Stormwater Institute

Rainfall to Results

THE FUTURE OF STORMWATER

2023

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The Water Environment Federation (WEF) is a not-for-profit technical and educational organization of 30,000 individual members and 75 affiliated Member Associations representing water quality professionals around the world. Since 1928, WEF and its members have protected public health and the environment. As a global water sector leader, our mission is to connect water professionals; enrich the expertise of water professionals; increase the awareness of the impact and value of water; and provide a platform for water sector innovation. To learn more, visit www.wef.org.

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EXECUTIVE SUMMARY

BACKGROUND

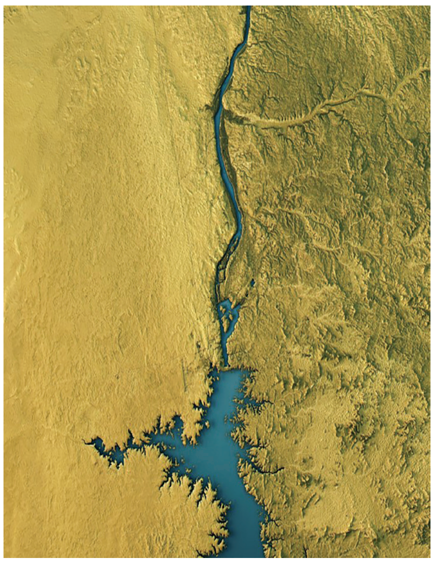
Stormwater presents several unique challenges when compared to its more mature water sector counterparts of drinking water and wastewater. The dispersed nature of stormwater makes responsibility for its treatment and control hard to assign. Since the promulgation of the Phase I and Phase II municipal separate storm sewer systems (MS4) regulation, communities have been faced with the task of managing stormwater flows based on early studies highlighting the potentially significant water quality effects of urban runoff.

Initial techniques to provide stormwater management focused on traditional "gray" infrastructure, but the evolution of stormwater has been heading in the direction of nature-based, or "green", infrastructure. Similarly, the passive practices used in the first generation of stormwater infrastructure investments is starting to give way to "smart" stormwater infrastructure that uses automated controls to enhance the performance of stormwater facilities.

In addition, the view of urban runoff as being a burden has morphed into a perspective that stormwater flows are valued as significant water resources to be captured and used in strategic ways. Lastly, the rise of emerging contaminants, such as microplastics and per- and polyfluoroalkyl substances , highlights the need for true source control in stormwater programs.

VISIONING FOR STORMWATER

In response to these challenges, the Water Environment Federation (WEF) has identified seven areas within the stormwater sector to drive change with a vision for each area:



WORK AT THE WATERSHED SCALE

All communities should complete watershed-scale assessments of water resource needs and challenges. Management of stormwater quality and quantity should be addressed within an integrated planning framework and aligned with larger watershed priorities, including aging stormwater and wastewater infrastructure, changing population and rainfall patterns, and competing funding demands. Communities should understand what is necessary to overcome these challenges and should have the technical, political/institutional, regulatory, and financial capacity to sustain stormwater management.

TRANSFORM STORMWATER GOVERNANCE

Governance frameworks for stormwater management will be more clear, specific, and measurable. Both water quality and water quantity will be considered. Sufficient staff and program management capacity at the state agencies with MS4 permitting authority will increase the likelihood of effective local MS4 permitting and stormwater management programs. Stormwater stakeholders, including stormwater utilities, MS4s, and national organizations, will have active programs to ensure that their voices are heard in Congress in a timely manner.

SUPPORT INNOVATION AND BEST PRACTICES

Stormwater best practices include digital solutions such as the Internet of Things (IoT), artificial intelligence, and digital twins to ensure that innovation is integrated with changing policies. Technology and business models are implemented to advance achievement of One Water, Net Zero Runoff, and Circularity. Continual improvement of stormwater prevention, source control systems, and methods to analyze and value the benefits support stormwater as a valuable resource.

MANAGE AND MAINTAIN STORMWATER ASSETS

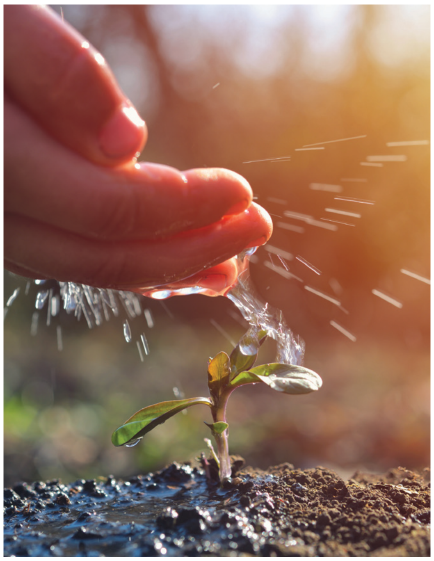
Stormwater systems will be maintained through robust asset management programs and supported by innovative information technology. An integrated planning approach will use automated data capture and analyses and predictive management to greatly improve capital planning and budgeting. Further, a multidisciplinary workforce will support the proper design; installation; inspection; and operations and maintenance, repair, and timely replacement of stormwater infrastructure.

CONTINUE TO CLOSE THE FUNDING GAP

Communities and utilities will have a dedicated stormwater funding source in place to leverage funding from federal and state sources. Stormwater management efforts will be aligned with broader community goals to have access to innovative market-based financing opportunities. Elected officials will support the investments needed to meet sustainable and resilient stormwater management objectives.

ENGAGE THE COMMUNITY

Management of stormwater will consider the direct and indirect effects on communities in which it is implemented. The public will have the opportunity to provide input on their desires and concerns as stormwater projects are developed. Solutions will help to address long-standing level of service issues and environmental justice, particularly in historically disadvantaged communities.



PLAN FOR STORMWATER RESILIENCE

Communities will have a strong understanding of the effect of climate change on stormwater infrastructure from changing precipitation trends, including extreme rainfall, drought, and snowmelt patterns. Communities will have the tools and funding to achieve greater resilience against these events through heightened awareness and advocacy of the integral role that stormwater management systems have in the larger resilience planning framework. The latest climate science will be integrated to proactive stormwater resilience plans and stormwater design, leveraging the use of advanced sensors, warning networks, and hydrologic and hydraulic modeling.

MOVING FORWARD

The first version of *Rainfall to Results: The Future of Stormwater* (WEF Stormwater Institute, 2015) provided a roadmap to catalyze change for the Water Environment Federation. This updated version provides an updated view of the stormwater sector, with specific actions within each of the seven critical areas identified in this report.

INTRODUCTION

Rainfall to Results: The Future of Stormwater was first published by the Water Environment Federation (WEF) Stormwater Institute in 2015. Its origin was based on a discussion between stormwater sector leaders who captured the trends and conditions of stormwater at the time. The Stormwater Institute's goal was and is to provide a window of opportunities and pathways toward a sustainable and financially sound stormwater sector. Since its publication, the WEF Stormwater Institute has used this document as a guide to drive action in the sector.

This is the first revision of the original document, reflecting both progress and emerging challenges in the last 5 years, as well as changes in technology, regulation, climate, and society. The document remains organized around "objectives for stormwater success" in support of the vision of sustainable clean water and healthy watersheds. In this edition, the original six objectives are retained, with an additional section focused on resilience:

- Work at the Watershed Scale
- Transform Stormwater Governance
- Support Innovation and Best Practices
- Manage and Maintain Stormwater Assets
- Continue to Close the Funding Gap
- Engage the Community
- Plan for Stormwater Resilience

This report presents a vision for the future and seven overarching objectives that will help achieve this vision. The vision conveyed here is formed not through the consensus of the discussion participants, but through their shared input as described by WEF.

Each chapter begins with a forward-looking statement describing the ideal future of the stormwater sector. The chapters describe how the current state of stormwater affects these seven overarching objectives. Each vision is supported by a series of concrete action items that build toward the overarching objectives and, ultimately, the vision—taking rainfall challenges and creating opportunities for results.

UNDERSTANDING STORMWATER

Ensuring thoughtful progress toward sustainably managed stormwater requires understanding why stormwater matters, how it differs from other water quality issues, what the sector has accomplished already (Figure 1), and what the path forward can hold.

In short, freshwater delivered through precipitation should be valued as a resource and an opportunity. Through holistic, watershed-based approaches, communities can use stormwater infrastruc-

Figure 1. Stormwater Regulatory Drivers and Milestones in the United States.

ture investments as a catalyst to improve not only water quality but also the vibrancy and resiliency of urban areas.

WHY STORMWATER MATTERS

Stormwater is the only growing source of water pollution in many watersheds throughout North America. More than half the world's population lives in cities, and urbanization is increasing. The combination of urbanization and climate change exacerbates stormwater pollution.

While some undisturbed landscapes retain, infiltrate, and delay the release of stormwater runoff to streams and rivers, impervious urban areas decrease groundwater recharge and increase stormwater runoff. Issues of both water quality and quantity are further intensified by a changing climate that threatens both greater droughts and floods.

To illustrate this point, the U.S. Environmental Protection Agency (U.S. EPA) has stated that a natural forested watershed under average soil conditions infiltrates about 50% of the precipitation it receives, and another 40% is taken up by plants. In urban watersheds, however, as much as 55% of precipitation can become runoff (U.S. EPA, 2009).

Roadways, rooftops, parking lots, and other impervious surfaces cover more than 5.7% of the coterminous United States, according to the National Land Cover Database (2019). These paved surfaces could cover an area nearly the size of Ohio.

This much cover means that even small storms generate a large amount of runoff. For example, a storm that drops 25 mm (1 in.) of rain on impervious area the size of a single standard soccer field (105 m x 68 m or 115 yd x 74 yd) would generate 180 000 L (50 000 gal) of runoff.

Just as problematic as the volume of water, however, are the pollutants stormwater collects as it flows across the urban landscape. Urban surfaces are littered with sediments, plastics, pathogens, nutrients, metals, and trash. When runoff carries these pollutants into streams and rivers, they can discourage recreational use, degrade aquatic habitats, and contaminate water supplies.

To put this issue in the context of environmental effects, in 1970, 85% of water quality impairments were associated with point-source pollution. The remaining 15% came from nonpoint sources such as agricultural and urban stormwater. Today, after significant advancements in wastewater treatment, these values have flipped—85% of impairments now stem from nonpoint and urban stormwater discharges (Brown, 2017).

WHAT MAKES STORMWATER UNIQUE

Stormwater presents several unique challenges when compared to its more mature water sector counterparts of drinking water and wastewater. The root of many of these problems is that stormwater can sometimes behave in a similar manner as both traditional point sources, with discrete conveyances, and nonpoint sources that can have more dispersed flows. Point sources have a discrete point of origin—usually the end of pipe—where measurements can be made, and responsibility assigned. Nonpoint sources lack a discrete point of origin or responsibility.

Some runoff enters waterways directly, but much of it also collects in underground pipes or sewers—some dedicated to stormwater and some combined with wastewater lines. Separate storm sewers typically deliver stormwater to waterways without treatment, while combined sewers convey flow to treatment facilities. The Clean Water Act governs some municipal stormwater through the National Pollutant Discharge Elimination System (NPDES) program, which regulates point-source pollution.

The dispersed nature of stormwater makes responsibility for its treatment and control hard to assign. Stormwater discharge, volume, and quality are intimately tied to land use. Human actions—from industrial processing and large-scale construction down to mowing a lawn or picking up after pets—all affect stormwater quality.

HOW STORMWATER HAS EVOLVED

In 1978, U.S.EPA launched the Nationwide Urban Runoff Program, which found runoff contained much more pollution than expected. The program also determined that the first 13 mm (0.5 in.) of runoff—known as the "first flush"—carried most of these pollutants. This report helped shift the paradigm from drainage to capture and treatment (U.S. EPA, 1983).

Informed by the Nationwide Urban Runoff Program, the Clean Water Act Amendments of 1987 initiated U.S. EPA's first stormwater regulations in 1990 as part of the NPDES program. This program already regulated point sources—water resource recovery facilities (WRRFs) and industrial facilities, for example. The change in 1990 expanded the program to cover certain MS4s.

Phase I of this program focused on controlling stormwater discharges from medium to large MS4s with populations greater than 100,000 as well as stormwater discharges from industrial and construction sites larger than 0.02 km^2 (2 ha or 5 ac). Nearly 10 years later, U.S. EPA initiated Phase II, which expanded regulations to smaller MS4s, construction sites, and industrial facilities. The launch of the Phase II program expanded the number of regulated MS4 communities from 750 to nearly 7500.

The Clean Water Act's Total Maximum Daily Load (TMDL) program also has become a significant regulatory driver for stormwater management efforts. A TMDL value is the maximum amount of a pollutant, such as sediment or nutrients, that a water body can receive and still meet water quality goals.

The Chesapeake Bay TMDL is the largest in the United States and a significant catalyst of stormwater efforts in the Northeast (Figure 2). Established in 2010, it assigns Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia targets to achieve specific pollutant reductions in nitrogen, phosphorus, and sediment by 2025. While the wastewater sector met the TMDL targets early, stormwater still has significant opportunities for load reduction.

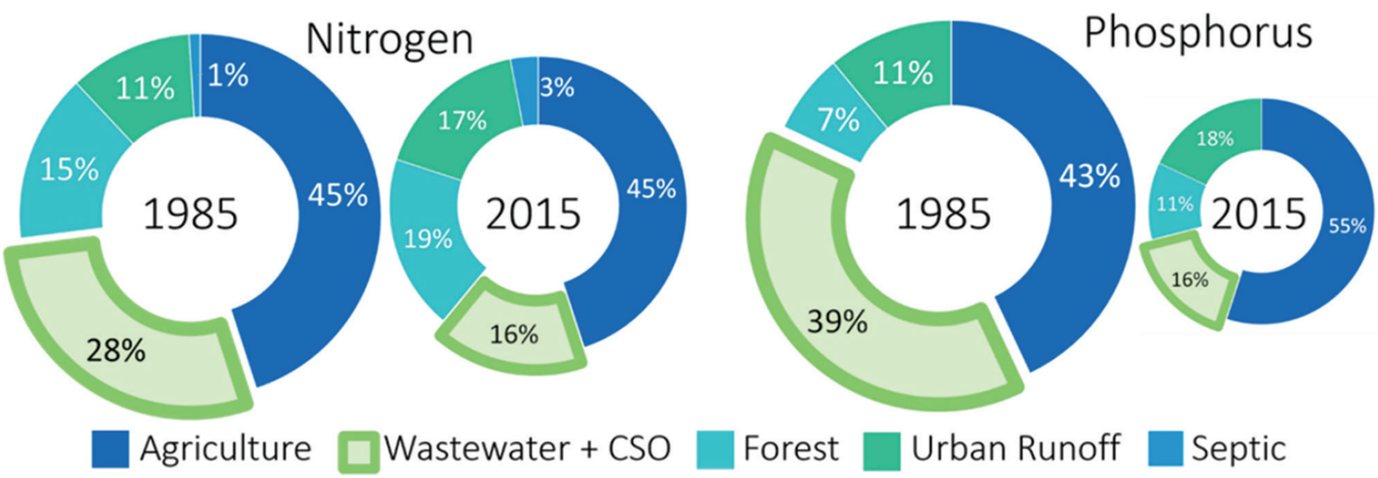


Figure 2. Chesapeake Bay Watershed Loads (U.S. EPA, 2016a).

Combined sewer overflows (CSOs) are another important stormwater management driver. A popular approach in the mid- to-late 19th century was constructing sewer systems that combine both stormwater and wastewater into a single pipe. Today, many communities struggle with the legacy design of these sewers, which include overflow points to prevent backup and flooding during storms. Currently, nearly 800 U.S. cities face CSO issues, and many are spending billions of dollars under legally binding consent decrees to reduce CSO frequency and volume.

A popular approach to controlling CSOs is to build underground tunnels that store wet-weather flows until they can be directed to a WRRF for treatment. These large-diameter tunnels can be miles long and cost billions of dollars to construct.

Nationwide, stormwater programs have made significant progress to address the effects of runoff. However, these efforts have been outpaced by urbanization.

The reality of the situation is that the current approach to stormwater management has not yielded significant water quality improvements—a fact recognized in the report titled *Urban Stormwater Management in the United States* (National Research Council, 2009). This report by the National Research Council of the National Academy of Sciences recommends a focus on retention-based programs using low-impact development (LID).

Low-impact development attempts to mimic natural hydrology and is best suited for new, suburban development. The term *green infrastructure* typically describes practices used in dense urban landscapes. In 2019, Congress enacted the Water Infrastructure Improvement Act (WIIA), which defines green infrastructure as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters". The purpose of both LID and green infrastructure is to provide treatment by retaining stormwater on site—especially for small storms that otherwise would transport "first flush" contaminants.

These practices use vegetation, soils, and natural processes to infiltrate water and make it available to plants. Green infrastructure most commonly encompasses site-scale practices, such as permeable pavement, bioretention, green roofs, and rainwater harvesting. However, green infrastructure can be used at a watershed scale in the form of enhanced riparian floodplain zones and wetlands that help to manage storm effects.

Though LID has been employed since the 1990s, U.S. EPA and states are increasingly encouraging LID within stormwater permits and as CSO control measures. Currently, stormwater permits for 17 states and the District of Columbia use retention-based performance standards for new development and redevelopment (U.S. EPA, 2011).

WEF'S EFFECT ON THE STORMWATER SECTOR

Since the initial 2015 publication of *Rainfall to Results: The Future of Stormwater*, the WEF Stormwater Institute has been working to better understand the state of stormwater to advocate for its needs in a more strategic manner.

