to plan effective multiple-benefit floodplain management projects in order to maximize the natural and beneficial functions.

As a nation we invest billions of dollars every year into projects that achieve one goal- flood control, clean water supply, habitat restoration, etc. Yet, our existing infrastructure is crumbling, there is a significant backlog of new projects that have been planned or authorized, and the environmental damage of projects from the past continues to pile up. In a warming world, the need to solve these problems will become even greater. Costs will continue to escalate and disaster damages will likely increase. In short, we need to figure out ways to spend limited money smarter.

To more effectively solve water resources problems and to get the most bang for our buck, federal and state agencies should break down silos and red tape in order to facilitate multiple-benefit floodplain restoration projects. Flood, water supply, and habitat problems can often be solved, at least in part, by restoring natural floodplains functions. Natural floodplains provide many benefits to society including reducing the speed and height of flood waters and buffering communities, absorbing and filtering water to recharge aquifers with clean water, and provide vitally important habitat that sustains commercial and recreational fisheries.

California's Central Valley is leading the way to engage in multiple-benefit floodplain restoration projects like expansion of the Yolo and Sacramento bypass and levee setbacks along the Sacramento River in West Sacramento. The region is planning and implementing innovative multiple-benefit projects and aligning their flood, drought and habitat restoration plans and spending to support these projects. These projects will reduce flood risk to urban areas by alleviating the pressure on aging, poorly engineered levees designed too close to the river. Floodplains will retain floodwaters and replenish underground aquifers, while also allowing flood managers to keep more water in upstream reservoirs, increasing the area's resilience to future droughts. And expanded floodplains will provide refuge for young and migrating salmon and other aquatic species that need floodplain access for food and shelter. Unfortunately, federal policies and rules frequently stand in the way of innovative multiple-benefit projects. There has been some progress in recent years, including the Federal Flood Risk Management Standard requirement that federal agencies consider nature-based approaches in their spectrum of project alternatives when spending federal dollars in the floodplain, but additional changes are necessary.

One solution is to allow multiple agencies to contribute towards projects that achieve multiple benefits. There are frequently prohibitions on utilizing multiple sources of federal funding on projects. This is a valid concern when you want to ensure that taxpayer dollars are spent responsibly. However, this can be a problem for multiple benefit projects because when one agency plans and pays for a project, opportunities to achieve multiple benefits may be missed. For instance, if funding from fisheries agencies like U.S. Fish and Wildlife Service were allowed to be paired with FEMA grants when rebuilding washed out culverts, many communities may be able to build larger road-stream crossings that will accommodate larger floods and improve fish passage.

Another is to seek opportunities to alter existing flood control structures to achieve multiple-benefits. The best opportunities for undertaking multiple-benefit projects are often after a flood when funds are available to repair damaged levees and other infrastructure. For a variety of reasons- lack of planning, lack of non-federal sponsor support, a rush to rebuild before the next flood, etc.- this is rarely done. One example of a river and project site that would benefit from efforts to adapt existing infrastructure to achieve multiple benefits is the Three Amigos Non-Structural Alternative Flood Control Project at the San Joaquin River National Wildlife Refuge. The project consists of over 3,000 acres of restored floodplain land purchased by the U.S. Fish and Wildlife Service after a 1997 flood. Despite the acquisition and restoration of the land, the Army Corps repaired levee breaches prohibiting the river from naturally inundating its natural floodplain. Today, all agencies strongly support breaching the levees to allow floodplain inundation but there has been considerable delay.

Perhaps the most important change that is needed is for river managers to think more holistically about how to manage watersheds to achieve multiple water resources goals rather than project by project basis. As the science and data of climate change impacts improves, so will our ability to plan and implement effective multiple-benefit floodplain restoration and reconnection projects. The federal family can help by sharing data, reforming policies to facilitate multiple-benefit projects, and being open to managing watersheds rather than projects.

What is "Climate Informed Science" and where is the Floodplain?

Owen McDonough, PhD, Environmental Policy Program Manager, National Assc. of Home Builders

The National Association of Home Builders is a Washington, D.C.-based trade association that promotes policies that make housing a national priority. Representing over 140,000 builder and associate member firms organized in approximately 800 affiliated state and local associations in all 50 states, the District of Columbia and Puerto Rico, NAHB's mission is to enhance the climate for the housing and the building industry.

With respect to flood management strategies, NAHB encourages policies and programs that are practical, predictable and protective of lives and property. NAHB's members take pride in building and remodeling resilient homes that will last for years to come. NAHB has long been a staunch supporter of market-driven solutions, which encourage greater resiliency in the housing industry while preserving housing affordability.

Due in part to federal, state and local regulations related to construction, loan approval and occupancy within floodplains, NAHB members pay particularly close attention to the location of the floodplain when considering whether or not to purchase property, develop lots, build homes or remodel existing homes. Home builders and developers rely on FEMA's Flood Insurance Rate Maps because they are an accepted and reliable means for determining whether their activities will occur in the 100-year floodplain. Because a construction project's location within a floodplain triggers additional mandates, legal obligations and liabilities, the definition and geographic extent of the floodplain matters to the industry.

As federal efforts shift from flood management strategies based upon historic data (e.g., the 100-year flood) and an established mapping program (e.g., FIRMs depicting the 100-year floodplain) to flood *risk* management approaches based upon future projections (e.g., the "climate-informed science" approach established in the recent Federal Flood Risk Management Standard) for which no maps exist, NAHB urges caution. Indeed, hasty implementation of such projections could undermine the practicality and predictability of the existing federal flood management strategy that has been in place for nearly four decades while affording untested flood protection. Before flood risk management strategies based upon climate-informed science can be put into practice, the federal government must, at the very least:

- Define what constitutes "best available" and "actionable" data;
- Quantify and plan for uncertainties associated with predicted future flood magnitude, timing, duration and frequencies across space and time;
- Conduct spatially explicit flood risk analyses;
- Develop maps depicting the spatial extent of the "climate informed science" floodplain and a map appeals process; and
- Conduct a cost-benefit analysis for any regulatory requirements triggered by location of state/local government and private actions within the "climate-informed science" floodplain.