As a result, the National Municipal Separate Storm Sewer System (MS4) Needs Assessment Survey program was initially launched in 2018. The survey occurs on a biannual basis with its third iteration in progress in 2022. The goal of the survey is to better understand MS4 program challenges, identify the information and resource needs of MS4 permittees, and approximate current funding levels and estimated funding needs in the MS4 sector. Through this report, WEF was able to identify the key drivers for investment, key sector challenges, and key information needed (Table 1).

Even though this data is not a full representation of all the MS4 utilities, it provides a snapshot in time of sector evolution and needs, a one-of-a-kind data set.

With this data and advocacy with other institutions, the American Society of Civil Engineers' 2021 Infrastructure Report Card included an independent category for stormwater for the first time (ACSE, 2021). This represents a large milestone in the sector as, since its inception, stormwater programs have suffered from the lack of a defined plan and clear solutions and are considered part of wastewater.

WHAT'S NEXT FOR STORMWATER?

Stormwater management will continue to bolster the advancement of sustainable practices, funds, resilience, and community buy-in across the sector. The WEF Stormwater Institute will continue to address non-point-source and point-source pollution issues, as both are integral to improving U.S. water quality and quantity issues as part of an integrated and holistic approach to "One Water."

In the future, stormwater runoff will be managed through integrated planning, asset management, watershed-based approaches, source control, remote sensing to better predict and understand changing rain patterns, application of technology to monitor water quality and quantity key performance indicators, and co-design between green and gray infrastructure to integrate funding needs, increasing community acceptance, and improving quality of life. The objectives for stormwater success outlined in this document provide an overview of futuristic perspectives as well as actions that can be taken to achieve the objectives for stormwater success.

Table 1. National Municipal Separate Storm Sewer System Needs Assessment Survey Results (WEF Stormwater Institute, 2021b).

	2018 Survey Results	2020 Survey Results
Key drivers for investment	Regulatory/TMDL compliance, local flooding, water quality, and habitat restoration	Aging infrastructure, water quality, land development
Key challenges	Funding, aging infrastructure, increasing regulations	Funding, aging infrastructure, increasing regulations
Key information needed	Funding and financing, GI and innovative best practices	Funding and finance, asset management, watershed-based stormwater planning

CHAPTER 1
A VISION FOR THE FUTURE OF STORMWATER

All stormwater will be considered a resource and managed through an optimized mix of affordable and sustainable green, gray, and natural infrastructure. Pollutant source control and management of runoff peak rate and volumes will be pursued aggressively as a complement to traditional stormwater control measures (SCMs). Stormwater is a valuable resource that will be used and reused in a manner that is most economical for the public but also meets the needs of the environment. Stormwater in urban and suburban areas will support habitats in creeks, streams, and other freshwater bodies, while also supplying some portion of domestic and agricultural demand.

A primary barrier to using stormwater for domestic and agricultural purposes is that it is expensive to store (Taylor et al., 2011). There is little surplus land in urban and suburban areas to store stormwater for later use and constructing storage in agricultural areas is expensive. The cost of storage for stormwater generally exceeds the cost of water from other currently developed sources (such as local rivers or groundwater). However, it is difficult to place a cost on the consequences of withdrawing water from lakes, rivers, and streams, or from groundwater sources, to achieve a fair accounting of the cost of water from all available sources. In short, the cost of water is currently subsidized because we do not adequately account for long-term effects on the environment. An objective perspective would be obtained from assessing the cost of water using a triple bottom line analysis procedure. Water allocation in the United States, particularly in the west, is based on a system of water rights—in many cases a property right that allows the holder to use or divert water from its source. This system does not account for the costs of the diversion on the local ecosystem and does not place a cost on the value of water that is diverted. The cost of water in the United States largely reflects the amount required to operate the treatment and distribution system.

In *Water Centric Sustainable Communities: Planning, Retrofitting, and Building the Next Urban Environment* (Novotny et al., 2010), the authors note that the idea of "wastewater" becomes obsolete in an efficient use context. They further explain that stormwater must play a dual role of ensuring ecological flow for rivers and downstream uses while also supplementing domestic supply. Novotny et al. postulate that the "City of the Future" will use and reuse water locally. This primarily means recovering water from WRRFs for direct potable use and/or purple pipe recycled water reuse. Such a system would also reasonably allow for incorporating a portion of stormwater from urban and suburban areas into the treatment system headworks. This scheme could not only make urban and suburban areas more water sustainable; it could also help solve the hydrologic balance problem from leaking pipes, landscape irrigation, and increased runoff from impervious surfaces.

An example of a water-sustainable city-state is Singapore. Novotny et al. (2010) describe Singapore as having diligently pursued water self-sufficiency over the past several decades. A single Public Utilities Board manages the entire water cycle for Singapore, including stormwater management and desalination as well as community education. The entire city/country is served by a sewer system, and about 30% of wastewater is used to reduce potable water demand. In the United States, the City of San Diego is currently working on a similar system, dubbed the Pure Water Program, scheduled to provide about 40% of San Diego's potable water supply by 2035 (see the City of San Diego Pure Water Program Case Study at the end of this chapter).

Using stormwater to supplement wastewater reclamation makes sense because the membrane technologies used are effective at removing highly soluble pollutants that are found in stormwater runoff. Using membrane technology for treatment of stormwater effectively mitigates the potential for soluble chemicals from stormwater runoff to contaminate the domestic supply, a safeguard that is currently much less certain.

In the City of the Future, urban and suburban stormwater becomes a supplementary source for a sustainable water system, effectively achieving circularity in the water supply and preserving a portion of stormwater runoff for natural uses. The quantities of stormwater captured for urban use and reuse will vary with location and climatic factors, subject to the development of a comprehensive urban water master plan.

Runoff from urban, suburban, and agricultural sources that is not used for domestic, commercial, or industrial purposes must still meet the water quality goals of the Clean Water Act and support local surface waters. Providing good quality water in waters of the United States will be accomplished most efficiently using source control techniques, which will include volume reduction and the maintenance of natural stream bed material load. There are three primary methods to implement source control: eliminating contact between the pollutant and rainfall/runoff, substituting a different compound that does not pollute, or eliminating the use of a chemical or compound that causes pollution.

ELIMINATING CONTACT BETWEEN POLLUTANTS AND RAINFALL/RUNOFF

The concept of eliminating the contact of potential pollutants with runoff or runoff with potential pollutants is a best management practice (BMP) that has been in use since the inception of the Clean Water Act. It is a highly effective approach, but difficult to implement in practice due to the sheer number of potential sources of pollution and the ubiquitous nature of rainfall. Source control of this type has traditionally focused on industry, through covering stored chemical stockpiles and industrial processes that may cause pollution. Unfortunately, industrial and even commercial sources of pollution are a small fraction of the total. For example, zinc is commonly used to treat steel to inhibit rusting. It is found on fencing, guard rails, roofing, and siding material for buildings. Zinc coatings are sacrificial, and zinc in both dissolved and particulate form is commonly found in runoff. An example of source control in which a product was altered is the copper-free brake initiative to remove copper and other constituents in certain brake pads. U.S. EPA, the Environmental Council of the States (ECOS), and the automotive industry signed an agreement to reduce the use of copper and other materials in motor vehicle brake pads (U.S. EPA, 2021b). In short, the elimination of contact between pollutants and stormwater is an important tool, but not a panacea.

SUBSTITUTING PRODUCTS

Substituting a non-polluting product for one that pollutes is also an effective approach to improving stormwater quality. The primary challenge is finding a substitute product that meets the functional requirements of the original compound without causing pollution beyond the point of use. Pesticides are a good example of implementing this type of source control. The pesticide chlorpyrifos was commonly found in surface waters downstream of suburban, urban, and agricultural areas and was implicated in causing acute toxicity of aquatic life in waterways. Exposure to chlorpyrifos during pregnancy was also shown to cause harm to children. Consequently, U.S. EPA banned most home uses of the pesticide in 2001, and chlorpyrifos sales has been banned in California as of 2019. Substitutes for chlorpyrifos include various types of pyrethroids, but these too have environmental consequences.

ELIMINATING THE USE OF A CHEMICAL OR COMPOUND

Eliminating the use of a chemical or compound that is causing pollution is a direct and efficient way to address the problem but can be difficult to implement if a suitable non-polluting replacement is not readily available. An example of this type of source control is the elimination of methyl tert-butyl ether (MTBE), a flammable liquid used as an additive to gasoline to reduce emissions via oxygenation. Unfortunately, MTBE has been discovered in groundwater supplies, largely from leaking underground storage tanks. The higher water solubility and persistence of MTBE allowed it to move through an aquifer matrix with greater efficiency than most other components of gasoline. Other approaches to oxygenating gasoline were used instead of MTBE once it was banned.

SUMMARY

Use of stormwater in urban areas is difficult because the cost to seasonally store, treat, and distribute urban stormwater is greater than what can be purchased from existing public potable systems. To overcome the cost problem of using urban stormwater, we must quantify and understand the true cost of water in the United States. Environmental, energy, and pollution costs are largely unaccounted for at this time, including all costs of water diversion. Sustainable urban water systems—circular systems—are perhaps the most feasible choice for the future.

CASE STUDY

CITY OF SAN DIEGO PURE WATER PROGRAM

The future of stewardship for water resources includes direct potable reuse (DPR). DPR has many advantages, and chief among these is the creation of a sustainable potable water supply. Urban stormwater has a role to play in DPR. Since some potable water is lost during treatment, distribution, and end uses (like irrigation), a DPR system can at most supply about half of the demand. Urban stormwater can supplement the source water for the DPR system, reducing the demand on local lakes, creeks, and groundwater.

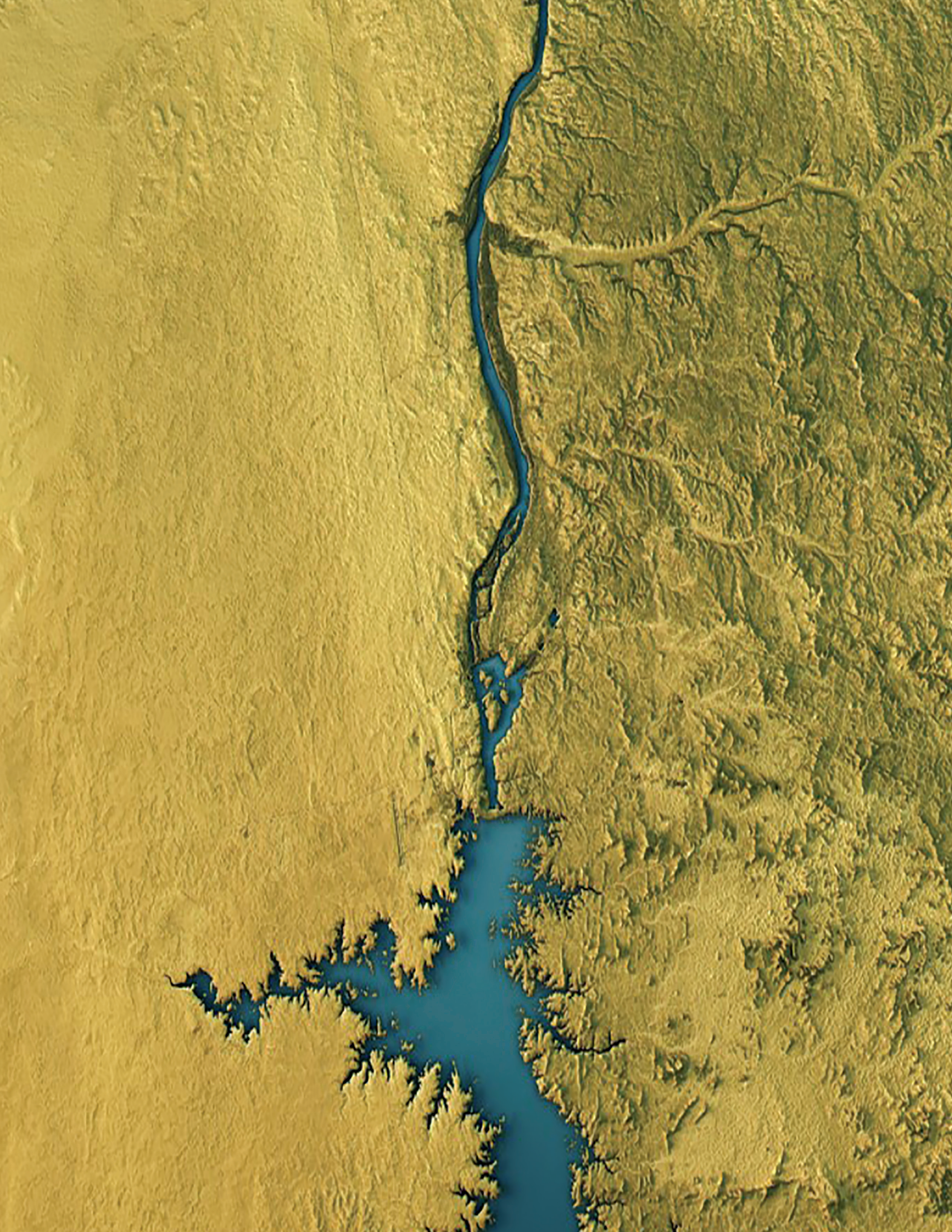
The City of San Diego has embarked on one of the largest U.S. DPR programs to date. Pure Water San Diego will supply about 40% of the domestic supply by 2035, using the current Bay Delta and Colorado River sources for the remaining supply. The first phase of this project is projected to cost about $1.5 billion and provide about 114 ML/d (30 mgd) of water to augment local domestic reservoirs. Phase II of the program will provide an additional 200 ML/d (53 mgd); costs for Phase II have not yet been finalized.

San Diego has relatively low rainfall (approximately 25.4 cm [10 in.] annually along the coast) and virtually no groundwater supplies suitable for domestic use, making the area dependent on imported water from northern California and the Colorado River. The city is in the process of retrofitting its stormwater system to improve the quality of urban runoff and faces major capital costs and technical challenges to integrate green infrastructure in a dispersed collection system.

An option the city is evaluating is augmenting the Pure Water system supply with urban runoff. This approach potentially has several technical and practical advantages for San Diego, among them:

- The marginal cost to divert stormwater to the Pure Water system headworks may not be substantially different than retrofitting green infrastructure to reduce stormwater runoff.
- Diverting urban stormwater to the Pure Water system can reduce the pollutant load to waters of the United States and assist the city in meeting its TMDL requirements.
- Urban stormwater requires less treatment as compared to domestic wastewater for potable use.
- Diverting urban stormwater to the Pure Water system could help reduce runoff volumes to pre-development levels, a requirement of the city's MS4 NPDES/Waste Discharge Requirements Permit.
- Use of urban stormwater for a beneficial purpose is a goal of the state's Water Resources Control Board and will reduce demand on water resources in northern California and the Colorado River.

Using urban stormwater to augment DPR supply supports the One Water concept and the principle of water circularity. The single-use principle for water is no longer sustainable, particularly in the arid southwestern United States. Reusing water within a closed-loop urban system is sustainable and provides additional supply for other uses such as agriculture and the environment. San Diego has taken an important step toward water sustainability and circularity. Other urban areas, regardless of their location or current water supply conditions, should begin planning to apply One Water and circularity principles to their domestic and stormwater systems.



CHAPTER 2
WORK AT THE WATERSHED SCALE

All communities will complete watershed-scale assessments of water resources needs and challenges. Management of stormwater quality and quantity will be addressed within an integrated planning framework and aligned with larger watershed priorities addressing aging stormwater and wastewater infrastructure, changing population and rainfall patterns, and competing funding demands. Communities will understand what is necessary to overcome these challenges and will have the technical, political/institutional, regulatory, and financial capacity to sustain stormwater management.

Working at a watershed scale is critical to achieving the vision for sustainable stormwater management. Water is not bound by local, state, or even national political boundaries. Rather, it flows based on watershed boundaries following topography, flowing downstream to one place. Because of this, pollution, associated water quality impairments, and flooding challenges transcend political boundaries, which makes watershed management problematic and fraught with political issues. Demands on water resources are growing, so effective management of stormwater runoff at the watershed scale is mandatory for the protection and restoration of our nation's water resources.

Effective stormwater solutions must address pollution sources within a watershed, including urban, suburban, and exurban areas, and associated land uses such as residential, commercial, industrial, and transportation. Ideally, pollutant loadings from agricultural areas will be addressed within the watershed context. However, lack of regulation governing runoff from agricultural lands currently limits the sector to voluntary and incentive-based approaches.

When communities and stakeholders cooperate, managing stormwater at a watershed scale can create opportunities to prevent pollution via source control and to share resources to achieve greater pollutant reductions than either party can do alone. In addition, communities can share the burden of pollutant load reductions via market-based approaches such as pollutant load/water quality trading. For example, if a community cannot meet its required pollutant load reduction, it may be able to pay a fee directly to a regulatory agency or purchase pollutant loading "credits" from another community. These pollutant loading credits can be traded between various point and nonpoint sources. The trading often results in more cost-effective solutions because it encourages pollutant load reductions from more economically feasible sources and locations. For more information and resources, visit U.S. EPA's *Water Quality Trading Toolkit for Permit Writers* (https://www.epa.gov/sites/default/files/2016-04/documents/wqtradingtoolkit_app_a_case_studies.pdf).

The benefits of working at a watershed scale extend beyond water quality to address water quantity/flooding issues. For example, flood management systems can be optimized based on a community's location in the watershed (upstream vs. downstream). Additional benefits are gained through an integrated planning framework that includes stakeholder input on watershed priorities, including stormwater and wastewater. Working together also enables communities to take further advantage of the economic, social, and environmental (the triple bottom line) benefits of stormwater and water resources management efforts. Aligning such priorities as aging infrastructure, transportation improvements, economic development, wastewater treatment, and open space planning with stormwater management objectives (water quality and water quantity/flooding) at the watershed scale can deliver the greatest benefit at the lowest cost. In addition, expanding the approach within an integrated planning framework and including triple bottom line prioritization can also result in economies of scale with significant cost savings and ensure that the most critical water resources are protected.