Regrettably, the federal government was not afforded the opportunity to address any of the above before President Obama issued Executive Order 13690 establishing the FFRMS with a preferred "climate-informed science" approach toward flood risk management. As a result, the Administration is putting the cart-before-the-horse in its haste to implement the FFRMS and issue regulations based on the nebulous concept of "climate-informed science."

Practitioner Implementation

A River Runs Through It: A Lesson for Inland Waterways

Karin M. Jacoby, P.E., J.D., M.P.A, Senior Counsel, Husch Blackwell LLP

The highly acclaimed movie, "A River Runs through It," is a coming-of-age true story set in the 1920s along the Blackfoot River in the Rocky Mountains region of Montana. The story follows two sons of a Presbyterian minister—one studious and the other rebellious—as they grow up with a shared devotion to fly fishing. I am from Missouri, and for me, there are some strong connections to this classic movie. The central character, Paul Maclean, was played by actor Brad Pitt who was raised in southern Missouri. More so, afternoons devoted to trout fishing happen daily in Missouri, and at least a part of the cool clear headwaters of the Missouri River, so close to the Blackfoot, eventually flow through my home state. Down in the lower part of the basin we don't fish for trout in the Big Muddy, but we do flip flies along the State's many spring-fed streams. While I've yet to see anyone loop-cast as artfully as Pitt did in the movie, many Missourians have nearly elevated their casting to an art-form with many days spent practicing their particular technique.

So, why start writing a paper about trout fishing in Missouri when I should be thinking about the state of climate informed science? Truthfully, it's mostly because I've yet to go fishing this season and I am missing those peaceful days on the water. As someone that has spent an entire life, including most of my career, playing, working and living along the rivers and streams in Missouri, I often think about our waterways. I recall as a child watching the Mississippi floodwaters creep up the Arch steps, and have since seen them swallow the bronze statue of Lewis and Clark on the riverfront. As a college student, I came home with a friend to help clean up his father's bottomlands home in the wake of widespread flooding. After college, my first house as a young adult flooded and was only accessible by canoe for days. Although after that I moved out of the floodplain, I still choose to live, work and play along the state's many beautiful waterways.

It occurs to me that my life history can be told along a timeline with significant changes marked by floods, among them the Great Flood of 1993, tragic deaths in 1998 along urban streams in Kansas City, the aftermath of Hurricane Katrina, devastation wrought along the Missouri in 2011, and more. And, I wonder what the future may bring. Will flooding be more frequent? Will heavier rains overwhelm the many area flood control works that have been built and that today are working so well? What might an anticipated significant increase in rainfall across the northern Midwest mean "on the ground" here? Will flood stages be higher, events last longer, both? Will science answer the questions it's raised, and, if so, when and how?

The answers to those questions could have far reaching implications and be especially significant to flood protection and floodplain management. While there are some extensive studies that look at how climate change may impact sea-level rise and consequently coastal flooding, not much appears to have been done to determine what may happen along the nation's inland rivers. Why does that matter? In part, because there is now being developed a regulatory framework for flood risk management that applies nation-wide, and not to just coastal areas. Climate-informed science is beginning to show up in various places, for example, in the Administration's new federal flood risk management standard, in revised Corps of Engineers agency issued planning guidance, in the 2012 congressional language reauthorizing the National Flood Insurance Program, and elsewhere.

Recently I heard that science is not as useful in answering questions as it is in asking them. Perhaps that is the case with climate change and future flood risk. Will flooding along our inland waterways change? Probably, but when, where and by how much – it's still too hard to definitively say. In the meantime, putting in place a framework based on questions rather than answers is contributing to controversial, as well as perhaps contestable, decisions.

Looping back, you may recall that in the movie the older brother, Norman, seemed wise beyond his years while his younger brother, Paul (Pitt's character), was a wild child. Norman lived a long productive life and wrote their story. Unfortunately, Paul's fast life-style led to a tragic death at a young age. Today, in those places where a river runs through it, a practical, disciplined and well-reasoned approach to climate informed science could have long-term value and lead to effective risk communication, a recognized means to achieving better decision making by the individual as well as all levels of government. The lesson of the MacLean's story is one of succumbing to the attraction of grabbing too quickly for as much as can be had and the resultant tragic consequences. As the practice of flood risk management grows, care should be taken lest the use of climate informed science suffer a similar fate.

Communicating Flood Risk from Climate Change to Communities

Matthew Metcalfe and **Stephanie Udler**, Booz Allen Hamilton

Although climate change effects are generally considered to be far term, federal, state and local agencies are recognizing that weather uncertainty is impacting their missions and that they need an effective framework to integrate climate adaptation as part of mission assurance and mission planning. In particular, the frequency and magnitude of flood events is increasing along with the associated costs and the number of victims affected. The vast majority of the United States population lives in urban or coastal areas and our infrastructure is aging, making us more exposed and vulnerable to disasters.

Government agencies, interagency working groups and federal advisory committees are currently working to collect data and develop standard methodologies and tools to assess vulnerabilities to flood-related disasters enhanced by climate change, and Booz Allen Hamilton is helping to support many of these efforts. A key component of achieving national resiliency, however, is the means by which those data, tools and approaches are used to effectively communicate and encourage local action to mitigate flood risk. This is particularly critical when communities and local officials are challenged with taking into account the increased risk posed by future conditions resulting from climate change. This paper focuses on opportunities that federal, state and local agencies can consider when working with communities to understand the future flood risk posed by climate change and, in turn, take action to prevent and recover faster from economic, environmental and social losses.

It is imperative that communities at risk of flooding have the information they need to take action. There are several opportunities to improve communications to the public on the risk of flood-related disasters posed by climate change.

1. **Additional Community-Specific Data and Tools.** Government agencies provide a multitude of data and tools to communities to help communities analyze, communicate and visualize their flood risk. Some of these products include maps, risk assessments, levee simulators and geographic information system databases and layers that contain risk information. Government agencies should consider how to customize this data and tools based on specific community needs and interests. For example, new or amended products could focus on a community's critical infrastructure that could fail as a result of a flood (e.g., aging bridge on the main thoroughfare) or perhaps the risk to economic areas of interest (e.g., a local Walmart that employees 30 percent of the population of a given county). Visualization of riverine flood risk to noted community landmarks over time, taking a note from National Oceanic and Atmospheric Administration's Sea Level Rise Viewer, would also be particularly powerful.

2. **Innovative Awareness Campaigns.** Federal, state and local agencies should consider new and innovative approaches to building flood risk awareness and encouraging mitigation action in communities. This should entail building more holistic messages about risk and resiliency; incorporating narratives about the impact flooding has on all sectors of society. For example, in addition to the financial risks to personal property, awareness efforts could also highlight how long public schools might be closed and how far students might have to travel while a community

recovers from a flood. Additionally, the success of awareness campaigns that have direct connections to the community such as the Federal Emergency Management Agency's High Water Mark Initiative and the U.S. Army Corps of Engineers' Silver Jackets Program, should be borrowed and built upon to continue to build momentum behind resiliency and future flood risk mitigation in the nation's communities.

3. **Connect Communities to Funding Sources.** Communities often have difficulty prioritizing and funding flood risk mitigation projects even when their current risk is quite high. When considering how to help communities take action to mitigate future flood risk, government agencies should seek to build local capability around how to take advantage of multiple grant programs to achieve resiliency (e.g., EPA's Smart Growth Program in conjunction with FEMA's Hazard Mitigation Grants Program). Government agencies should further seek to build local capability around innovative financing for individuals/property owners in a community to mitigate their flood risk. Some techniques include rebates, tax credits and low-interest loan programs. For example, "Shore Up Connecticut" is providing low interest loans to individuals to finance property elevations and retrofits.

4. **Demonstrating Return on Investment.** Government agencies should improve communications with private industry to have them consider flood risk management as a selling feature of a property by demonstrating a return on investment. For example, the U.S. Green Building Council has incorporated minimum standards of floodplain avoidance into its Leadership in Energy and Environmental Design for Neighborhoods. While this is a good start, perhaps USGBC should incorporate higher floodplain avoidance standards into its LEED criteria to further incentivize developers to meet these standards. Government agencies could also provide private industry with tools to calculate the return on investment for flood risk management.

These opportunities, implemented together or independently, can make a big difference in addressing flood risk associated with climate change. Booz Allen is poised to partner with government agencies to execute on these opportunities.

Exposure, Vulnerability, and Decision Support: Leveling the Scientific Playing Field for Communities Engaging in Climate-Informed Flood Risk Management

Jordan Fischbach and **Debra Knopman**, RAND Corporation

In this paper, we advocate for the development of nationally consistent information on local exposure and vulnerability to flooding under conditions of climate change uncertainty. Such information could serve as a baseline for local planning. We further argue for development of standard protocols for incorporating climate-informed science into decision support processes as local planning for flood risk management evolves.

Under the current U.S. model of federalism, flood risk management blends local, regional, state and national roles and responsibilities. Producers of the science to inform flood risk management are further spread among local, state and federal agencies, academic institutions, and in some places, non-profit research or advocacy organizations. Among local flood management agencies, analytical capacity and sophistication in planning methods vary widely. The rapid expansion of data and methods to bound and project forward the potential impacts of climate change is challenging for all communities, but particularly so for those communities that lack access to scientific and technical expertise to advise on appropriate methods of climate downscaling and scenario building.

Exposure and vulnerability information are the building blocks of sound flood risk management. Under current funding constraints, the Federal Emergency Management Agency produces base maps of flood hazards in communities across the U.S. that are updated with varying frequency depending on population and need. For example, FEMA first released a Flood Insurance Rate Map for New York City in 1983, and only minimally updated it at various times between 1991 and 2007. FEMA released a significant update in the form of a Preliminary FIRM in January 2015, but remains under review. FEMA does not make nationwide data available in summary form on average times between FIRM updates, but a large-scale program to improve map quality and shorten the update cycle has been under way since 2004. These FIRMS are first and foremost intended to support the National Flood Insurance Program, but often serve as the sole source of information for local risk-based flood management due to the lack of research alternatives available for most communities. In addition, at present, the FIRMs do not project plausible future flood risk or incorporate information on changing climatic conditions. Instead, they embed assumptions of climate stationarity into their risk estimates. As a result, the information used to conduct floodplain management throughout the country is based on exposure and vulnerability estimates that are often well out of date, and inconsistently informed by the best available climate science.

Our own experience in working in Louisiana, New York City and other regions in the U.S. and abroad suggests the collective value that would flow from the production of nationally-consistent information on exposure to flooding across the nation and vulnerability of communities to flood damage under the influence of climate change. First, as conditions for federal and state aid, communities will increasingly be asked to demonstrate their progress toward incorporating long-term adaptation to climate change in their infrastructure and land use planning. The Hurricane Sandy Task Force resilience guidelines are just one recent example.

Second, communities have differential access to expertise in climate science. The provision of nationally-consistent information to inform local decision making is a cost-effective means of diminishing the information gap among communities while also mitigating the much larger cross subsidies that arise when disaster strikes the less prepared communities. In Louisiana and New York, following their respective flooding disasters, the federal government appropriated approximately $100 billion and $60 billion, respectively, to deal with the aftermath. However, such large infusions of federal disaster assistance elsewhere are likely to be unsustainable as flood losses mount.