Working at a watershed scale can take many different forms and occur on various scales ranging from a small drainage area within a jurisdiction to a multi-state regional area such as the Chesapeake Bay, as illustrated in Figure 3. These efforts can encompass just a few or many municipalities. Today, NPDES permits serve as a link among some communities in the same watershed because their permits include requirements associated with a goal at the watershed level. Through the NPDES program, regulatory agencies issuing "watershed-based" permits are implementing integrated planning, adaptive management, and other innovative approaches to improve water quality, implement effective TMDL, facilitate pollutant load/water quality trading, and encourage stakeholder involvement. Other communities are voluntarily participating in watershed planning as a strategy to achieve water resource goals even though they are not required by an MS4 or other permit requirement. These strategies bring together the actions, participants, and resources needed to implement the plan.

However, experience shows that working at a watershed scale in either capacity can present numerous challenges, including the additional coordination and negotiation of funding responsibilities. Encouraging innovation and flexibility is critical in structuring successful watershed-scale governance arrangements. Working at the watershed scale should not infringe on cities' land use authority or completely forgo their regulatory autonomy. Planning schedules, objectives, and financial constraints also should align among all participants, and entities must trust each other and cooperate.

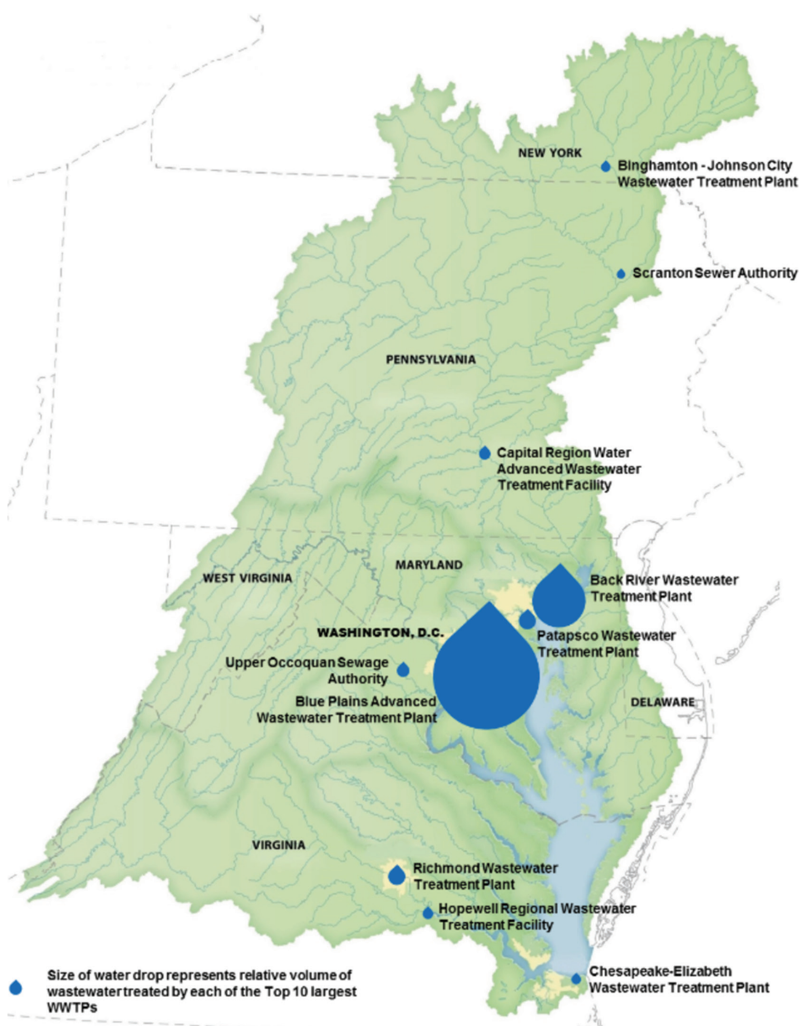


Figure 3. Chesapeake Bay Watershed (U.S. EPA, 2016a).

RECOMMENDED ACTIONS

ACTION 2.1

Better connect stormwater needs and investments to other community priorities and long-range planning efforts across jurisdictions within watersheds

Runoff quality and volume are intimately tied to land use. Therefore, it is essential that stormwater management is coordinated across multiple agencies and departments within a watershed, from transportation to parks departments. Many opportunities exist to integrate various water resources objectives including source control, treatment, reuse, and recreation. Efforts should be made to better align scheduling and planning processes among departments and agencies throughout watersheds. Ideally, planning efforts should be integrated, or at least coordinated, so that projects can be conceived and designed to serve multiple community needs and optimize cost-effectiveness and benefits.

Working together in this manner aligns with the One Water concept and requires building local capacity to support regional and cross-departmental planning and operations as well as balancing regulatory enforcement with economic and social incentives. Cross-departmental planning at the watershed scale will help communities garner stronger support for needed stormwater management investments, optimize overall community value, and maintain affordability.

ACTION 2.2

Understand and incorporate the co-benefits of stormwater control measures into community decision-making at the watershed scale

Stormwater management infrastructure has much to offer to community redevelopment, quality of life, and climate resiliency efforts. Stormwater controls reduce flooding and improve water quality, thereby protecting drinking water supplies, wildlife habitats, commercial industries, and recreational areas. These benefits have monetary value, and many benefits can be quantified and monetized. Improving water quality can cut costs for drinking water treatment and enhance commercial and recreational activities—such as fishing and boating—that make significant economic contributions. Examples of additional water quality benefits include avoidance of beach closures and fish kills. Flood reduction benefits include protecting people, property, businesses, bridges/roadways, and streambanks as well as avoiding the significant costs of flood damage repair and insurance. Managing stormwater also presents unique opportunities to create landscapes that engage the public. For instance, municipalities have created stormwater treatment wetlands with walkways so that visitors can appreciate nature while reading signs that educate about the value of water. In addition, studies have shown that stormwater wetlands in residential areas provide therapeutic benefits for the elderly, terminally ill, and/or veterans suffering from post-traumatic stress disorder (Sutton-Grier et al., 2019).

Communities have used stormwater controls in urban renewal projects that repurpose underutilized spaces and connect places. Research from Philadelphia shows that green infrastructure may even play a role in reducing crime (Kondo et al., 2015).

By creating more vibrant spaces, communities can increase property values, improve human health, and address equity and environmental justice issues. Installation and maintenance of stormwater controls also presents a significant opportunity to increase entry-level green jobs. Yet these co-benefits often are not incorporated into community decision-making. To support this outcome, community stakeholders need easy-to-access, easy-to-articulate information on common co-benefits of stormwater controls.

ACTION 2.3

Encourage the application of an integrated planning framework to prioritize competing clean water infrastructure investment needs and select the most beneficial approaches

In response to ongoing and emerging challenges facing the regulated community in addressing the requirements of the Clean Water Act, U.S. EPA developed the 2012 Integrated Municipal Stormwater and Wastewater Planning Approach Framework. The framework provides a tool to assess and prioritize investments in stormwater infrastructure, wastewater treatment facilities, and sewer systems and includes six elements (U.S. EPA, 2012a). In 2019, Congress enacted the WIIA directing U.S. EPA to report on the implementation of the framework and to continue supporting communities with their voluntary integrated planning efforts. The report to Congress (U.S. EPA, 2021a) documented that 27 municipalities have developed integrated plans and, as a result of prioritizing stormwater and wastewater issues based on stakeholder input, many have recognized significant water quality improvements and cost savings to meet their goals.

Addressing Nonpoint Source Pollution

According to U.S. EPA, the nonpoint source program has documented hundreds of water quality improvements spanning 968 waters, including 18 300 km (11 400 mi) of rivers and streams and 69 000 ha (170 000 ac) of lakes and other waters. Each year, states document an average of 50 additional waters restored to their water quality standards through nonpoint source efforts. These efforts are described on the U.S. EPA web page, "Success Stories about Restoring Water Bodies Impaired by Nonpoint Source Pollution" (https://www.epa.gov/nps/success-stories-about-restoring-water-bodies-impaired-nonpoint-source-pollution).

However, water quality goals cannot be adequately addressed ***without the full cooperation of all pollution sources in a watershed***.

For all water bodies across the nation that have been assessed and a possible source of impairment identified, 85% of rivers and streams and 80% of lakes and reservoirs are polluted by nonpoint sources (U.S. EPA, 2016a).

Nutrients are a pollutant of growing concern responsible for algae blooms and associated anoxic zones from oxygen depletion. Although the Clean Water Act's NPDES and associated permits have been complemented by TMDL requirements to regulate nonpoint sources of pollution, significant improvements must be made to meet water quality goals (refer to Case Study 1).

CASE STUDY 1

WORKING AT THE WATERSHED SCALE FOR THE CHESAPEAKE BAY WATERSHED

The Chesapeake Bay TMDL (U.S. EPA, 2022a), established on December 29, 2010, is the largest developed by U.S. EPA encompassing six states (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia) and the District of Columbia (DC). The TMDL was established because extensive and ongoing restoration efforts via agreements by the jurisdictions since 1983 have not corrected the impairment. The pollutants of concern include nitrogen (N), phosphorus (P), and sediment (commonly measured as total suspended solids or TSS). The pollutant load reduction requirements for N, P, and TSS are typically included in either the Phase 1 or Phase 2 MS4 permit as a "special condition" issued by the six states and DC. The TMDL and associated phased MS4 permit requirements are designed to fully restore the Bay and its tidal rivers by 2025. Achieving this goal would not be possible without the coordination of the various communities who are "working on a watershed scale."

CASE STUDY 2

WORKING AT THE WATERSHED SCALE IN MINNESOTA

To address the challenge of jurisdictional boundaries not matching watershed boundaries, some states such as Minnesota have established local units of government corresponding to watersheds to address water-related problems (Minnesota Association of Watershed Districts, n.d.).

Minnesota has 42 watershed districts, each governed by a Board of Managers appointed by County Boards of Commissioners. Authorized in 1955 with the passing of the Watershed Act, the watershed districts are responsible for water quality, groundwater levels, managing drainage systems, regulating the use of water, protecting wildlife, enhancing recreational opportunities, maintaining hydrological data, stormwater design criteria (such as culvert sizes), and other related projects.

The Minnesota Association of Watershed District's strategic goals include 1) education and training; 2) communication and collaboration, and 3) lobbying and advocacy. The Minnesota Association of Watershed District holds meetings annually and prepares annual reports summarizing accomplishments ranging from providing education to elementary school children, to partnering with other organizations for the design and construction of projects to restore lakes, to collaborating with state agencies on legislative issues to improve water quality.

CASE STUDY 3

INTEGRATED PLANNING IN AKRON, OHIO

The City of Akron, located in northeastern Ohio, includes a comprehensive storm sewer system along with combined and separate sanitary sewer systems. In 2014, based on an estimated discharge of 1.2 billion gallons of CSOs per year, Akron was issued a consent decree requiring a long-term control plan (LTCP). The previous year, the city had initiated an integrated planning process to consider other innovative and more cost-effective solutions than what was included in the LTCP. Using this approach, including a financial model and addressing triple bottom line weighted criteria, the City of Akron saved $158 million in project costs between 2015 and 2019. In addition, the city treated an additional 826 million gallons of wastewater beyond the requirements of the consent decree.

CHAPTER 3
TRANSFORM STORMWATER GOVERNANCE

Governance frameworks for stormwater management will be more clear, specific, and measurable. Both water quality and water quantity will be considered. Sufficient staff and program management capacity at the state agencies with MS4 permitting authority will increase the likelihood of effective local MS4 permitting and stormwater management programs. Stormwater stakeholders including stormwater utilities, MS4s, and national organizations will have an active program to ensure their voices are heard in Congress in a timely manner.

Depending on the perspective, the NPDES stormwater regulatory program is now decades old. The Phase I program started in the early 1990s, and the Phase II program rule was published in 1999. One of the most important and useful lenses through which to view stormwater governance is that of the maturity of the stormwater sector and regulatory framework.

U.S. EPA is taking an approach designed to achieve significant, measurable, and timely results in reducing stormwater pollution and to provide significant climate resiliency benefits to communities. The strategy focuses on pursuing immediate actions to help communities address their stormwater challenges. The agency has deferred action on rulemaking to reduce stormwater discharges from newly developed and redeveloped sites and on other regulatory changes to its stormwater program and is leveraging existing requirements to strengthen municipal stormwater permits. In addition, U.S. EPA will be providing incentives, technical assistance, and tools to communities to encourage them to implement strong stormwater programs, including the promotion of green infrastructure as an integral part of stormwater management.

In considering the success of the stormwater regulatory programs, it is remarkable how much we still have to learn about their performance or results on a national scale. We do not know how many programs and nonstructural BMPs or constructed SCMs have been built or implemented by both public and private entities. This gap also lends itself to an asset-management approach to stormwater infrastructure akin to what is used for wastewater and drinking water. We do not know how much these local programs and SCMs have cost or have quantified results for pollution load reduction or prevention. This lack of knowledge has been an impediment to stormwater being viewed as a significant public infrastructure sector, one worthy of Congressional attention and funding.

With all that said, the sector recently has made some significant progress toward maturity. Stormwater was added as a new public infrastructure category in the Infrastructure Report Card (Grade D)(ASCE, 2021). The WEF Stormwater Institute conducted and published the results of its *2020 National Municipal Separate Storm Sewer System (MS4) Needs Assessment Survey* (WEFSI, 2021b). Congress is including stormwater in bills, including the recent bipartisan Infrastructure Investment and Jobs Act (IIJA), and is requesting more ideas and information from the stormwater sector.

As a new and immature sector and set of programs, stormwater was included within the U.S. EPA Office of Wastewater Management due to the fact that stormwater falls under the Clean Water Act. Stormwater has often been poorly served by being combined with wastewater, in multiple contexts. Stormwater is included with wastewater under the Clean Water State Revolving Fund (CWSRF) program, but stormwater projects have received only 1.8% of the cumulative CWSRF funding between 1988 and 2020. Stormwater has been included with wastewater in the Clean Watersheds Needs Survey (CWNS), but in the last CWNS in 2012, only 21% of the MS4 permittees reported needs and 16 states had no reported stormwater needs at all (U.S. EPA, 2016b). Because of the challenges faced by stormwater within a wastewater construct, some organizations have even advocated for the creation of an Office of Stormwater Management within the U.S. EPA Office of Water, and independent offices of stormwater at state regulatory levels. Others contend that creating a separate Office of Stormwater Management will focus energy on creating a bureaucratic structure and distract from the critical challenges facing stormwater today, such as funding and financing.

Regardless of the organizational structure, regulatory agencies should review all stormwater funding programs to determine whether stormwater has been receiving and will receive appropriate and necessary levels of funding. For example, agencies should check to determine whether stormwater project information submitted under programs like the CWSRF Green Project Reserve Green Infrastructure category is accurate and suitable for the category.

Agencies should also revisit the quantification of investment in and benefits from stormwater programs and infrastructure because of Clean Water Act regulations. In the years since the 1990 and 1999 federal stormwater rules, the regulations and the sector have changed significantly. An effort should be made to quantify the cost of the regulations and estimate the cost/benefit relationship between stormwater regulations and the resulting benefits, both for water quality and local flood preparation and reduction.

U.S. EPA has continued to expand valuable stormwater work and programs in green infrastructure, long-range planning, integrated planning, and CSOs. These should continue.

There should be increased focus on and inclusion of local stormwater programs, of all sizes and capacity, in stormwater governance. Regulations should be integrated to address climate change, resilience, and localized flooding. The recommendations of the U.S. EPA Environmental Financial Advisory Board (EFAB) 2020 report, "Evaluating Stormwater Infrastructure Funding and Financing," should be implemented toward achieving these goals. Local programs should be supported and provided funding and technical assistance to move toward clear, specific, and measurable MS4 permit requirements and make progress toward meeting TMDL waste load allocations (WLAs).

RECOMMENDED ACTIONS

ACTION 3.1

Integrate the federal supports and actions related to localized flooding, including local stormwater programs

Localized flooding caused by intense and long-duration rainstorms has become a significant and dramatic problem in multiple regions of the United States. Local stormwater programs serve important functions that are not well understood or appreciated by federal agencies. These functions include setting local stormwater design standards for new development and redevelopment projects, both public and private, and reviewing stormwater designs and calculations for these projects.

Local stormwater programs depend on precipitation frequency estimates derived by federal agencies, including Technical Paper 40 (National Weather Service's Rainfall Frequency Atlas, https://www.weather.gov/gyx/TP40s.htm) and Atlas 14 (National Oceanic and Atmospheric Administration's [NOAA] Precipitation Frequency Data Server-PFDS/HDSC/OWP, https://hdsc.nws.noaa.gov/hdsc/pfds/). These estimates, specifically Atlas 14, need stronger federal support in the form of national funding, execution at a national scale, and a regularly updating schedule. Precipitation frequency estimates should be integrated and unified across NOAA, the U.S. Army Corps of Engineers, the Federal Emergency Management Agency (FEMA), U.S. EPA, U.S. Geological Survey (USGS), and other federal agencies.

Addressing local flooding concerns and providing support must be integrated across multiple federal agencies, including U.S. EPA, especially because in many areas, rainfall is powerfully influenced by climate change.

The U.S. EPA CWNS is the primary federal effort to quantify capital needs nationwide for the public stormwater sector. The purpose of the CWNS is to assess capital investment, eligible for State Revolving Funds (SRF) funding, needed nationwide for publicly owned wastewater collection and treatment facilities to meet the water quality goals of the Clean Water Act. Therefore, any stormwater needs collected by the survey should have a water quality component. As a result, projects characterized as "flood control" without a stated water quality benefit were not accepted for CWNS 2012. (U.S. EPA, 2016b).