Our experience in various regions has also reinforced the value of tailoring climate-relevant information to the evolving needs of decision makers and stakeholders in the context of their own unique flood risk management planning and implementation processes. Communities and regions are largely improvising on how to incorporate uncertainties about sea level rise, changes in precipitation, storm frequency and intensity and temperature changes into their long-term planning. Climate-informed scenario development can be technically challenging, especially when flood management is combined with other key planning objectives in an integrated framework. For example, planning for flood resilience in the neighborhoods surrounding Jamaica Bay in New York City is closely linked with the ecosystem and water quality planning for the Bay that has been underway for decades. Integrated analysis allows for a comparison of interventions and looks at outcomes across all of these planning areas, but the technical challenges, computing requirements and expense of such analyses is often a bar to effective integrated planning. While there is no reason that scenario development needs to be consistent across regions, there would be value in establishing technically-defensible protocols that could be applied under a range of contexts. As with the exposure and vulnerability information, such protocols could be particularly helpful to those local communities that currently lack access to climate experts or the resources to fully engage such experts in providing decision-relevant climate science for flood risk management.

Flood Risk Management in a Changing Climate: A framework to increase resilience

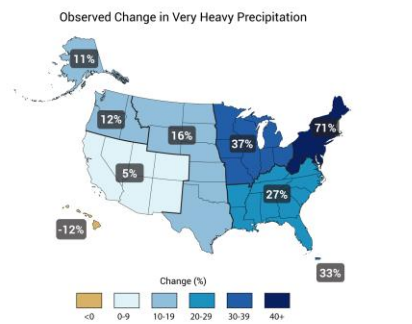
Shana Udvardy, CFM, Udvardy Consulting

When it comes to the essence of a changing climate, the author Margaret Atwood and former Secretary of Defense Chuck Hagel come to mind. Atwood speaks to climate change as the "everything change" and Hagel describes it as a "threat multiplier." Indeed both are true and reflect recent remarks by President Barack Obama who, in his second term, has made climate change, both mitigation and adaptation, a priority.

At the Global Leadership in the Arctic Conference in Alaska, President Obama gave strong remarks on the science and impacts of climate change and on the need to reduce greenhouse gas emissions and to become more resilient. He repeated again, climate change is "here, it is happening now." The President spoke to the fact that the nation will need to move entire villages due to sea level rise, coastal erosion, increased seasonal flooding, storm surge and thawing permafrost.[1] In fact, six Alaska communities are planning partial or total relocation, and 160 have been identified as threatened by climate-related erosion by the U.S. Army Corps of Engineers, which estimates relocation costs at $30 to $50 million per village.[2] As the President noted in his remarks, Alaska is on the leading edge of climate change and is our indicator of what the planet faces.

For some time we have known a few trends to be true for U.S. coastal areas. First, that sea level has been rising and second, that more people are moving to the coast placing a great portion of U.S. citizens at risk (about 55-60 percent live in counties along the Atlantic or Pacific Ocean, Gulf of Mexico or Great Lakes) and a sizeable amount of assets are in harm's way (roughly $66 billion to $106 billion worth of coastal property is estimated to be below sea level by 2050).[3] Now, with new NASA data, we must contend with a new trend. NASA satellite data suggest that sea level rise will be much higher than previous studies indicated and that as one scientist put it, we are "locked-in" to at least 3 feet of sea level rise and probably more. What is less clear is to how soon this will happen.[4]

In AECOM's 2013 study, the authors estimated that climate change (as well as population growth, increases in impervious surfaces, etc.) will increase the risks of riverine flooding 45 percent by 2100.[5] As this figure indicates, heavy downpours are increasing nationally, especially over the last three to five decades with the largest increases in the Midwest and Northeast.[6]



USGCRP 2014 National Climate Assessment.

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[1] President Obama delivers remarks at the GLACIER Conference in Alaska. August 31, 2015.https://www.whitehouse.gov/photos-and-video/video/2015/08/31/president-addresses-glacier-conference

[2] NASA blog by Michael Carlowicz. August 26, 2015. Sea Level Rise Hits Home at NASA. http://earthobservatory.nasa.gov/Features/NASASeaLevel/

[3] Alaska Sea Grant. Sea Level Rise and Storm Surge. https://seagrant.uaf.edu/map/climate/docs/sea-level.php

[4] NASA August 26, 2015. NASA Science Zeros in on Ocean Rise: How Much? How Soon?

[5] AECOM. 2013. The Impact of Climate Change and Population Growth on the National Flood Insurance Program through 2100. June 2013

[6] U.S. Global Change Research Program National Climate Assessment 2014.

Just a few days prior to his Alaska trip, President Obama travelled to New Orleans to commemorate the 10th anniversary of Katrina and to focus on his “all-of-Nation approach” to helping communities build back stronger and more resilient.[7] Many lessons can be drawn since Katrina and other recent events based on actions and innovations that have come from the public and private sectors and have been captured in the 2014 National Climate Assessment.[8] Included here is a five-part framework for flood risk management in a changing climate.