ACTION 3.2

Provide better and more timely information and ideas to Congress about how to improve and strengthen the stormwater sector

Congress has demonstrated an expanded interest in and willingness to support and expand funding and institutional support for the stormwater sector. This can be seen in multiple stormwater measures written into the recent bipartisan IIJA.

Staff from Congressional offices and committee offices are looking for good ideas and well-informed feedback from the stormwater sector. The sector, unfortunately, is not currently structured or funded to provide that input in a timely or comprehensive manner.

The national organizations involved in stormwater management need to organize a coalition structure that can respond to Congressional requests in a timely and competent manner. This work needs staff and funding support and must be informed by a detailed understanding and knowledge of the methods, protocols, and challenges used and faced by local stormwater programs.

A wide range of professionals in stormwater management should be engaged in this effort, including

- Local stormwater program managers
- State regulators and funding authorities
- Academics and researchers
- Stormwater products industry
- Watershed organizations
- Regional planning agencies
- Environmental advocacy organizations
- Agriculture leadership
- Consultants

ACTION 3.3

Catalyze and support the formation of stormwater utilities

Stormwater utilities provide a vitally important dedicated funding source and bonding capacity for community stormwater needs and priorities. Currently, the United States has about 1850 stormwater utilities, according to a 2021 report on stormwater fees from Western Kentucky University. This means that only about 28% of the approximately 6500 MS4-permitted cities nationwide have a local utility (Campbell & Bradshaw, 2021).

The need for more local stormwater utilities is widely recognized, but progress has been so limited that this action item is relatively unchanged since the first edition of *Rainfall to Results* was published in 2015.

The regulatory pressures and demands on permittees have increased in recent years. Having a dedicated funding stream, as from a stormwater utility, is an essential element of any successful CWSRF funding application in many states. Operations and maintenance (O&M) have become increasingly costly for local programs as the numbers and complexity of stormwater control measures have increased over time.

These are all strong reasons to support the institution of stormwater utilities in communities that do not have them. However, significant barriers to the formation of utilities in many states and communities remain.

The regional Environment Finance Centers are thought, by many, to be institutions supporting and providing technical assistance for the formation of utilities. This is a reality in some states, but in many others, local stormwater managers are barely aware of the existence of their regional center. U.S. EPA also has a dedicated technical assistance program (see https://www.epa.gov/water-infrastructure/water-technical-assistance).

In several states, the statutory authorities to support the formation of stormwater utilities is not in place. In other states, court rulings have determined that local stormwater utility fees are taxes rather than fees.

There should be a comprehensive national program to support and aid communities' stormwater needs through the creation of local stormwater utilities. Local stormwater managers should be included, as stakeholders, in the design and implementation of this program. A clearinghouse for information on statutes, legal mechanisms, court rulings, model local ordinances, local educational and outreach materials, and other factors that affect the success or failure of local stormwater utilities should be established. A low-interest loan program, similar to or imbedded within the CWSRF program, to support the formation of local stormwater utilities should be considered, with the proceeds from the establishment of these utilities paying off the loans.

ACTION 3.4

Increase state agency capacity to support sustainable stormwater management

In most cases, state agencies are responsible for writing and enforcing permits to enact Clean Water Act requirements. U.S. EPA also bears the responsibility for auditing state programs and compelling them to meet minimum program standards.

Through these permitting and enforcement actions, U.S. EPA and state agencies set the tone for stormwater management decisions and, therefore, play a role in supporting sustainable stormwater management. State programs, however, are often understaffed and face continuous budgetary pressure as well as pressure from those entities that are regulated. The capacities of state stormwater programs vary significantly from state to state.

U.S. EPA and other entities should engage with state programs to identify stormwater and wet-weather needs and help state programs to meet those needs. Examples include supporting the development of joint technical training, providing information on innovative permitting approaches, or aiding with state stormwater manual updates.

U.S. EPA should periodically collect and publish quantitative information about every state's stormwater permitting program. These data should include

- Status of stormwater permits
- Permit fees
- Local program audits performed by each state
- Enforcement actions
- State agency staff levels
- Stormwater funding assistance provided by each state
- Status of technical assistance, such as state stormwater manuals

This information would provide valuable accountability for state agency capacities.

ACTION 3.5

Support the transition of the MS4 permits to clear, specific, and measurable requirements

When the MS4 permitting program began, it was largely qualitative, BMP-based, and nonnumeric. In recent years, this program has been evolving. The 2016 MS4 Remand Rule includes a requirement that MS4 permit conditions be clear, specific, and measurable. More TMDL WLAs have been explicitly linked to MS4 permits. In some states and in some locations, MS4 permittees are required to estimate and report on the pollutant load reductions that result from SCMs they have or will implement. Taken together, these changes represent a significant transition for the MS4 permitting program that merits structural changes to federal stormwater governance and guidance.

It is important to note that during this transition, the MS4 program retains the Maximum Extent Practicable permit standard and the expression of permit terms and conditions as BMPs, narrative requirements, and/or adaptive management strategies. The MS4 Remand Rule preamble includes this text: "[U.S.] EPA clarifies that 'measurable' does not necessarily mean that water quality monitoring must be required in every instance to assess compliance. Likewise, it does not mean that numeric, end-of-pipe pollutant concentrations or loadings must be included in permits" (NPDES MS4 General Permit Remand Rule, 2016).

U.S. EPA should provide technical and funding assistance for these changes and this transition. This assistance should be linked to and coordinated with the new Centers of Excellence for Stormwater Control Infrastructure Technologies created under the IIJA. U.S. EPA should also create and maintain a national clearinghouse of information, quantitative parameters, and methodologies to address this transition. States should be supported with funding, research, and tools to lead this transition. Some U.S. EPA regions have tools to help with estimating pollutant load reductions. However, there should be an enhanced focus on developing improved quantification methodologies for estimating pollutant load reductions and regulatory crediting and reporting systems for permittees. It is essential that local stormwater programs managers are included, as stakeholders, in all this work.

ACTION 3.6

Include the "small" MS4 permittees in the stormwater governance framework

Of the approximately 7550 municipalities that are MS4 permit holders in the United States, approximately 855 are Phase 1 permittees (e.g., large- and medium-sized MS4s defined under the federal rule) (U.S. EPA, 2022b).

The majority of MS4 permittees are defined as "small". It is very difficult to communicate and work interactively with such a large number of entities. Being relatively small, many of these municipal permittees do not have the staff capacity or financial resources to do things such as

- send people to conferences
- put people on the boards of national water organizations
- spend time making sense of research papers and results
- educate and lobby Congress
- work with U.S. EPA staff or academic researchers to articulate the needs and priorities of local stormwater programs

State- and regional-level coalitions of MS4 permittees have been useful, but these exist only in about half the states.

New and widely used web-based communications methods and structures should be built upon and expanded to disseminate important information and lessons learned to these numerous local stormwater professionals. There should be frequent and regular communication and discussion between U.S. EPA and the numerous local stormwater programs. Coalitions of local stormwater programs should be encouraged and supported. Methods and structures for raising and spending funds should be encouraged and supported to address the collective needs and goals of local stormwater programs. The principles of information diffusion and technology transfer should be applied to better inform and guide local program managers and decision-makers, perhaps starting with the new Centers of Excellence for Stormwater Control Infrastructure Technologies created under the IIJA. Local stormwater professionals should be integrated into the process of identifying and prioritizing stormwater research needs at the national level.

CASE STUDY

CLEAN SWEEP PROJECT, NEW HAMPSHIRE

The goal of this project is to develop consensus-based recommendations for pollutant load reductions for street sweeping and to ensure that the credit received under NPDES stormwater regulatory permits is commensurate with the latest science. Since its beginning, this project has also moved to include consideration of leaf pickup programs.

The lead partners for this project are

- University of New Hampshire Stormwater Center
- Piscataqua Region Estuaries Partnership
- Roca Communications

This work was informed by research on the contributions of leaves deposited on impervious surfaces to nutrient pollution in urban stormwater runoff in Minnesota and Wisconsin. These states have recently introduced regulatory credits for phosphorus reductions through street sweeping and leaf management. This work was led by Sarah Hobbie and Larry Baker of the University of Minnesota, and Bill Selbig from the USGS.

The results of this research have shown the limits of our prior understanding about some basic parameters of urban stormwater and techniques to manage it (Hobbie et al., 2020). Nearly 60% of the annual phosphorus yield can come from leaf litter in the fall. Timely removal of leaf litter can reduce phosphorus load by 80%. Street sweeping, especially during the times of seed, flower, and leaf drop from trees, can remove significant amounts of phosphorus from a stormwater system at a cost of less than $100/lb (0.45 kg) phosphorus.

The Clean Sweep Project is motivated by an understanding of the needs and priorities of local stormwater programs and the broader interest in making demonstrated progress toward meeting water quality goals. It is an example of the necessary linkage between scientific research, regulations, and local programs. The project will use an expert panel process and an advisory committee comprised of municipal stormwater staff, regulators (including U.S. EPA Region 1), consultants, and experts in the fields of hydrology, fate and transport of urban pollutants, and engineering.

This project is partly based on recognizing the value of quantitative regulatory credits in the contexts of TMDL WLAs and MS4 permits. In the world of municipal decision-making, stormwater has to compete with a wide range of other important municipal priorities, from parks to police to other public works. Few things make a presentation to a city council or city manager more persuasive than regulatory credits tied to cost efficiency and effectiveness. This project aims to develop and provide this information for local program managers and state and federal regulators.

CHAPTER 4
SUPPORT INNOVATION AND BEST PRACTICES

Stormwater best practices will include digital solutions such as IoT, artificial intelligence, and digital twins to ensure innovation integrated with changing policies. Technology and business models will be implemented to advance achievement of One Water, net zero runoff, and circularity. Continual improvement of stormwater prevention, source control systems, and methods to analyze and value the benefits of stormwater practices will bolster stormwater as a valuable resource.

In general, BMPs are expected to represent state-of-the-art, advanced standards. Nothing could be further from reality. Best practices are conventional standards reinforced by continual update. They are the baseline of practice to meet regulatory requirements, and often may not achieve their intended outcomes unless designed for specific conditions, installed properly, and maintained effectively. Innovation is the "beyond-best" development of technologies and business models for their financing, implementation, and operation and maintenance. Innovation can also apply to personnel sourcing, stakeholder and community relations, and societal engagement.

At one end of the spectrum and representing the majority of the efforts of stormwater management, best practices are designed to meet the presumption of managing *drainage*, to protect the buildings and infrastructure that caused excessive runoff in the first place by disturbing the natural retention, infiltration, and ponding of rainfall. At the opposite extreme are best practices based on restoring or mimicking the natural retention, infiltration, and ponding of rainfall, preferably as close as possible to where the rain falls. In the regulatory context, both actions are required to reduce or prevent stormwater pollutants and the deleterious effects they have on receiving water bodies. The ability to protect water quality is therefore still the standard against which BMPs are assessed, although simply meeting the allowed pollutant loadings to waters is not where stormwater best practice innovation is focused.

Low-impact development (also known as green stormwater infrastructure, and now nature-based solutions) represented the most significant transformation in stormwater best practices until artificial intelligence, real-time automation, digital twins, and other intelligent capabilities were applied to stormwater management controls.

As the powerful forces of climate change, social change, artificial intelligence, generational staffing turnover, and credit markets break across the existing stormwater business model, they combine with an emerging undercurrent in the policy realm—One Water—that has the potential to recognize "stormwater" as a valuable resource.

These key indicators combine to drive rapidly evolving innovation in *stormwater control management* best practices that exceed the standards of previous best practices. They also promise to change the entire business model upon which *stormwater control measure management* will be delivered. Although there has been a significant gap/lag in implementation, government, stormwater utilities, and the industry that serves them are rapidly adopting climate mitigation, adaptation, and resilience as the core policy context associated with *rainfall management*.

Driving this shift beyond the conventional perspective of *stormwater control management* is the *net zero* policy framework that is rapidly becoming the core policy objective of civic programs for energy, waste, and transportation. Net zero can also be said to be at the core of the One Water framework. If *stormwater control management* cannot be said to enhance the water quality of receiving water bodies, the hydrologic ecosystem, or overall watershed health, it is flood control or wastewater management. For the stormwater sector to define itself apart from wastewater management, it must focus on the protection and enhancement as an ecosystem and human water security of the supply of its primary constituent, namely rain. That hasn't typically been the case, but it is rapidly becoming clear that stormwater management without targets for net zero, One Water, or circular reuse as the core component will soon be measured as less viable on a financial, operational, or outcomes basis.

As a result of shifts in the policy, ecosystem, social, fiscal, operational, business, and technological spheres, it is proposed that WEF update its Position Statement for the efficient and effective management of stormwater runoff to recognize rainfall as a resource for protection prior to it becoming contaminated stormwater, and thereby to prioritize source water protection over stormwater control management.

With the 2021 American Society of Civil Engineers (ASCE) acknowledgement of stormwater as an individual public administrative infrastructure category apart from wastewater management, the stormwater utility sector is poised for a more significant shift in budget allocations following the rapid expansion of federal infrastructure funding (ASCE, 2021). Stormwater utilities established to meet the sector's chronic underfunding are now in the spotlight as infrastructure funding enhances budgets for long-overdue allocations to maintain conventional infrastructure, and to launch a new wave of best practices grounded in artificial intelligence, data science, and automated devices.

All practitioners will agree that *asset management* is the basic requirement for effective best practices, but few will recognize the innovation shift reimagining what constitutes asset-managed infrastructure, or more relevantly, where asset-managed infrastructure is located. One of the major shifts in best practices innovation relates to the transfer of stormwater management into a realm that it has traditionally avoided—private property. Cities are recognizing that they cannot effectively meet the needs of climate adaptation or simply mandate water-quality requirements on a cost or operationally effective basis without addressing the significant amount of privately owned property area and especially the impervious area represented by the collective of residential property rooftops. Cities within the Chesapeake Bay watershed have tended to lead the focus on implementing "green acres" or RiverSmart or BayStars objectives.

Associated with this significant shift that asset management brings to best practices innovation is a complementary shift in the service delivery business model. As the National Municipal Stormwater Alliance (NMSA, 2022) notes, the community-based public private partnership is a game-changing development in the delivery of asset-managed stormwater best practices.

Finally, the latest transformation in best practices innovation, stormwater retention credits (SRCs), is a financial mechanism associated with net zero that mimics the carbon credit market. Stormwater retention credits will likely drive how stormwater best practices are financed, priced, and rewarded for their outcomes through retention market mechanisms.

RECOMMENDED ACTIONS

ACTION 4.1

Ensure best practices integrate innovation aligned with changing policies

Funding for stormwater management is generally dedicated to the building and maintenance of conventional conveyance and storage treatment methods. As a result, efforts like the International Stormwater BMP Database, where submittal of data is voluntary, can contribute to gaps in novel BMP design, thus limiting the comprehensive ability to inform practitioners about advances in the best practices of innovation. As with data science, the input values are what determine the clarity of the analysis of outcomes. Practitioners are unlikely to take up advanced methods for rainfall management and use these as a *core* stormwater undertaking unless that decision is positively reinforced by a comprehensive BMP database.

Innovation in the stormwater sector has two areas of action:

- Stormwater manuals could be transformed into interactive, online training portals where users can virtually design systems and solve problems using methods. Online manuals would be easier to update and include easy-to-use, curated, unit-process-based information on stormwater controls. Stormwater manuals should include up-to-date best practices
- Extend asset management to digital systems by prioritizing digital over legacy conventional assets, digitizing existing legacy assets, and digital twinning of existing legacy assets.

ACTION 4.2

Support pollution prevention through source control efforts and systems

Shift the focus for stormwater to pollution prevention from pollution treatment by moving away from the pollute-and-treat ethos and updating current best practices to adapt to climate change and its subsequent effects on society and the economy.

Source control should focus on reducing pollutant loads and stormwater communities must engage in efforts at the federal, state, and local levels to make this possible.

Retention-based systems should be focused on reducing runoff volume and stormwater source prevention. Project designs in the latter category should prioritize reducing volumes and rates of stormwater entering combined and separated sewers for the objective of reducing CSOs, hydraulic and hydrologic flooding and, wherever possible, maximize its reuse for drinking water security, potable offsets for nonpotable demands, and ecosystem flows.

ACTION 4.3

Align stormwater best practices with the development and deployment of innovative technologies and business models to advance achievement of One Water, net zero runoff, circularity, and associated policy objectives

- *Artificial intelligence, IoT, and digital twins*: this trifecta of internet-enabled technology spans the entire spectrum of operations from legacy detention ponds all the way up the treatment train to property-based retention and reuse. Artificial intelligence consists of models of behavior given real-world conditionalities. Quantitative precipitation forecast algorithms are an excellent example of using real-time data (weather forecasts) and correlating them to local conditions to predict runoff volumes. Coupled with IoT devices such as sensors, pumps, and valves, storage retention can be automated to respond to future wet-weather events.
- *Property-based retention networks:* the combination of artificial intelligence with IoT–managed retention has created a new set of practices applied to but entirely transforming analog devices. The best examples are AIoT (artificial intelligence/internet of things)–enabled stormwater ponds, networks of residential property-based intelligent cisterns, and blue roofs, either within a larger regional network or as stand-alone infrastructure.
- *Digital twins* are rapidly becoming the modeling process of choice for designers faced with highly dynamic variables. Digital twins represent a real-world system that is used to describe, diagnose, predict, and optimize *through actions* enabled by a combination of models and static and dynamic data.
- *Generative Adversarial Networks* are an advanced application of artificial intelligence creating synthetic load profiles (floods, droughts, etc.) arising from the interpretation of past variables against forthcoming models of behavior.
- Business model process innovation
  - City climate adaptation strategies such as OneNYC have identified a significant need to extend stormwater management infrastructure onto private property. This is the eventual recognition of what was formerly referred to as the *lot-level approach* to source control. What differentiates present and future practices from existing property-based programs is the necessity of integrating property-based infrastructure into the asset management framework of the utility.
    - Integration of property-level infrastructure requires adopting business models similar to those used to promote non-managed assets.
    - Climate variable extreme events make calculations of flows from individual events more relevant than overall annual flows. Sizing of infrastructure for the 100-year event does, however, result in excess capacity. It is proposed

that real-time automation for retention and detention serves as the baseline technology to avoid building excess capacity required only for extreme events.