Make the business case through public private partnerships (P3s). A few P3 examples include:

- In Kunreuther’s recent paper on the role of insurance in reducing risk, he states “public–private partnerships can encourage investment in protective measures prior to a disaster, deal with affordability problems and provide coverage for catastrophic risks.”[9] The National Flood Insurance Program could incorporate the P3 concept to assist homeowners who cannot afford to invest in protective measures and to provide financial protection against catastrophic losses for risks that are considered uninsurable by the private sector alone.[10]
- The Dow Chemical Company and The Nature Conservancy collaborated to make the case for incorporating nature into global business goals, decisions and strategies. For example, in Texas, they are working together on the role coastal marshes play in protecting Dow’s facilities and local communities from storm damage.
- The Rockefeller Foundation’s 100 Resilient Cities initiative provides financial support to hire and empower a city with a Chief Resilience Officer to manage resilience building activities.
- The Climate Resilience AmeriCorps Pilot Program – the Administration recently selected ten new cities selected for the program that will support local resilience-building efforts.[11]

Implement regulatory incentives and standards at the federal, state, and local levels. A few examples include:

- Executive Order 13690 (revises Executive Order 11988) proposes a new Federal Flood Risk Management Standard and gives agencies the flexibility to select one of three approaches to establish the flood elevation and hazard area they use in siting, design, and construction and requires, where possible, the use of ecosystems and nature based approaches.[12]

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[7] The White House. Commemorating the 10th Anniversary of Hurricane Katrina. https://www.whitehouse.gov/blog/2015/08/27/commemorating-10th-anniversary-hurricane-katrina. See also President Obama to Commemorate 10th Anniversary of Hurricane Katrina. August 19, 2015. https://www.whitehouse.gov/the-press-office/2015/08/19/fact-sheet-president-obama-commemorate-10th-anniversary-hurricane

[8] USGCRP 2014 National Climate Assessment, Chapter 6: Adaptation. file:///C:/_Climate/NCA3_Full_Report_28_Adaptation_LowRes.pdf

[9] Howard Kunreuther. 2015. The Role of Insurance in Reducing Losses from Extreme Events: The Need for Public–Private Partnerships. The International Association for the Study of Insurance Economics. http://opim.wharton.upenn.edu/risk/library/J2015GPP_The-Role-of-Insurance-in-Reducing-Losses-from-Extreme-Events_Kunreuther.pdf

[10] *Ibid*. *See* also http://www.ibamag.com/news/10-years-after-katrina-what-an-unstable-nfip-means-for-flood-insurance-24137.aspx

[11] White House Blog. https://www.whitehouse.gov/blog/2015/08/20/10-new-resilience-americorp-cities-selected-its-climate-resilience-pilot-program

[12] EO 13690 https://www.whitehouse.gov/the-press-office/2015/01/30/executive-order-establishing-federal-flood-risk-management-standard-and-

- State building codes. IBHS found that modern building codes reduced the severity of losses due to Hurricane Charley in 2004 by 42 percent and loss frequency by 60 percent.[13]
- Boulder was more resilient after the September 2013 flooding due to a few policies in place including: 1) a high hazard property acquisition program; 2) open space designations; 3) critical facilities ordinance and 4) multiuse paths along many creeks.[14]

Provide innovative financial incentives and resources to pre-event risk reduction.[15] Investing in pre-disaster risk reduction, particularly natural infrastructure (dunes, wetlands, marshes, living shorelines, oyster beds, etc.) is cost-effective and provides multiple benefits.

- Along the Charles River in Massachusetts a fee-simple purchase and conservation easement acquisition of wetlands in the watershed costing one-tenth of the original dam and levee project.[16]
- Michael Bloomberg speaks to many important examples and strategies in a recent Foreign Affairs City Century blog including providing credit ratings eliminating laws that prevent them from investing in and profiting from sustainable projects.[17]
- In 2014, Connecticut implemented its "Shore Up CT" program to assist residential or business property owners elevate buildings, retrofit properties with additional flood protection, or assist with wind-proofing structures on property that is prone to coastal flooding. Homeowners are able to receive a 15-year loan ranging from $10,000 to $300,000 at an annual interest rate of 2¾ percent.[18][19]

Demonstrate what works. Social and behavioral scientist Dennis Mileti found that one of the first best practices to flood risk preparedness is to demonstrate preparedness actions.[20] As Mileti has explained, it's as simple as "monkey see monkey do". Additionally, often metrics are unavailable for resilient approaches. For both of these reasons, it is critical to demonstrate what works by sharing case studies of flood risk management approaches that have proven to safeguard communities. To ensure and guide

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[13] https://www.disastersafety.org/building_codes/benefits-statewide-building-codes/

[14] Emergency Management. June 24, 2014. 6 Key Takeaways from Colorado's Devastating Flooding. http://www.emergencymgmt.com/disaster/6-Takeaways-Colorados-Devastating-Flooding.html

[15] *See* Zurich and Wharton School report. Beyond Katrina: Lessons In Creating Resilient Communities. August 20, 2015. http://zurichna.com/internet/zna/SiteCollectionDocuments/en/Windstorm/whitepaper_beyond_katrina.pdf and SmarterSafer.org report Bracing for the storm http://www.smartersafer.org/wp-content/uploads/Bracing-for-the-Storm.pdf

[16] Carolyn Kousky.2010. Journal of Natural Resources Policy Research. Using Natural Capital to Reduce Disaster Risk. http://www.tandfonline.com/doi/pdf/10.1080/19390459.2010.511451

[17] Michael Bloomberg. September/October 2015.City Century: Why Municipalities Are the Key to Fighting Climate Change https://www.foreignaffairs.com/articles/2015-08-18/city-century.

[18] http://shoreupct.org/

[19] http://www.floods.org/Files/Conf2014_ppts/G3_Cobleigh.pdf

[20] ASFPM Annual conference. 2010. Dennis S. Mileti, Ph.D., Professor Emeritus, University of Colorado-Boulder: Influencing the Behavior of Individuals to Prepare for and Mitigate Flood Risk http://www.floods.org/index.asp?menuid=%20655

future investments in what works government agencies and academia should partner to measure the resilience of the different approaches.[21]

Think outside of the box. To move from planning to implementation and beyond incremental changes a few strategic steps include[22]:

1) Remove barriers to implementation by finding innovative approaches to funding, policies and regulations, and better anticipating climate-related changes at the local level.
2) Find the similarities from other approaches in different regions and sectors and adapt those to fit your scale and needs.
3) Be strategic on how your goal can fit within other societal goals such as sustainable development, conservation, improvements in quality of life, among others so as to help incorporate that approach into existing decision-making processes.
4) Assess threats and the tradeoffs of flood risk management approaches that incorporate multiple stresses by addressing costs, benefits, and risks of available options.