- The Water Reuse Association is focusing stormwater management with respect to maximizing its retention for use. Stormwater management policies for circularity and One Water are rapidly expanding.

- Financial innovation
  - Outcomes-based financing is a bond financing process whereby repayment terms are tied to (preferably) real-time automated and digitally measured operational outcomes from nature-based (real or mimicked) solutions.
- Active digital asset management
  - Digital device sensors provide real-operational management and failure diagnostics ensuring optimum scheduling of maintenance. For example, in-pipe sensors can detect variable flows associated with blockages or other issues.
- Infrastructure democratization
  - Real-time IoT automation offers the ability to extend asset-managed stormwater infrastructure planning to the individual lot level, and by extension across watersheds directly correlated to the activities of property owners. In this way, whole communities can be monitored for stormwater runoff from rooftops and other sources to determine flows and incidence of flooding. The location of AIoT-enabled, self-regulating infrastructure on private property offers a *positive feedback mechanism* for stormwater utility rate payers who would otherwise not participate in property-based installations. Real-time data also illustrates the individual operational benefit of a property to the overall achievement of environmental outcomes.

ACTION 4.4

Increase the ability to analyze and value alternative methods of stormwater management on a multi-benefit basis

Communities that have effectively analyzed the value of potential stormwater efforts have developed both quantitative and qualitative metrics to capture the benefits of stormwater management. For example, SRCs offer a monetized facility for the quantified measurement of ecosystem and infrastructure benefits. While there has been an increase in analyses of conventional methods of stormwater management on a multi-benefit basis, there are still benefits that have not been considered. Future analyses and valuations should consider the following:

- Flood and related insurance risk reduction
- Climate variability resistance
- Carbon

ACTION 4.5

Advance the tools and methods necessary to support the continual improvement of stormwater prevention and management

- Advancing best practices to accommodate changing policy, climate, social and financing opportunities
- Embedding circularity into practices such as low-impact development or reestablishing natural hydrology through nature-based technology
- Implementing market mechanisms such as monetary value that can be traded, which can facilitate a national stormwater retention credit monetization and trading process within watersheds, or instituting SRCs or permeability coefficient fees, which would transform stormwater management into a user-based system

CASE STUDY

HOUSING HELP PLUS, DISTRICT OF COLUMBIA

Housing Help Plus is a not-for-profit housing provider in Washington, DC. Its portfolio of 48 buildings is largely comprised of geriatric properties in significant need of upgrading, with substandard mechanicals, and nonexistent stormwater source controls. Consequently, the housing provider undertook to upgrade the buildings. This included an examination of how to achieve sufficient stormwater controls to avoid paying SRCs, and potentially to raise the bar to the point of generating sufficient property-based source control to "farm" SRCs. The SRC market in Chesapeake Bay is an innovative example of applying market forces to drive innovation, and coupled with a green stormwater infrastructure rebate program, illustrates how a joint public–private partnership model can accelerate the uptake of stormwater source controls.


STORM DRAIN

CHAPTER 5
MANAGE AND MAINTAIN STORMWATER ASSETS

Stormwater systems will be maintained through robust asset management programs and supported by innovative information technology. An integrated planning approach will use automated data capture and analyses and predictive management to greatly improve capital planning and budgeting. Further, a multidisciplinary workforce will support the proper design, installation, and inspection, as well as operations and maintenance, repair, and timely replacement of stormwater infrastructure.

Inadequate attention to O&M and a lack of effective planning for repair and replacement are additional significant challenges in the stormwater management sector. The WEF/ASCE/Environmental & Water Resources Institute manual titled *Urban Stormwater Controls Operation and Maintenance* (WEF Manual of Practice No. 39, 2022) includes best practices for the continued operation of stormwater control measures (SCMs) for stormwater programs. The material covered is of particular use to designers of SCMs, utility managers, and O&M staff. Readers can find this document at wef.org/ShopWEF. All stormwater controls, regardless of type, require maintenance to function properly. Sustainable stormwater management requires the sector to address maintenance needs through an asset management framework. Asset management is important particularly for stormwater systems, which often encompass many decentralized controls that are disparate in type and function. Stormwater professionals can benefit from processes and tools developed for water and wastewater management professionals to develop or improve asset management procedures for stormwater assets.

An effective asset management approach considers the current state of assets, required levels of service, and the assets critical to overall system performance. It also requires stormwater managers to consider long-term maintenance and capital improvement needs and funding. Further, as stormwater managers address effects of climate change—particularly, more intense rainfall events and sea level rise—evaluating capacity and function of existing systems will be of increased importance. Through asset management, the design, system adequacy, and installation and maintenance of stormwater controls can be integrated fully into community planning. Stormwater managers can make more informed decisions when deploying limited human and monetary resources. Improved asset management also puts the sector on a path to improved benchmarking. By establishing key performance indicators and developing standard methods for collecting performance data, stormwater managers can strive for and achieve improvements in the function and performance of stormwater controls.

A well-trained, multidisciplinary workforce and the use of information technology will vastly improve stormwater asset management systems. Stormwater management controls serve numerous purposes including water quality, flood control, water capture and repurpose, water harvesting, groundwater replenishment, and downstream channel protection. Reflecting these stormwater drivers and a shift toward green infrastructure, the stormwater workforce must grow its size and its multidisciplinary skill sets.

Technologies such as adaptive control, remote sensors, drone aircraft, lidar surveys, aerial imaging, and augmented reality systems are being used to manage assets for water and wastewater systems. Many of these can also be applied to stormwater systems. These technologies can assist in optimizing existing infrastructure capacity and improve the performance of stormwater control measures.

RECOMMENDED ACTIONS

ACTION 5.1

Expand deployment of comprehensive asset management programs for stormwater infrastructure

Asset management programs have been successfully implemented in the water and wastewater sectors. Their successful implementation follows a proven asset management framework based on the asset providing a desired level of service at the lowest life-cycle cost and lowest appropriate risk. Comprehensive asset management begins with asset inventory, condition assessment, determination of level of service goals; and follows through with determining asset criticality, asset risk, identification of O&M strategies, and development of capital projects and risk-based, long-term investment plans.

Similar to the water and wastewater sectors, it is increasingly important that stormwater managers take a comprehensive approach to inventory, plan, operate, and maintain physical assets. This is crucial for stormwater systems for all types of stormwater controls—gray infrastructure, green infrastructure, and natural assets such as wetlands or restored streams. The condition, capacity, and remaining useful life of many of these systems is largely unknown, yet important to determine so that stormwater managers can maintain levels of service, system reliability, and resiliency. For stormwater systems for which the maintenance methods differ depending on the type of control, their condition and capacity can change significantly without proper maintenance and greatly increase the system's risk, resulting in flooding, erosion, and/or reduced water-quality benefits.

Asset management practices for stormwater should draw from successful techniques and best practices used in other mature infrastructure sectors. However, asset management for stormwater also must address the complexities associated with stormwater infrastructure. For example, automated methods for conducting condition assessments of wastewater lift stations and interpretation of closed-circuit television for wastewater pipelines and manholes may be modified for use with stormwater systems. However, other features, such as pond dams and embankments, require establishment of unique and new approaches.

Because stormwater systems can include ponds, ditches, driveway culverts, connections to major waterways, or other systems that involve issues of land ownership, right-of-way, or jurisdiction (e.g., city to city, city to federal land), it is important to define ownership and operational roles using a whole systems approach.

Confusion over who owns and is responsible for maintaining stormwater assets complicates stormwater management. Issues of maintenance responsibility should be resolved as part of a comprehensive asset management approach. Installing or incentivizing stormwater controls on private property and across jurisdictions requires particular attention to provisions for long-term monitoring, operation, and maintenance.

Best practices for stormwater asset management, including operation and maintenance, continue to emerge. Stormwater practitioners can capture lessons and combine them with knowledge from other sectors to further inform the stormwater community of the value of asset management and its benefits, including life-cycle costs and long-term planning, maintaining levels of service, and managing risk.

ACTION 5.2

Integrate operations and maintenance planning with stormwater capital project development

Lack of sustained O&M is a consistent challenge for stormwater programs across the United States. The breakdown can begin as early as the capital project development stage. Four deficiencies contribute greatly to inadequate consideration of O&M during project planning: 1) lack of monitoring data and performance metrics for stormwater controls; 2) lack of information characterizing failure modes; 3) lack of long-term maintenance needs and costs; and 4) lack of up-to-date analyses to accurately assess the effects of climate change. These deficiencies inhibit effective evaluation of stormwater control alternatives based on life-cycle costs. This lack of consideration also has limited the development of adequate technical and financial capacity to support ongoing stormwater infrastructure performance.

Further, the lack of reliable information on O&M and long-term costs is a significant barrier to the widespread implementation of innovative stormwater management techniques, especially green infrastructure. Many public works departments consider it fiscally imprudent to build certain stormwater controls without an accurate prediction of the full life-cycle costs.

It is recommended that the stormwater sector emphasize the creation and sharing of O&M requirements for stormwater controls. This will enable the sector to make optimized stormwater management decisions and drive systems toward improved maintainability and long-term performance.

ACTION 5.3

Develop the use of automated information technology to support sustainable stormwater management

Asset management includes asset performance monitoring and reporting. For stormwater systems, changing climate conditions, changing impermeability conditions, and post-construction regulatory requirements such as trash capture devices must be monitored to evaluate its performance and effects to its level of service. The use of automated information technology to monitor performance and provide data to inform stormwater managers making data-driven decisions can support sustainable stormwater management. Through the use of data, a system's original design can be evaluated and decisions regarding rehabilitation or replacement with more resilient improvements can be made and communicated to stakeholders.

Stormwater infrastructure is inherently decentralized, and with performance demands increasing, real-time sensors and controls can play a critical role in cost-effective transformation of the nation's urban stormwater infrastructure. Real-time stormwater control technologies can improve the ability to reduce runoff and CSOs in addition to maximizing stormwater harvesting.

Drinking water and wastewater systems have long used real-time information technology, such as supervisory control and data acquisition systems, to monitor and control O&M. These applications can be considered and developed further for stormwater infrastructure.

Real-time controls can connect SCMs to the Internet and to one another to create a connected system that is more effective at the watershed scale, such as accessing predictive information (e.g., weather forecasts) that can react automatically. For example, cisterns provide more effective stormwater control if they are emptied before storms to hold more rainwater. The system can be programmed to react automatically to open a valve or start a pump to empty a cistern before a storm. Some automated systems also offer the ability to check system status online and relay commands. Real-time controls can reduce the size and expense of SCMs by optimizing their capacity.

Information technology such as sensors, remote cameras, drones, augmented reality, and information platforms also have great potential to bring about positive change in the stormwater sector. These technologies can improve data collection and help stormwater managers more effectively use that data in design, maintenance, and construction of stormwater controls. Augmented reality is the live view of the environment supplemented or enhanced by computer images or information layers, such as the location of stormwater pipes or maintenance dates. Drones could be used to collect high-definition photographs and videos, map contours using light detection and ranging maps, place construction materials, and collect water samples—physically or via sensors.

ACTION 5.4

Support development of a diverse, highly skilled, and multidisciplinary stormwater workforce

Stormwater management has undergone a substantial evolution. It began with a relatively straight focus on drainage and has grown into addressing the more complex issue of water quality. Adding to this complexity is the interconnectedness with wet-weather effects on wastewater infrastructure. Maintenance is important not only for ensuring proper function, but also for aesthetics and the community value that stormwater controls can provide.

In addition, regulators, such as those in the Chesapeake Bay watershed, require maintenance and documentation of maintenance activities for stormwater controls in order to receive water-quality credits toward loads assigned in the established Chesapeake Bay TMDL. Municipal stormwater managers require specific guidance on maintenance activities for diverse stormwater controls. Finally, maintaining green infrastructure stormwater controls requires specialized knowledge and an understanding of the systems' function.

In particular, O&M of green infrastructure provides significant opportunities to expand entry-level, long-term green jobs within communities. Critical disciplines such as landscape architecture, soil and plant science, and microbiology are required to design and provide maintenance guidelines for these practices to meet multiple objectives The evolution in stormwater management drives the need to attract, train, and retain a more diverse workforce.

Action in this area can follow several key paths. First, a review of current training content could reveal gaps, provide an opportunity to develop a directory of learning opportunities, and reveal the potential for collaboration between groups. Second, establishing a career path could help potential stormwater professionals understand the training and skill sets required to move from one position to another as well as progress from entry-level to higher-level positions. Third, certification could ensure that professionals have the needed skills to perform stormwater management jobs while bolstering their credentials. Fourth, the sector needs recognition programs that acknowledge and award high-performing individuals, communities, and organizations. Finally, a leadership program is needed to impart the multidisciplinary skills necessary for running successful stormwater management.

It is recommended that training follow a blended learning approach that combines opportunities to study online with conference education, networking opportunities, and hands-on training. Of particular interest

are efforts that support and engage stormwater managers and key staff in "twinning" exercises. In these exercises, stormwater authorities visit peers or exchange staff to learn from the on-the-ground experiences of other authorities.

Other professionals including builders, construction personnel, and field inspectors also interface with stormwater controls and may be involved in their construction and maintenance. Outreach to these professionals is necessary to ensure systems are installed correctly.

Increased and diversified maintenance requirements of stormwater controls lend to the development of an asset management approach that includes predictive, routine, and "as needed" maintenance platforms.

CASE STUDY

IDENTIFYING AND FUNDING CRITICAL STORMWATER IMPROVEMENTS, CITY OF ANAHEIM, CALIFORNIA

The City of Anaheim, located in southern California, was founded in 1857 and covers an area of about 129.500 km^2 (50 sq mi). The city is home to a population of more than 350,000 and typically receives 25 million visitors annually who visit the Disneyland Resorts, attend baseball and hockey games, or participate in one of many other tourism and entertainment events and venues throughout Anaheim. Typically, the city enjoys an average of 280 sunny days per year and fewer than 35 cm (14 in.) of rainfall. However, storm events have pushed the city's drainage system to its limits. Anaheim has taken a proactive asset management approach to address its storm drain needs to reduce the risk of severe flooding, property damage, reduced services, and pollution from runoff carrying debris, trash, and other pollutants.

The City of Anaheim's storm drain system is quite diverse and comprises eight watersheds, each with unique underground and above-ground storm drain infrastructure, separate from the wastewater system. For each watershed, the city prepared a storm drain master plan to identify the current state of its storm drain assets with respect to hydraulic capacity and deficiencies and priority ranking of proposed improvements based on compliance with 10-, 25-, and 100-year flood protection levels. Findings from the master plans resulted in over $800 million (2021) in proposed improvements for all watersheds. Currently, storm drain maintenance and repairs or rehabilitation are performed as needed or in response to an emergency scenario or reactive situations. The city has no dedicated source of funds or rate structure in place for storm drains, thus relying on limited general funds and grant funding sources.

Moving forward, given limited funding and the need to develop a long-term funding strategy, the city embarked on implementing asset management best practices, including ranking based on failure modes, multi-beneficial use (e.g., groundwater recharge, community enhancements), life-cycle costs, and risk-based prioritization. The asset management approach developed by the city was consistent with U.S. EPA's Five Core Questions of infrastructure asset management (U.S. EPA, 2008). U.S. EPA approach uses a process that is comprised of 10 steps or elements, culminating with an asset management plan. This process has been widely and successfully used by many water and wastewater utilities throughout the United States.

To assist with prioritizing its storm drain improvement projects, the city evaluated the following failure modes and high-level management strategies using data from its master plans, record drawings, maintenance records, recorded effects to level of service, and regulatory requirements, as shown in Table 2.

Table 2. City of Anaheim Failure Mode and Management Strategy Analysis

Asset Failure Mode	Tactical Aspects (examples)
Capacity	Growth, system expansion, increase in impermeable surfaces
Level of Service	Codes, permits, life safety, services (flood, effects of ponding water), change in regulations (pollution, trash capture, receiving water body loading limits), multi-benefits
Mortality	Asset deterioration due to age, usage, or premature deterioration, structural condition, level of corrosion, failing controls or automation
Efficiency	High O&M costs, high life-cycle costs

Based on these initial evaluations, the City of Anaheim was able to further prioritize its projects, taking into account the asset failure's mode and criteria developed by the city. Findings from this exercise resulted in developing a list of high-priority improvements with a funding need of approximately $177 million, much less than the total funding of $800 million identified in the master plans (Figure 4). As the city continues its asset management journey, there are several next steps that will lead to comprehensive understanding of the current state of the assets, level of service, determination of the consequences of failure, and determining which assets present the greatest risk to the city. These steps will lead to further prioritization of storm drain improvements and present funding requirements that are risk-based and founded on a proven asset management framework that is tailored to the needs and level of service required by the city and its stakeholders.

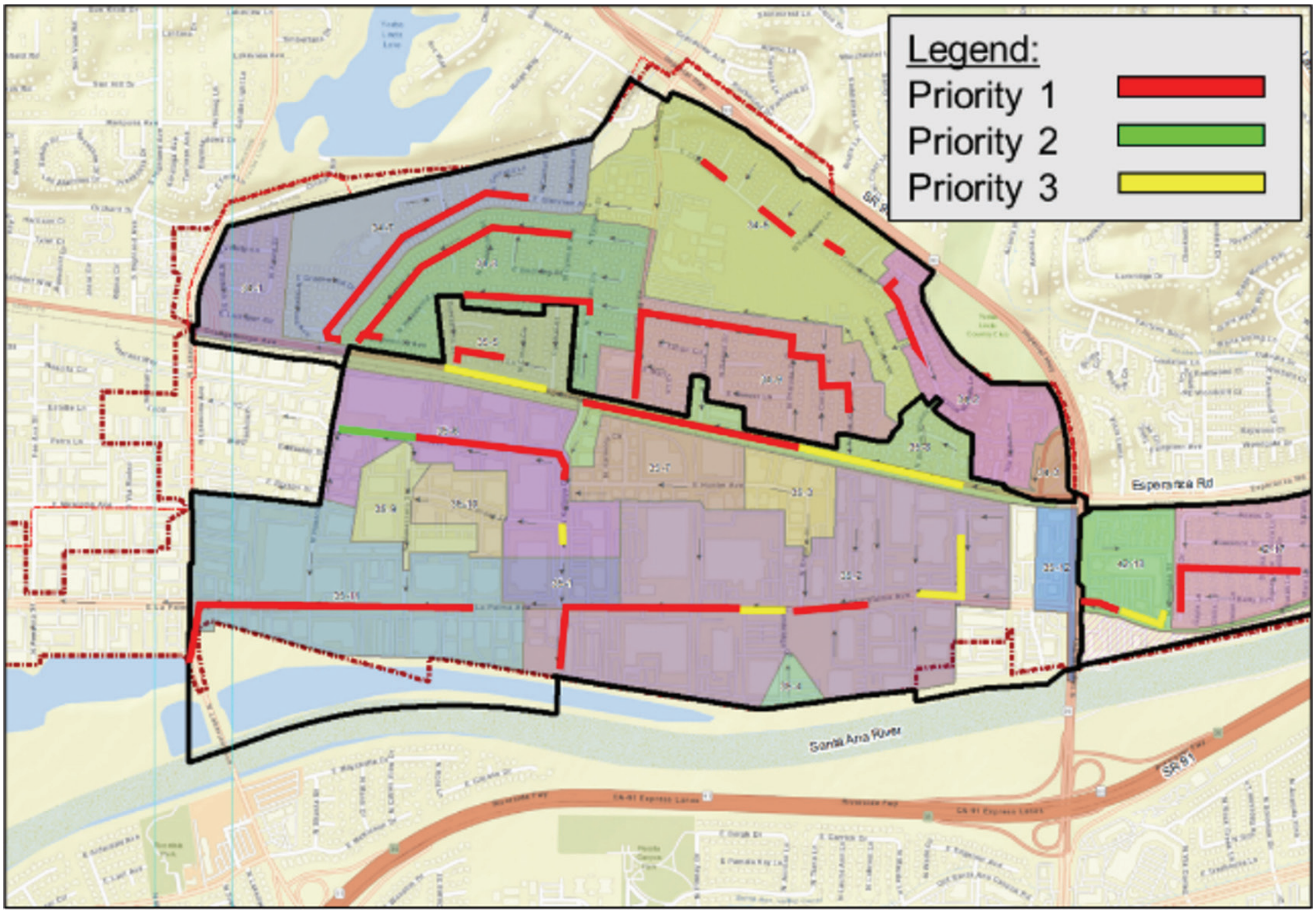


Figure 4. Project Priorities in Anaheim

CHAPTER 6
CONTINUE TO CLOSE THE FUNDING GAP

Communities and utilities will have a dedicated stormwater funding source in place to leverage funding from federal and state sources. Stormwater management efforts will be aligned with broader community goals to provide access to innovative market-based financing opportunities. Elected officials will support the investments needed to meet sustainable and resilient stormwater management objectives.

CHALLENGES AND ESTIMATES OF THE FUNDING GAP

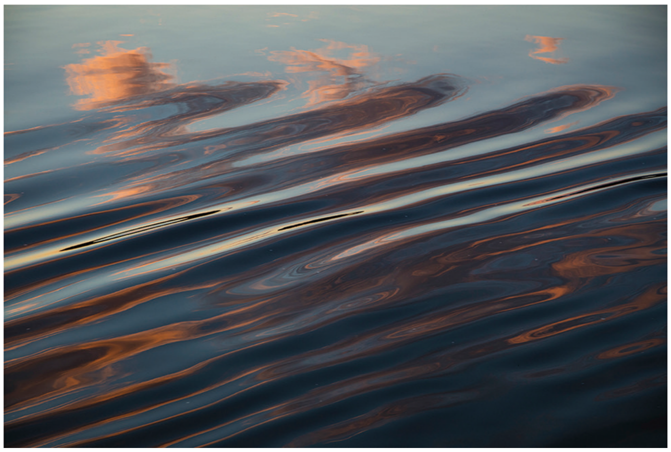
Stormwater infrastructure is widely viewed as a key part of the solution to improving water quality in the nation's waterways, reducing local flooding problems, and enhancing community resiliency. However, the challenges related to funding stormwater infrastructure are daunting; the stormwater sector is still maturing, and traditionally has not been funded as a true "utility" operation like wastewater and drinking water utilities.

The "lack of funding or availability of capital" was identified as one of the top two ranked challenges in WEF's Stormwater Institute *2020 National Municipal Separate Storm Sewer System (MS4) Needs Assessment Survey* (2021b). Dedicated and adequate funding and financing continues to limit the stormwater sector from becoming a true utility operation with reliable funding. The first step to address this challenge is for communities to determine their funding needs through master planning efforts that align stormwater management with other community priorities, thus opening additional funding opportunities from government, private, and nonprofit sources.

The 2020 Stormwater Institute survey report estimates the annual funding gap to be $8.5 billion for all MS4s across the United States (WEF Stormwater Institute, 2021b). This funding gap was a key piece of data used by the ASCE to give a first-ever grade of D for stormwater in its 2021 Infrastructure Report Card (ASCE, 2021). Through a separate effort, U.S. EPA estimated in 2012 that $67 billion is needed for stormwater (MS4 and CSO) investments over the next 20 years across the country (U.S. EPA, 2012b). All these challenges and estimates reinforce the critical need to continue to work to close the stormwater funding gap.

In addition, communities and utilities developing and implementing funding strategies for stormwater infrastructure programs also need support in addressing the following issues:

- Funding opportunities exist, but they come with significant political resistance to establishing new fees or taxes to pay for stormwater programs. This is further complicated when coupled with the affordability concerns of all water services.
- Cost distribution for stormwater is not as easy as setting a meter to record water use when talking about drinking water. The use of impervious areas as a means of estimating stormwater continues to be the most used method to assess stormwater fees.
- There is no clear answer for ratepayer accountability concerns—responding to questions such as Who is responsible of funding the services and benefits of applied stormwater management techniques in downtown? Is there a difference in benefit distribution between upstream homeowners and downstream homeowners? These questions, often raised by ratepayers, show that the public misunderstands the community-wide service that adequate stormwater management presents and how it benefits all property owners.
- Stormwater management benefits, in general, are also not well understood by the public which is reluctant to support bonds or other funding sources since it does not "see" many of the assets that will be built.



- Even though triple bottom line analysis supports investment in stormwater infrastructure, utilities and municipalities across the nation have limited funds to meet all of their needs, and billing for the true cost of services has not been universally accepted.
- There are eight states in which stormwater utilities or similar dedicated revenue vehicles for stormwater are not enabled. In these states, localities do not have the option to form these vehicles. Some states, with California as an example, may allow for the formation of stormwater utilities, but other practical barriers exist, such as extremely high bars for public or political support.
- The history of assistance to support urban stormwater infrastructure investments through the Clean Water SRF program reflects a very limited level of assistance. Specifically, less than 2% of all SRF assistance has gone toward urban stormwater infrastructure, which is less than assistance provided to nonpoint projects.

FEDERAL EFFORTS TO ADDRESS STORMWATER FUNDING

Stormwater Infrastructure Funding Task Force. America's Water Infrastructure Act (AWIA) of 2018, Section 4101, directed U.S. EPA to create a Stormwater Infrastructure Funding Task Force "to conduct a study on, and develop recommendations to improve the availability of public and private sources of funding for the construction, rehabilitation, and operation and maintenance of stormwater infrastructure" to meet the requirements of the Clean Water Act (AWIA, 2018, p. 106). U.S. EPA formed the task force of expert consultants as a workgroup of the EFAB in 2019.

Specifically, the Task Force was charged with the following tasks:

- Identify existing federal, state, and local public and private sources of funding for stormwater infrastructure.
- Assess how the source of funding affects affordability, including costs associated with infrastructure finance.
- Evaluate whether these sources of funding are sufficient to support capital expenditures and long-term operational and maintenance costs required to meet the stormwater infrastructure needs of municipalities.

The Task Force developed a report published on the U.S. EPA's Water Infrastructure and Resiliency Finance Center website in March 2020 and U.S. EPA sent the report to Congress in 2022. The report states that stormwater infrastructure requires funding, and it has been inadequately funded for far too long. There is a need for federal investment in stormwater infrastructure, similar to the level of investment that federal funding programs have provided in the past to, among other things, begin building our interstate highway system, upgrade our wastewater infrastructure, and deliver safe drinking water to our homes (EFAB Stormwater Infrastructure Finance Task Force Workgroup, 2020).

Per the report, the task force recommendations were grouped in the following categories:

- Stormwater funding education and technical assistance: Educating the public and elected officials on the need for stormwater funding is critical to the successful implementation of and community support for funding solutions. In addition, many communities need technical assistance related to evaluating and securing funding and financing mechanisms.
- Simplification and/or modification of existing federal grant and loan programs and affordability support: Federal grants, loans (e.g., from State Revolving Funds), and support to enhance affordability are needed to maintain sustainable local funding sources.
- Dedicated federal stormwater funding assistance: Given the magnitude of the stormwater needs described in this report, there is a need for federal investment similar to the investments in the National Interstate Highway system and historical WRRF upgrades.

Infrastructure Investment and Jobs Act (H.R. 3648). Significant investments in water infrastructure are being discussed as part of the IIJA in 2021 and 2022. The following are funding "channels" for stormwater infrastructure that will need to be explored as guidance from U.S. EPA is being developed in 2022 in response to the IIJA:

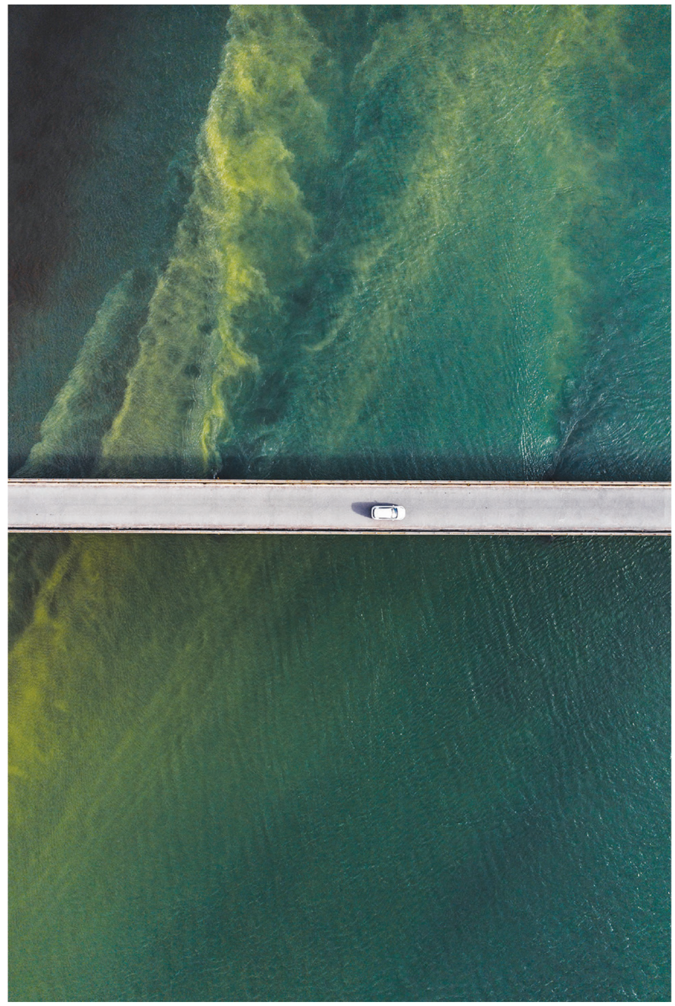
- Clean Water State Revolving Fund (SRF) and Drinking Water SRF: Reauthorizations have increased and the bill includes provisions for loan forgiveness (see **https://www.epa.gov/cwsrf)**
- Water Infrastructure Finance and Innovation Act (WIFIA): Additional funding to be allocated (see **https://www.epa.gov/wifia)**
- Sewer Overflows and Stormwater Reuse Municipal Grants: Additional funding and appropriations will increase funding opportunities (see **https://www.epa.gov/cwsrf/sewer-overflow-and-stormwater-reuse-municipal-grants-program**)

LOCAL INVESTMENTS IN STORMWATER FUNDING

Identifying and implementing funding sources has become a necessary activity for local governments and utilities that are charged with managing stormwater programs. WEF's Stormwater Institute and other professional organizations, such as the National Association of Clean Water Agencies (NACWA), the National Association of Flood and Stormwater Agencies (NAFSMA), and others have developed publications and held workshops on how to develop and implement funding mechanisms. Their advocacy efforts have also elevated the discussion on the need for funding and the importance of affordability.

Federal stormwater investments complement local dedicated funding sources, such as user-based stormwater fees or special-service tax districts, that are essential to driving community investment in stormwater management. However, several innovative funding and financing approaches can help public dollars go further. For instance, the private sector can be a source of significant investment through public–private partnerships, municipal bonds, green bonds, and water quality or volume trading programs. In addition, incentive programs to partially fund green and gray infrastructure can further attract private investments. Innovative funding mechanisms, coupled with reliable traditional mechanisms (e.g., stormwater utilities, fees-in-lieu-of, drainage/taxing districts) provide local programs with reliable alternatives to fund their stormwater needs.

Perhaps the most intuitive way to extend public investments is by improving cost efficiencies associated with sustainable stormwater management. Many communities are using integrated planning and green infrastructure to reduce the cost of long-term control plans and other Clean Water Act requirements. Additionally, the stormwater sector should further advocate for large-scale investments in stormwater infrastructure. These investments can generate project savings through economies of scale focused on design and construction of SCMs. Further, by working at a watershed scale, communities can better identify low-cost opportunities to invest in stormwater infrastructure. Finally, working at a watershed scale enables communities to reduce costs by bundling multiple SCMs, encouraging regional projects, and incorporating SCMs into other planned community or resilience projects.



All the efforts described above and your organization's involvement with stormwater programs will help the stormwater sector continue to close the funding gap.

RECOMMENDED ACTIONS

ACTION 6.1

Continue to support the collaboration between communities and municipalities to identify stormwater funding needs, summarize the available funding, and determine the funding gap

The stormwater community must have a realistic understanding of the true costs of achieving sustainable stormwater management. This involves inventorying existing stormwater infrastructure within communities and estimating the maintenance or replacement costs for those systems. Communities also must determine the additional infrastructure or programmatic changes needed to meet regulations or community goals. Comparing these calculated costs to the funding currently available reveals the size of the funding gap.

Wastewater and drinking water sectors conduct funding gap assessments. The assessments are well-publicized, and the funding gap has become a centerpiece of local, state, and national communication efforts. A similar effort has started in the stormwater sector and needs continued support. The *2020 National Municipal Separate Storm Sewer System (MS4) Needs Assessment Survey* (WEF Stormwater Institute, 2021b) and the *Clean Watersheds Need Survey* (U.S. EPA, 2016b) provide some valuable information regarding this gap. However, additional coordination is needed to augment this effort to capture regulatory/compliance needs, operations and maintenance needs, as well as flood risk management and resilience needs of the stormwater sector.

The stormwater funding assessment also should consider potential and actual returns provided by stormwater investments, including ancillary social and environmental community benefits.

ACTION 6.2

Advocate for and build capacity to implement dedicated funding sources for stormwater management and articulate how stormwater management can meet the requirements of available grant and loan sources

Stormwater efforts potentially can align with and support many community priorities associated with state, federal, and nonprofit funding sources. Examples include grants that address transportation, climate resiliency, urban redevelopment, environmental education, and habitat protection. Often, stormwater management co-benefits are the subject of separate federal and state programs and investment opportunities. In particular, programs at the U.S. Departments of Agriculture, Housing and Urban Development, Energy, Transportation, and Interior as well FEMA, U.S. EPA, and the U.S. Army Corps of Engineers present opportunities for multi-benefit projects. Several private foundations and nonprofits also provide grants related to the water environment and community co-benefits.

Stormwater managers need resources to help identify and value the multiple benefits of stormwater management while identifying overlaps with various funding programs. These resources should articulate how stormwater project scope, design, construction, and long-term O&M activities can best meet the objectives and requirements of available funding sources. If properly aligned, these resources can help build local program skills and capacity to successfully advocate for funding at the state and local levels, prepare long-term financial plans, and improve awareness of state or federal funding sources available for stormwater-related projects. For example, recent legislation in Pennsylvania and New Jersey authorizing the creation of stormwater utilities or authorities has significantly increased the number of localities that now have dedicated funding sources.

Stormwater advocates should encourage better alignment of funding sources at the federal level to encourage stormwater projects that provide multiple community benefits. One example is leveraging the Clean Water SRF to expand investments in stormwater infrastructure, as recommended by U.S. EPA's Stormwater Infrastructure Funding Task Force.

Only a cumulative of 1.8% of SRF funds between 1988 and 2020 were used for stormwater management (U.S. EPA, 2016b). However, some states are updating their SRF programs to encourage these investments. Loans are made at low interest rates (0% to market rate) for terms of up to 20 years. All 50 states and Puerto Rico operate Clean Water SRF programs.