[21] *See* Zurich and Wharton School Report beyond Katrina: Lessons In Creating Resilient Communities. August 20, 2015. http://zurichna.com/internet/zna/SiteCollectionDocuments/en/Windstorm/whitepaper_beyond_katrina.pdf
[22] *See* USGCRP 2014 NCA Chapter 6: Adaptation Key Messages. file:///C:/_Climate/NCA3_Full_Report_28_Adaptation_LowRes.pdf

Future Conditions Floodplain Mapping: Charlotte-Mecklenburg's Experience

W. Dave Canaan, Mecklenburg County (North Carolina), Water and Land Resources

Charlotte-Mecklenburg Storm Water Services was the first agency to implement community floodplain mapping for future conditions on FEMA flood insurance maps. This innovative strategy, replacing 500-year floodplain mapping, evolved as stormwater mitigation paradigms shifted to resolve the conflict between the development and construction demands of a growing community and the unyielding axis of topography, hydrology and climatology. Ultimately, the impetus to change was crisis: two 100-year flood events in three years.

Never let a good crisis go to waste. - Sir Winston Churchill

Floodplains are meant to flood.

…our (Mecklenburg County) creeks are a natural resource…the use of creeks as a stormwater disposal method shall be secondary to the preservation of creeks…- From resolution by Mecklenburg Board of County Commissioners

If we are going to put all these folk in the floodplain, can we only do it once?- Statement by a city of Charlotte Councilmember

Generally, we do not like additional regulations; however, we also do not like to build homes and businesses that will flood in the future.- Commentary from Real Estate and Building Industry Collation

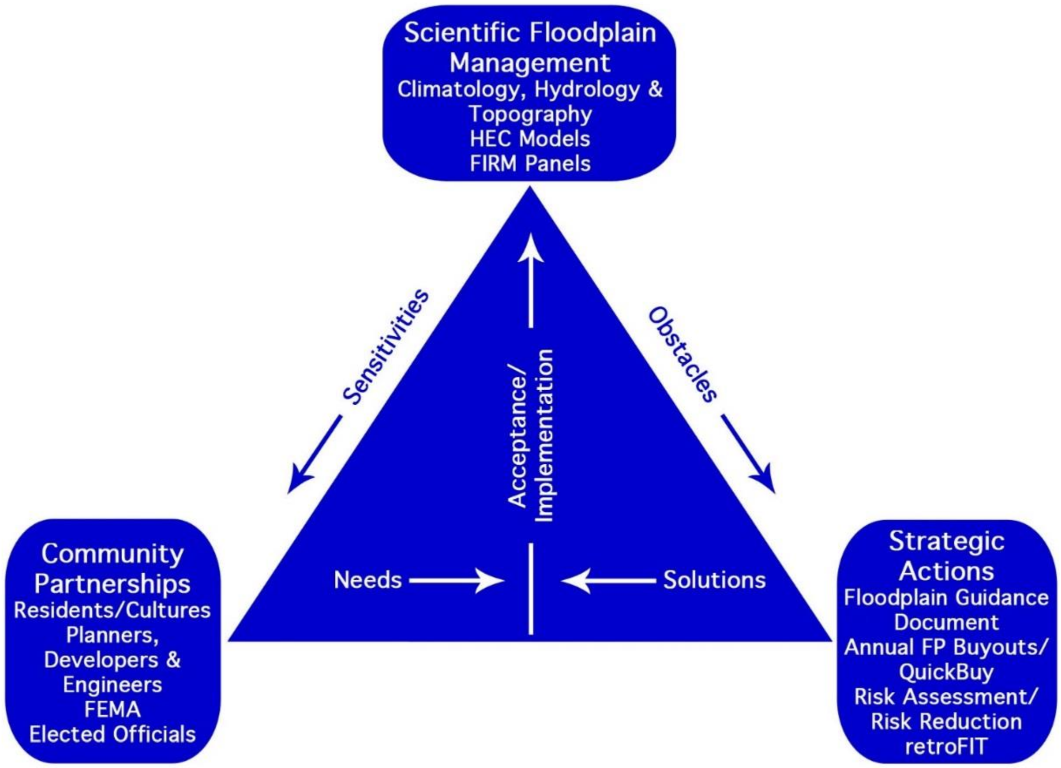
In 1996, in response to a 100-year flooding event, CMSWS initiated an aggressive approach to reform floodplain management. The result was a draft Floodplain Management Guidance Document containing six strategies. Two of those strategies were most impactful:

- New development should be managed so flood problems are not increased.
- Flood Hazard Mitigation Plans should be prepared to solve local flooding problems.

In 1998 (after a second 100-year flood in three years), the Floodplain Management Guidance Document was adopted and the implementation of the new strategies initiated. By mid-2004, full implementation was complete.

This aggressive 6-year process required elevating floodplain management to the standards required by the constants of science along the delicate continuum of community acceptance while balancing strategies with the sensitivities of constituencies and cultures. This balance succeeded through the engagement of partnerships, pairing strategies to desired partner outcomes – not much different than the intent of the Gilbert F. White Flood Policy Forums.