The private sector also should be encouraged to implement and maintain stormwater management projects that provide multiple benefits. These are SCMs that communities could count toward stormwater management goals while reducing the financial burden to local governments. Additionally, these controls would provide benefits to the developer. For instance, certain stormwater controls can add significant amenity value and provide points to help earn Leadership in Energy and Environmental Design certification. Research on urban stormwater management lakes, for instance, has shown that residents enjoy both tangible benefits, such as property value increases, and intangible benefits, such as recreation opportunities and a sense of community and belonging.

ACTION 6.3

Support communities in understanding and accessing the full range of stormwater funding and financing approaches

If the stormwater sector is to fund sustainable stormwater management fully into the future, it must use existing funding sources more efficiently, as well as explore new funding and financing approaches.

The sector must continue to advocate for dedicated user-fee-funded sources such as stormwater utilities, authorities, and/or tax districts. Sustainable stormwater programs need these dedicated and reliable long-term funding sources. Seed money for stormwater utilities could come from federal or state startup grants.

Municipal "water bond" measures could help finance community infrastructure needs. In July 2014, DC Water issued $350 million in taxable, green century bonds, marking several firsts for the utility and the municipal sector (WEF, 2014). Proceeds from the century bonds finance a portion of the DC Clean Rivers Project, a massive $2.6 billion effort to reduce combined sewer overflows, including some green infrastructure components. Further, the Water Infrastructure and Resiliency Finance Center, launched in January 2015, created a new type of municipal bond to encourage public–private partnerships. In the stormwater sector. Community-based public–private partnerships are an innovative financing option that is being tested in several municipalities. Public–private partnerships provide a way to accelerate and finance stormwater and green infrastructure investments. They can take many forms, including private property incentive programs and stormwater credit trading. Community-based public–private partnerships involve a contract between the public and private sector to arrange financing, delivery, and typically long-term O&M of integrated green stormwater infrastructure. These partnerships focus investments on green infrastructure approaches that create local jobs, encourage economic growth and revitalization, and improve quality of life in urban and underserved communities.

Other financing opportunities that leverage private capital include impact investments that are intended to generate social and environmental benefits as well as financial return.

Water quality and volume trading offers an innovative, market-based means of complying with Clean Water Act requirements. Through trading, regulated entities have the flexibility to reduce water pollution more cost-effectively by purchasing and using pollutant reduction credits generated by other sources in a watershed. Trading can accelerate the adoption of stormwater control measures by nonregulated entities and on private property. In-lieu fees is often combined with trading where permittees can either purchase credits or pay an in-lieu fee. In this context, regulated entities pay to compensate for unavoidable environmental effects. The money often is used to mitigate the environmental damage off site. Mitigation banking is a similar concept in which an independent third-party entity speculatively and proactively restores a site. It then sells the rights to that restoration to a company or entity that affected the environment.

In 2003, the national mitigation banking rule created the legal certainty and standards needed to encourage and leverage private investment and market participants. Thanks to a shared vision and a federal mitigation rule, there now exist more than 1000 mitigation banks, protecting more than 405 000 ha (1 mil ac) of wetlands (Dolesh, 2013). A similar vision is needed if water quality or volume trading is to be equally successful.

ACTION 6.4

Reduce the cost of sustainable stormwater management programs and stormwater control measures

If sustainable stormwater management costs less, capital and operating dollars will go further. As the stormwater sector matures, it must expand its mindset beyond customized project designs and, instead, develop standard project design templates for common SCMs and O&M practices. Even if these standard designs and O&M practices require tailoring to specific circumstances, a well-tested starting point can significantly reduce project costs and long-term maintenance costs.

The sector should share openly stormwater management designs and maintenance data to encourage economies of scale. The sector can achieve cost efficiencies by planning for and bundling multiple, similar stormwater projects. Bundling stormwater contracts for design, construction, O&M, and monitoring across projects and across jurisdictions within a watershed can save money.

Some communities are incorporating SCMs into other community projects, such as parks or transportation improvement projects, to

create opportunities for savings. Project-level and development regulations also should evolve to support and provide credit for more cost-effective regional stormwater projects.

Removing public perception or regulatory barriers to rainwater harvesting and other innovative SCMs will also reduce costs. For instance, developing the capacity to capture and use stormwater resources reduces pressure on community water supplies, especially in increasingly water-stressed areas, and saves energy associated with treatment and distribution. This effort also would require work to update or remove regulations, codes, and ordinances that hinder the use of stormwater as a resource.

As discussed in Action 6.3, nontraditional project delivery and market-based forces, such as public–private partnerships and stormwater trading schemes, are options for financing stormwater infrastructure. Additionally, these options often can reduce overall costs and time required to deliver stormwater management projects.

CASE STUDY 1

CHATTANOOGA'S RESOURCE: RAIN STAY ON VOLUME TRADING AND CREDIT PROGRAM

The City of Chattanooga, Tennessee, has a credits program to integrate development incentives into stormwater regulations and requirements. The credit program was established in 2013 and includes a credit coupon program and an in-lieu-fee (ILF) program to facilitate compliance with stormwater requirements and the MS4 permit. This program is volume based, and the city refers to the volume required to be captured as the "stay on volume" (SOV).

Eligibility Requirements: Redevelopment and new development on commercial properties in the City of Chattanooga are eligible to participate in either the ILF or credit coupon program. Developers work with the city and its consulting engineers to determine constraints for utilizing the ILF and credit coupon program. In most cases, ILFs and credit coupons can only be used for up to 50% of the required SOV without demonstrating a hardship. Credits are generated after 1 inch of rainfall volume is able to be retained on site through bioretention and can either be sold (price is not regulated; the market determines the price) or the developer can receive a credit coupon and apply the coupon to another site in the same watershed.

Regulatory Basis: The ILF and credit coupon program was developed in conjunction with the implementation of a stormwater fee (called a "water quality fee") for users of the stormwater system in 2009. The intent of the water quality fee and the ILF and credit coupon program was to assist the city with meeting MS4 requirements, improving water quality, and reducing the stormwater program costs of service. In the first year of the program, property owners were allowed to achieve 100% of their SOV through ILF or credits. However, this has since changed. Commercial properties undergoing redevelopment or new development are now required to achieve at least 50% retention on site, with the remaining portion able to be satisfied with either on-site mitigation or the purchase of credits or payment of ILF. If hardship is demonstrated, the city may make an exception and allow greater than 50% of the SOV to be mitigated via credits or ILF.

Program Specifics: The ILF and credit coupon program is only available for nonresidential parcels, but all property owners are subject to the stormwater fee. Credit coupons can be generated for retention exceeding 2.5 cm (1 in.) of rainfall volume up to 5.3 cm (2.1 in.) of SOV storage. These coupons can be used in full or in partial amounts at any time; they do not expire but must be used at the primary development site. Above 5.3 cm (2.1 in.) of SOV, pollutant loading is relatively low, so the benefit of installing additional retention begins to decrease. Stormwater management practices that can generate credits include permeable pavement, infiltration beds, infiltration trenches, bioretention, vegetated swales, vegetated filter strips, infiltration berms, and green roofs. If the retention requirement is exceeded onsite, SOV credit coupons are validated by the City of Chattanooga, and then credits can be sold by the developer or property owner. The funds from these sales are returned to the credit generator.

Stay on volume credit coupons are bought and sold on an open market, and pricing varies. The open market is self-regulating among developers and other generators and purchasers of the credits; the City of Chattanooga has no input over the sale and purchase of credit coupons, but it does track how many coupons are issued. Credit coupons are based on the SOV, and therefore pricing is evaluated by cubic foot of storage. The city has a feature that is unique in regard to "credit coupon multipliers." Credit coupons earned on redevelopment/retrofit sites can be applied at a ratio of 1:1 (installed:earned) anywhere in the city outside of the combined sewer system to meet another site's SOV. For new development sites, the ratio for application is 1.5:1, and can only be applied within the same watershed to meet another site's SOV. The intent of the multiplier is to put a premium on SOV credits installed on redevelopment projects but does not rule out the option for additional SOV installations on new developments.

All funds generated from the ILF program are deposited in the Public Stormwater Project Fund. This fund serves to partially or fully fund design, permitting, construction, and installation of public stormwater BMPs. The city reserves the right to pool fees from multiple sites to fund a project.

CASE STUDY 2

STORMWATER MANAGEMENT FEE, HAMPDEN, PENNSYLVANIA

Communities throughout Pennsylvania that have MS4s are challenged financially by aging infrastructure rehabilitation needs, MS4 permit requirements, pollutant reduction plan requirements, and the need to improve local drainage and reduce flooding. The combination of growing infrastructure needs, increasing regulatory requirements, and a reluctance to raise local taxes has led many communities to implement or to consider implementing a stormwater fee program.

Hampden Township was one of the first townships in Pennsylvania to implement a stormwater management fee to support the stormwater management program following passage of Pennsylvania Act 68 of 2013, which allows authorities to collect fees for the financing of stormwater planning, management, and implementation. The intent of Act 68 is to provide funding sources, other than taxes, for stormwater management. All single-family residential properties are charged one equivalent residential unit (ERU) and all nonresidential properties are charged multiples of ERUs based on its total impervious surface. An ERU is equal to the average impervious surface of single-family residential property in Hampden Township and is calculated to be 328 m^2 (3534 sq ft).

Township staff understood the importance of internal (elected officials and management staff) and external stakeholders (stormwater utility customers) and implemented a proactive public outreach approach that resulted in acceptance of the stormwater fee and the funded stormwater activities. The public outreach program started with workshops with the local authority and the formation of a Stormwater Advisory Committee (SAC) with representatives from the building community, homeowner associations, business community, environmental groups, as well as local and regional organizations and elected officials.

The SAC input together with feedback from key managers were incorporated in the development of the following tasks used to implement the stormwater management fee:

- Assess current conditions to determine revenue requirements.
- Address program priorities through integrated planning principles.
- Develop an effective outreach strategy/education process to continually inform the public and stakeholders during stormwater utility implementation using multiple media forms including website posting, newsletter, press releases, and bill stuffers with frequently asked questions.
- Facilitate a stakeholder advisory committee to provide feedback on program goals and priorities and make recommendations about the program.
- Calculate the ERU based on a detailed parcel analysis and evaluate alternative rate structures for the stormwater management fee.
- Develop steps for implementation that address budget, organizational structure, timeline for implementation, continuation of the internal and public/stakeholder outreach and involvement; finalize the development of the rate structure; develop a billing mechanism; prepare a credit policy; and adopt a stormwater management ordinance creating the utility and establishing the fee.

Hampden Township's credit policy included the traditional credits provided to commercial parcels served by SCMs. In addition to those credits, Hampden and several communities in Pennsylvania and other states are implementing nonstructural credits for property owners that are helping to reduce the stormwater effect. Examples of nonstructural credits include

- Education credits for in-kind services, such as education given by schools or churches that will support the education and public outreach requirements of MS4 permits.
- Pollution prevention credits that recognize, for example, property owner participation in nutrient management classes and reduced application of lawn fertilizers in grassed or landscaped areas of the property.
- Buffer preservation credits that are applicable to properties adjacent to streams that preserve the riparian buffer though an easement. Innovative credit programs increase acceptance of the stormwater management fee and can promote program stewardship.


ENGAGE
JOIN
PARTICIPATE
UNITE
INVOLVE

CHAPTER 7
ENGAGE THE COMMUNITY

Management of stormwater will consider the direct and indirect effects on the communities in which it is implemented. The public will have the opportunity to provide input on their desires and concerns as stormwater projects are developed. Solutions will help to address long-standing level of service issues, particularly in historically disadvantaged communities.

BACKGROUND AND CURRENT CONDITIONS

Proper management of stormwater is essential to the quality of life. Nuisance ponding, unplanned drainage networks, and poor water quality of local water bodies all affect the people of a community daily. In more extreme wet-weather conditions, stormwater runoff can result in flooding that disrupts transportation systems, damages property, and can result in the loss of life. This is particularly true in historically disadvantaged communities. These communities tend to live in locations that are older (and were thus constructed before current design standards) and have had the least amount of reinvestment. Thus, these locations may need the greatest amount of renewal and investment in the future.

Trust with the community is built by first listening to the concerns and priorities of the general public and stakeholders. Trust is reinforced when input is sought early and before decisions are made. Stormwater managers should seek to understand the audience's point of view. They must understand how municipal stormwater goals align with audience motivations and interests. Engagement should include educational components to improve the public's understanding of requirements, challenges, and options. To serve and gain the support of the public, stormwater professionals need to be able to speak comprehensively about all stormwater issues, and how these relate to public safety, aquatic habitat health, and aesthetics of the community.

Stormwater management is implemented on public and private property. This results in a wide range of constituencies, including anyone who is involved with the planning, design, construction, and maintenance of publicly owned space (rights of way or parcels) or private land, including a variety of governmental entities, developers,

property managers, and residents. As a result, stormwater managers often need ways to engage with and garner the support of relevant constituencies, as well as nongovernmental organizations (NGOs) and a variety of institutions. Success will be greater if communication is clear, instructions are straightforward, and benefits are explained.

The actions described below are intended to help stormwater professionals engage in two-way communication, support community-based solutions, and enlist the public in the broader support of stormwater goals.

RECOMMENDED ACTIONS

ACTION 7.1

Support stormwater managers in a broader understanding of constituencies and their areas of concern

To reach the people that they serve or seek to influence, stormwater professionals must invest in better understanding the various stakeholders. These constituencies may include public officials and decision-makers, other governmental agencies and departments, civic and environmental groups, grantors, property owners, and the general public. Stormwater management areas of concern are multidimensional. They are interrelated to community appearance, health, safety, and quality of life. An understanding of how disparities in stormwater management have played out in disadvantaged communities will provide a greater sensitivity to these communities.

Helping stormwater managers understand these areas of concern would include more opportunities to hear directly from affected constituencies and to access case studies that identify issues and or strategies that were both successful and repeatable. Identifying the range of constituencies that have an interest in stormwater management is also important in considering the effects collectively and individually on each group.

ACTION 7.2

Support stormwater managers in adapting effective strategies to hear from and communicate with their various stakeholders

Stormwater professionals need additional strategies and tactics to connect to their stakeholders; work collaboratively with other departments, agencies, and NGOs; and gain support for various undertakings. These communications need to be implemented in a way that builds trust and helps to improve conditions, without overcommitting to objectives that cannot be achieved. Managers need access to interdisciplinary materials that help explain the role that stormwater management plays in various types of issues. Multiple benefits of stormwater management as they relate to economic development opportunities, flood risk management, clean water, sustainable water supply, climate resiliency, green job creation, and community amenities such as parks and open spaces need to be better illustrated with case studies.

Specific items include

- Strategies to engage with stakeholders, such as identifying intermediaries, holding vision meetings, and clarifying areas of influence of the project.
- Tactics including tools to help frame the question, define the options or range of options, and best times to seek input.
- Materials that help to communicate how stormwater intersects with community concerns and help to explain the issues that stormwater can address.

ACTION 7.3

Engage with new communication methods

Social media has become a significant tool for communities to provide information and contact with the public. These platforms offer the opportunity to engage the community in conversations. Additional visualization tools improve the communication of highly technical data. Opportunities for real-time reporting of problems have become more significant and accessible. These include social media, 311 platforms, and problem-reporting applications.

ACTION 7.4

Encourage and support peer-to-peer information sharing between public officials on stormwater challenges, successes, and failures

Exchange opportunities between public officials and others involved with public engagement will support the development of a shared understanding of best practices. These forums often result in expanded approaches that can be applied more broadly.

CASE STUDY 1

SHAPE OUR WATER, SEATTLE PUBLIC UTILITIES

Shape Our Water, Seattle Public Utilities' (SPU) 50-year strategic plan (2021), aims to be a "catalyst to do things differently." The plan seeks to confront and respond to past harms, particularly systemic racism and injustice, and "shift how projects and programs are designed by moving toward a collaborative planning process that includes communities and cross-sector partners." This shift began with the making of the Shape Our Water vision itself. To develop the plan, SPU engaged a community team of co-creators who designed and hosted community engagement activities, distilled community values to inform the plan's goals, and helped develop a community vision for Shape Our Water. Over the course of 2 years, "community engagement activities were co-created with a variety of community members who shared their expertise in social and environmental justice, public health, storytelling, and sustainability. Shape Our Water prioritized engagement with historically underrepresented Black, Indigenous, and People of Color (BIPOC) groups and worked to incorporate and elevate voices from youth, artists, grassroots organizers, and representatives from community groups."

Due to the Covid-19 pandemic, the team had to think creatively about how to approach engagement differently. Engagement activities included an informational booklet introducing drainage and wastewater basics; three-part virtual gatherings with national and local thought leaders; lived-experience water stories told by BIPOC community partners and an intergenerational focus group; interactive walking tour maps; a two-day convening with public, private, and nonprofit professionals; and a project website that includes opportunities for community input. Activities such as the online informational booklet and virtual tours were done in part because they could still be conducted safely. The pandemic also meant that SPU and the community design team had to engage with community-based organizations differently. Rather than attending in-person events, they instead gathered community water stories. This ultimately allowed SPU to engage in a way that centered listening first. The team effectively adapted and found innovative solutions that still allowed for close, community centered partnership throughout the planning process. In result, Shape Our Water's vision and strategic goals deeply informed by and co-created with the community despite uncertain times. By engaging with many different individuals and community organizations as essential partners upfront, the Shape Our Water vision is a plan by and for those who it affects most.