Exhibit: Floodplain Management Process Model



The premise of the CMSWS process model is that acceptance and implementation of our scientific floodplain management goal requires assessing current data and setting scientific standards as community goals. Partnerships are formed within multiple constituent groups, some of whom have sensitivities to address. Strategies are developed to provide solutions for community outcomes. As needs are balanced with strategic solutions, obstacles are overcome and sensitivities decrease. Each milestone measures progress toward the goal of elevating the entire community toward scientific floodplain management.

The following are two examples of key milestones critical to the success of the initiative:

- When CMSWS operated in a transparent manner with the entire community (partners) in the development of the Floodplain Guidance Document (strategic action) and provided the engineering community the flood models from pilot studies (scientific floodplain management), the engineering community informed the development community that the only ethical thing for them to do was to design to higher standards (acceptance).
- When the community (partners, especially those in the floodplain) were informed of the higher flood elevations (scientific floodplain management), we provided them the new floodplain buyout program (strategic action) to which many complied (acceptance).

Implementing Future Conditions floodplains may not be applicable for every community. However, an open dialogue that engages partners, is focused on good science, and is tied to comprehensive, strategic thinking is the best way to develop and implement a higher standard. That has been the experience for Charlotte-Mecklenburg.

Hydrologic Modeling to Evaluate Impacts of Climate Change on Flooding

William Merkel, MS, PE, Hydraulic Engineer, USDA – Natural Resources Conservation Service, Beltsville, MD, Practitioner Issues – Hydrologic modeling of future climate scenarios

The following issues are formulated from the perspective of application of hydrologic models for estimating storm runoff volume and peak discharge, water yield from watersheds, design and operation of dams for purposes of flood control and water supply through analysis of watershed characteristics, weather and streamflow data. Additional related concerns which could be analyzed through use of hydrologic models are how rainfall and runoff impact soil and gully erosion, floods and droughts on landscapes including stream channels, flood plains and wetlands, and how vegetation cover and soil moisture changes impact storm runoff.

Single event-type hydrologic models have been traditionally used to evaluate flood risk. Deterministic models have the advantage of being able to analyze effects of physical features such as dams, levee systems and changes of land use on the flood risk in critical locations. The Natural Resources Conservation Service supports the hydrologic model WinTR-20 (USDA-NRCS, 2015), which may be used to analyze these situations. Traditionally, data used in these models have been developed based on stationary or non-changing conditions. If data such as precipitation were based on non-stationary analyses, a single event hydrologic model could be used effectively. In order to analyze climate change scenarios, the precipitation, precipitation distribution during the storm, land use and other factors could be based on future projections. The new version of WinTR-20 has an option to import precipitation data from 5-minute through 24-hour duration and develop a rainfall distribution. These precipitation values could be based on future climate change scenarios.

Continuous simulation models may be useful for a different class of situations. Two of the models supported by the USDA are AGNPS (Agricultural Non-Point Source Pollution Model) (USDA-ARS, 2015) and SWAT (Soil and Water Assessment Tool) (USDA-ARS, 2015). These are designed for analysis of the hydrologic cycle in small, medium and large watersheds. This type of model would be useful in developing a time series of runoff volume into a reservoir to analyze its operation during a future climate change scenario. Also, the model could be used to estimate sediment delivery during a future climate change scenario. Sediment delivery could cause loss of flood storage, for example. If continuous simulation models are going to be used effectively to analyze impacts of climate change on the water cycle, a technically solid weather generator will be needed. A weather generator that will analyze non-stationary data with statistical values such as mean and standard deviation changing over time is needed. Since analysis of flood risk and water quantity is so dependent on data collection, there is a significant need to continue and even increase our collection of weather and water data.

Research Issues – support of hydrologic modeling of future climate scenarios

Being able to model climate change impacts on the hydrologic cycle involves being able to characterize non-stationary data in two principal ways. One is to be able to estimate probabilities of future occurrences of various climatic and hydrologic conditions at locations where they have been instrumented and measured in the past. These include, but are not limited to stream flow and precipitation at various durations. A useful product for use in a single-event hydrologic would be to estimate a 100-year 24-hour precipitation for the year 2050, for example.

The second is to develop statistics based on non-stationary data in order to simulate daily (and perhaps shorter duration) time series. Weather generators depend on estimates of mean, standard deviation, skew for precipitation at various durations, maximum and minimum daily temperature, wind speed and direction, dewpoint temperature, and solar radiation and other factors such as days between precipitation events in order to generate the time series. If these statistics were non-stationary, the resulting time series could be representative of a future weather scenario based on climate change. An example of this would be to use a weather generator to simulate a 50-year time series of precipitation, temperature, wind speed and direction, dewpoint temperature and solar radiation. Such a time series could be used in conjunction with a continuous hydrologic model to generate a time series of stream flows from which to analyze impacts of climate change.

A possible research approach would be to study output of general circulation models (GCM) for non-stationary trends and estimate how the mean, standard deviation, and skew change over time for the climatic characteristics such as maximum daily temperature or 24-hour precipitation. Perhaps, a moving average-type analysis could be done which evaluates mean, standard deviation, and skew for a 30-year moving window, for example. Another advantage of studying GCM results is that changing climate trends would be spatially distributed.

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Reducing Flood Risk by Use of Better Hydrologic and Hydraulic Data and Methods

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Introduction

President Barack Obama on Jan. 30, 2015, signed an Executive Order establishing a Federal Flood Risk Management Standard. The EO was an update and expansion of EO 11988 Floodplain Management with specific focus on community resilience in full consideration of adapting to a changing climate. Specifically the order directed federal agencies that are performing or funding an action in the flood hazard management with specific focus on community resilience in full consideration of adapting to a changing climate. It is contemplated that the flood hazard area be identified using an approach consistent with the following: "…the elevation and flood hazard area that result from using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science…." As an alternative the EO also allows for using either the 500-year standard or the 100-year standard that includes 2 feet of freeboard for standard federal actions or 3 feet of freeboard for federal "critical actions." The above stated goals and objectives involve use of engineering and mathematical analyses that will leverage the analyses conducted in the original design approach. Retrofit will likely be a key approach to accommodating changes in floodplain risk and impacts to existing flood control elements, particularly storage facilities and levees. Consequently, there may be significant cost savings and flood risk reduction by increased accuracy in the computations used in the engineering analyses. With a large portion of the flood control protection system being built using prior standards and analyses procedures, the ability to enhance existing systems by better use of computational methods and techniques may prove to be a significant flood risk reduction approach in itself. Extending the engineering and mathematical curriculum to include more computational and mathematical engineering techniques may be a worthwhile investment towards addressing the changes caused by the selected climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data and methods.

Discussion

In the last decade, new advances have been made in computational and mathematical methods in hydrology, hydraulics and related engineering works. For example, the U.S. Army Corps of Engineers has recently released a two-dimensional unsteady flow computer program extension of their well-known computer program HEC-RAS. This enhanced computer program enables the detailed analysis of steady and unsteady flow characteristics in small and large scale two-dimensional floodplain problems. Three-dimensional computer programs, commonly known as Computational Fluid Dynamics or "CFD" computer programs, are also becoming used more frequently as the computational costs decrease with advancements in inexpensive computer power. Generally, the CFD applications can be found in rapidly varied flow effect modeling such as spillways, dam breach analysis, turbulent flow situations and other highly computational problem simulations. These computational advances enable a significant increase in computational accuracy and the simulation of complex effects that were typically not considered in the original engineering design. Rather, more conservative designs were often adopted as a reasonable and safe engineering solution to flood risk problems. But with retrofit situations likely to become more of concern, the conservativeness built into the prior engineering designs may find additional use in providing increased flood risk reduction, assessed by more accurate mathematical computations and analyses made possible by use of the improved computational methods.

In order to better distribute such increased computational and mathematical methods to the practicing engineering and planning community, there is a need to enhance the inclusion of computational and mathematical engineering methods in the university curriculum. Although most civil engineering programs include at least one-dimensional hydrologic and hydraulic analysis tools in their curriculums, there may be a new need to augment such courses to include two- and three-dimensional computer computational methods such as CFD and two-dimensional HEC-RAS, among other computational tools. Also needed are courses detailing the more complex mathematics utilized in such enhanced computational tools.

A review of the university curriculums indicates programs of computational and mathematical engineering exist, but such programs of study are not yet commonplace throughout the nation. There are "themes" such as "computational geosciences" that typically involve several courses of more advanced mathematical areas of study that transcend the typical level of mathematical study for many engineering programs. Again, such inclusion of more advanced mathematical coursework is not commonplace.

Recommendation

It is our recommendation that engineering curriculums be reviewed in light of the available computational and mathematical tools and knowledge base, and that focus be made, if possible, in enhancing such curriculums to address world level problems such as the climate change impacts. For example, at the Department of Civil and Mechanical Engineering at the United States Military Academy at West Point, New York, an infrastructure engineering course is as much about "policy" as it is about "technical engineering." As such, university curriculums that may consider adding such a course may consider trying to include other departments such that an inter-disciplinary learning environment can better develop. At West Point, there has been good success with the infrastructure engineering course, including non-engineering majors, especially in the area of policy discussions. Other possible programs of study may include mathematical techniques for modeling and simulation as well as methods for organizing, exploring, visualizing and analyzing very large data sets. This new curriculum leverages the power of computation in addressing the most important challenges in engineering.

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense or the U.S. government.

The Need for Clear and Accurate Language when Communicating about Flood Risk and Changing Climate

Michael Powell, Environmental Program Manager, Delaware Department of Natural Resources and Environmental Control and Co-chair ASFPM Regulations Committee

Floodplain managers have long argued that the effective communication of flood risk should include information about anticipated future conditions. This is especially important in areas where flood risks are known to be increasing, such as in watersheds where land cover is changing, when floodplain storage is being reduced through encroachment, and along eroding shorelines. As climate change and flood risk management become increasingly intertwined, communicating risk becomes more challenging, and the potential to confuse rather than educate becomes greater.

The way we characterize current flood risk is confusing enough. The term "100 year flood" is confusing because it implies that such events only happen once a century, when in fact they can happen more or less frequently. Even flood managers' preferred term of "1 percent annual chance flood" is problematic in areas faced with increased runoff or sea level rise as today's 1 percent annual chance flood height could easily have a 10 percent annual chance of occurrence well within the useful lifetime of a building. As modelled flood risk and changing climate are blended together into an overall communication of risk, already complicated terminology and messaging will become even more so.

The term climate change itself can be misleading, and frustrate attempts to manage flood risk. Building first floor freeboard (above the 1 percent flood level) into new development has been widely recognized as a critical way to reduce risk. There are many reasonably easy-to-communicate reasons why freeboard is already critical under current conditions. Emphasizing climate change as a justification for freeboard can imply that freeboard may become necessary in the future if conditions change or worsen. This perception is exacerbated by messaging in the popular media, governmental agencies and academic research using terminology such as "climate change will occur" as if the process is not already occurring.

Communication about climate change as a future risk can be detrimental to flood risk management if it displaces current need as the primary justification. For example, Delaware Senate Bill 64 formed a committee aimed at identifying higher regulatory standards to recommend to communities (which resulted in nearly every community in Delaware adopting 18 inches of freeboard voluntarily). In debating these higher standards, the committee was told by community officials to minimize references to climate change, because it would lessen the likelihood of local adoption in communities for whom expensive flood insurance and minimizing the adverse impacts to others of unwise development were more compelling justifications for higher standards.

Education and outreach are critical components of risk management. Improvements in modeling and other tools allow us to more accurately forecast risk will be less impactful if we do not also improve our ability to communicate and educate.

Research