CASE STUDY 2

VIOLA LIUZZO PARK, DETROIT, MICHIGAN

In 1982, the City of Detroit dedicated a neighborhood playground to the memory of Viola Liuzzo—a Detroit civil rights activist murdered in Alabama after the march on Selma in 1965. In 2014, the Viola Liuzzo Park Association initiated an effort to revitalize and redesign the park space for the community's enjoyment and to continue to honor Viola Liuzzo by educating the community about her sacrifice and legacy. The Detroit Water and Sewerage Department (DWSD) learned of the community goals and recognized the opportunity to integrate innovative green infrastructure features into the park's redesign to beautify the park while improving Detroit's water quality. Detroit Water and Sewerage Department initiated efforts to perform surveys and develop conceptual design of green infrastructure in 2015, coordinating with recreational improvements that were being led by the Detroit Parks and Recreation Department. The community was directly engaged in the design of the rain gardens and recreational amenities. Additional funding and support were provided by the Michigan Department of Natural Resources, United Auto Workers, and City of Detroit departments. The improvements included a walking path, a new play structure and fitness equipment, picnic facilities, and pickleball courts. The project was celebrated in a groundbreaking and dedication ceremony and a statue of Viola Liuzzo was added to the park in 2019 (Figure 5).

The project was unique in that it was an opportunity to support a community-led initiative to revitalize a park, draw multiple stakeholders and project funders together in a common objective, and achieve the dream of honoring a civil rights hero with a space of enjoyment for the people who live in the area today.

Figure 5. The Viola Liuzzo Park in Detroit, Michigan, Revitalized and Redesigned Through Innovative Green Infrastructure Features That Are Aimed at Improving Detroit's Water Quality and Beautify the Neighborhood Park

CHAPTER 8
PLAN FOR STORMWATER RESILIENCE

Communities will have a robust understanding of climate change effects on stormwater infrastructure, including changing precipitation trends such as extreme rainfall, drought, and snowmelt patterns. Communities will have the tools and funding to achieve greater resilience against these events through heightened awareness and advocacy of the integral role that stormwater management systems have in the larger resilience planning framework. The latest climate science will be integrated into proactive stormwater resilience plans and stormwater design, leveraging the use of advanced sensors, warning networks, and hydrologic and hydraulic modeling.

Climate change has resulted in increasing intensity and frequency of rainfall (and in some cases worsening droughts), creating more frequent and intense storm events that exceed the capacity of existing stormwater infrastructure. When compounded with increased urbanization, these events result in unprecedented flooding, loss of infrastructure service, public and private property damage, and loss of life. Drought conditions resulting in hardened soil and decreased short-term infiltration rates can amplify these effects and pose water-quality degradation due to lower base flows and concentrated pollutant loads between rain events. Communities need data, guidance, funding, and tools to adapt to climate change and make informed, resilient decisions with support from regional and state-wide efforts.

Effective communication is often the first step toward realizing success. Stormwater practitioners would benefit from adopting clearer terminology to describe the risk posed by these events and facilitate planning around them. The recurrence interval language of a "XX-year storm" is often misinterpreted as meaning that a storm will occur only once in XX years; this terminology can reduce the perceived risk. Instead, this definition means that a storm has a 1 in XX chance of occurring in any given year, regardless of prior occurrence. This misinterpretation is common and presents a barrier in understanding and planning for these events. The stormwater sector should develop updated standard terminology to convey this risk and facilitate discussion of appropriate design standards more clearly. Furthermore, the current classification of such events is often based on historic and outdated data. Academics, federal agencies, and consultants are constantly developing new climate projections based on recent scientific data, and our industry would benefit from a clear path forward to apply this science into practice.

Stormwater design standards also need a climate change refresh, shifting from single, synthetic events of specific rainfall duration and intensity to a broader range of events that facilitate a more holistic assessment. Relative to more costly capital improvements, these issues can be addressed now through science, policy, and communication.

The sector will also need to effectively communicate to stakeholders the cost-benefit relationship of resilient planning and design (Figure 6). In many cases, investment in mitigation efforts far outweighs the cost of non-action, and planners would benefit from a consistent way to message and quantify this relationship to improve funding and public support. At the same time, in some cases it's not practicable to design infrastructure to prevent a certain risk, and funds may be better spent recovering from such an event than preventing the effects. Practitioners will need an improved stormwater resilient toolbox of solutions, requiring combinations of green and gray, small and large, centralized and decentralized, and structural and non-structural mitigations. Planning for these solutions will require development of complex hydrologic and hydraulic models to test and size various resilience options that help communities adapt and holistically assess the effects of resilient planning to meet tomorrow's climate challenges.

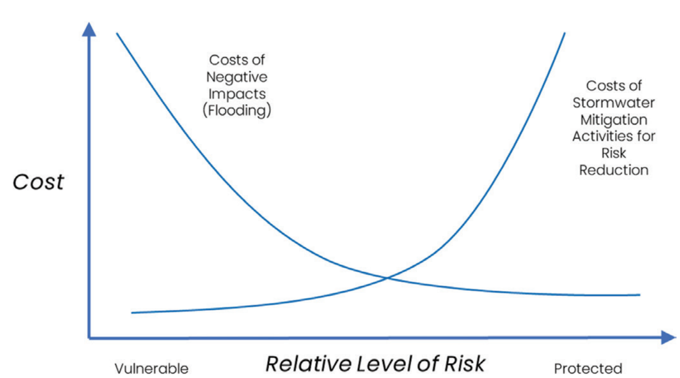


Figure 6. Relationship between cost-benefit and vulnerability.

RECOMMENDED ACTIONS

ACTION 8.1

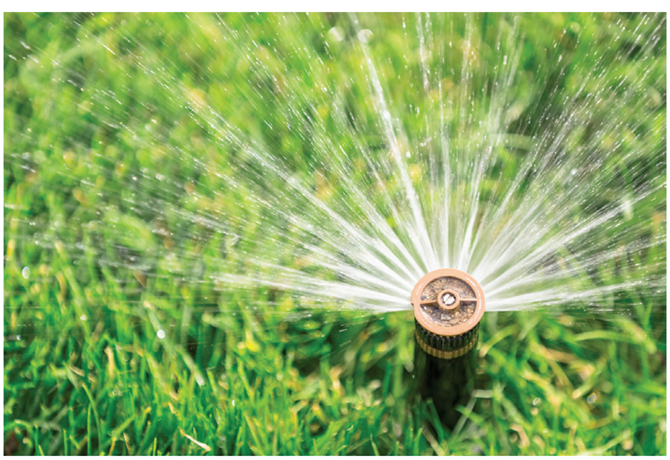
Integrate stormwater into more comprehensive resilience planning strategies

The level of study and investment in coastal and riverine flood risk reduction far outweighs the investment in traditional stormwater drainage infrastructure outside these typical floodplain areas. The stormwater sector needs to advocate for the same level of rigor to address stormwater resilience as is seen in other resilience planning efforts. Stormwater plays a critical role in comprehensive resilience planning and should not be looked at in a vacuum, but instead as a compounded risk when considering sea-level rise, coastal storm surge, and changing groundwater levels. The cost of protection of a certain area against future risk can vary greatly within a community, resulting in some areas being extremely difficult and costly to protect. Communities that are increasingly making difficult decisions regarding the concept of managed retreat, slowly giving high-risk areas back to nature with the recognition that they are increasingly becoming too costly and difficult to protect, will need to consider stormwater as part of this equation. This practice is already in use in coastal areas due to sea-level rise, and the stormwater sector would benefit from similar considerations. Communities can plan for this by working resilience into their solution toolbox and publications to support public consideration.

ACTION 8.2

Quantify and communicate the benefits of stormwater resilience mitigations relative to the cost of no action

One potential barrier to implementing more resilient stormwater management and infrastructure is the perceived value. The absence of a quantifiable cost-benefit analysis can make it difficult for communities to gain financial and community support for long-term investments. Although the likelihood of catastrophic events is low, the cost of recovery from such events often far outweighs the cost of mitigations. The National Institute of Building Sciences' *Natural Hazard Mitigation Saves Report* (2019) shows that federally funded grants provide a 7:1 benefit-cost ratio for riverine flooding. These analyses should be extended to non-riverine and coastal floodplain areas to support investment in stormwater drainage systems. The stormwater sector would benefit from a standardized, quantifiable way to communicate this cost benefit analysis.



With this information, communities can more appropriately plan for long-term resilience needs. A national program is needed to gather information from individual communities and analyses and produce standards and communication materials. Additional data collected (see Action 8.3) will help practitioners translate the costs of future flood events to continue to build the business case for resilient investment and facilitate future updates. On the local scale, as outlined in the American Flood Coalition's *Adaptation for All Guide* (2021), communities can use a three-step plan of 1) estimating past flood costs to build a business case for investment; 2) estimating future flood costs to appropriately plan future investments; and 3) partnering with neighboring communities, academic, and civic organizations to share data and coordinate a clear public communication plan.

Cost-benefit analyses should also consider climate equity, working to remove the current bias toward higher property values. As stormwater is further incorporated into this framework and traditional floodplains are expanded away from coastal and riverine areas, there will be greater variation in the populations at risk. Traditional focus on shoreline areas and depth-to-damage ratios does not account for more nuisance flooding that often occurs in older, underserved communities that often have had limited reinvestment in drainage infrastructure. Updated frameworks should incorporate this nuisance flooding to ensure investment is appropriated where it is needed most.

ACTION 8.3

Support deployment of advanced sensor systems and technology (drones, virtual reality, digital twins, etc.) at the community and national scale

The stormwater sector must improve our ability to quantitatively document extreme events, collecting data to assess effects and inform planning tools. In addition to expansion of current rainfall and in-sewer monitoring networks, surface-level sensors should be developed and deployed to capture flood depths and extents. Drone surveys, virtual reality, and digital twins can be used to better understand assets (probability and consequence of failure) and infrastructure and start linking asset performance to resilience metrics. These data will facilitate flood-risk mapping, improve climate change projections, and facilitate validation of hydrologic and hydraulic models. The use of technology will also help to improve management of stormwater systems and assets. A national effort, similar to the USGS stream monitoring and NOAA tide-level monitoring, can be implemented and coordinated across communities as identified in the WEF Stormwater Institute's *Recommendations to Improve the Stormwater Program in the U.S.* (WEF Stormwater Institute, 2021a).

ACTION 8.4

Expand stormwater flood warning systems

The stormwater sector should improve emergency preparedness and response by expanding the coverage and effectiveness of flood warning systems. Hurricanes are easier to predict than cloudburst rainfall events that develop much more quickly, making it difficult for those at risk to have ample evacuation warning. Existing tools developed by NOAA, FEMA, and USGS that focus on riverine and coastal flood zones should be expanded to cover areas outside these typical floodplains as more frequent, localized flash-flooding events occur. Urban and rural areas far removed from streams or beaches are at risk and often lack sufficient flood sensors and warnings systems. Expansion of the sensor network discussed in Action 8.3 will facilitate these improved warning systems (Figure 7). In the case of Hurricane Ida in September 2021, the deaths of multiple basement-apartment dwellers in inland portions of New York City may have been prevented if a more comprehensive warning system was in place to alert these communities outside of the traditional floodplain.

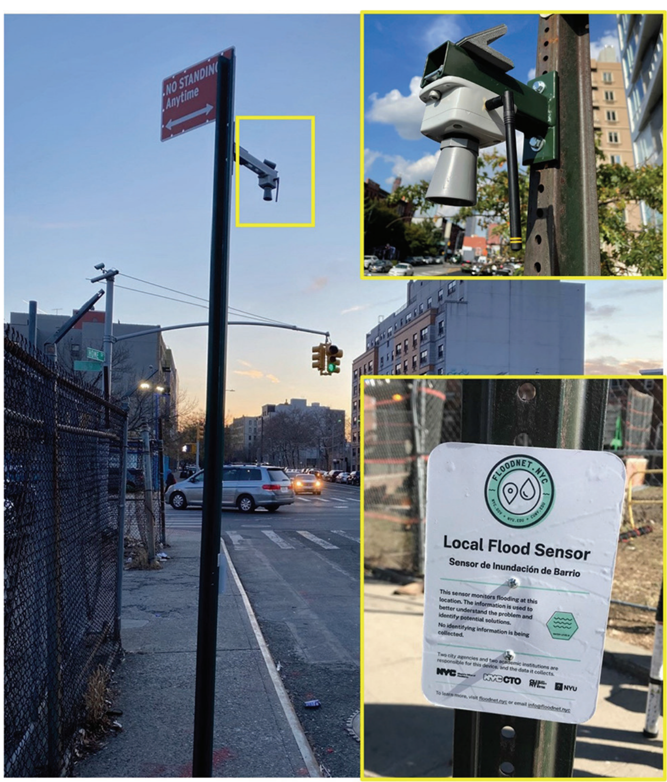


Figure 7. A FloodNet sensor deployed in NYC to capture quantitative flood event data. (reprinted with permission from FloodNet)

ACTION 8.5

Support standardization and consolidation of projected climate change effects on precipitation to create actionable data

Academics and scientists are conducting invaluable research to understand how our changing climate may affect future precipitation trends. Global and regional climate models are being downscaled to provide more local temporal and spatial resolution using a range of different approaches. However, as they stand, few of these studies can be readily used by the broader stormwater sector in analysis and planning because the results are difficult for stormwater practitioners to directly interpret and apply. The sector should support greater collaboration to standardize this research and make it more interpretable for use in updated planning and design guidelines. A plan to update projections more regularly and consistently should also be implemented as more data is collected (see Action 8.3) and climate change continues. These updates can include future projected intensity-duration-frequency estimates, commonly used to define design rainfall events, as was done in Chesapeake Bay Watershed and Virginia (Miro et al., 2021).

ACTION 8.6

Provide guidance on updating design standards, strategies, and level-of-service goals to incorporate climate change and resiliency

A clear next step to leverage improved and standardized climate science is to put this research into practice. Practitioners need guidance on how to revise and improve current design standards based on projected precipitation pattern changes. A standardized format of these projections (see Action 8.4) will help facilitate this process. Communities are encouraged to reassess current design standards more regularly and allocate funding for updates based on the latest climate science. Updated standards should consider a broader range of storm events for a more holistic assessment as opposed to a specific event (e.g., a 5-year, 24-hour storm may not be the most appropriate standard to assess flooding potential from a more intense, shorter duration 5-year, 2-hour cloudburst event). Design manuals should also consider the full suite of stormwater infrastructure solutions, including stormwater control measures (green infrastructure detention and retention practices, blue-belt projects, filters, etc.), piped and open-channel conveyance, and pumping stations.

In addition to adapting our design standards, we must also develop more resilient solutions. The sector has shifted from gray, man-made solutions to green, more nature-based solutions in recent years—a productive paradigm shift for managing water quantity and quality. Ensuring future resilience will require another shift, integrating a suite of green solutions sized for smaller storms with larger gray solutions to mitigate the most extreme events. The sector will need to communicate this shift to obtain the appropriate investment. For example, the misleading public perception that green infrastructure designed for typical-year rainfall events will prevent flooding under extreme storm events creates a barrier to right-sized stormwater solutions. Combinations of solutions will be required, mixing smaller distributed, site-scale mitigations with larger-scale infrastructure projects. Practices that are both green and sized for the extreme will be critical, such as stream daylighting (returning buried water courses back to more natural conditions).

Communities should also reassess level-of-service goals through a climate change and resilience lens. As extreme precipitation becomes more frequent, stormwater managers will need to reconsider their target level of service. Communities should not expect all stormwater infrastructure to perform to the same level of service regardless of the subjected conditions, but instead understand that part of building resilience means better responding to and recovering from extreme events. For example, if stormwater infrastructure in a community is designed to prevent all flooding under a 5-year storm, some degree of flooding in less-critical areas may be considered allowable under larger events like the 100-year storm. Incorporating this language into standards and communicating service goals will improve stormwater utilities' customer relations and provide a platform for continued discussion.

Finally, climate change will subject stormwater infrastructure to more frequent extremes, including intense rainfall and drought. As noted in a Chesapeake Stormwater Network technical memo (2020), communities are concerned with increased cost of maintenance on stormwater BMPs, citing concerns regarding pollutant removal and flood control functions. To combat this risk, the stormwater sector should support funding of research that quantifies this effect and provides guidance on developing more resilient asset management and maintenance plans.

CASE STUDY

NEW YORK CITY STORMWATER RESILIENCY PLAN AND FLOOD MAP

The New York City Department of Environmental Protection (NYCDEP) and Mayor's Office of Climate Resiliency took a significant step towards flash flooding resilience in May 2021 with the release of the NYC Stormwater Resiliency Plan and Flood Map. The Plan outlines goals and initiatives for the City to implement over a period of 10 years, including new policies for resilient stormwater management, the integration of future-looking climate change projections into long-term drainage planning, changes to the City's flash flood emergency response procedure, and an increased focus on public communications related to rainfall-based flooding.

The online Flood Map communicates rainfall-driven flood risk to the broad public. The flood maps are shared through an interactive website, allowing New Yorkers to assess flood risk and better prepare and plan for future events. To develop the Flood Maps, the NYCDEP completed a hydrologic and hydraulic modeling effort using 1D-2D models to quantify and map areas at-risk. Collectively, the Flood Map and Plan will help New Yorkers prepare for flooding events and help the City plan for emergency response and long-term management.

After the devastation caused by Hurricane Ida in September of 2021, the City issued The New Normal Report: Combating Storm-Related Extreme Weather In New York City. The report prioritized stormwater resilience initiatives, including bringing cloudburst management projects into neighborhoods vulnerable to flooding from heavy rain. To identify initial cloudburst neighborhoods, the City formed an Inter-Agency Cloudburst Task Force. The task force is led by the Department of Environmental Protection (DEP) and the Mayor's Office of Climate Resiliency and includes the NYC Departments of City Planning, Parks and Recreation, Emergency Management, Design and Construction, Transportation, and the New York City Housing Authority, among others. Together, these agencies are carrying out a multiyear approach to cloudburst neighborhood planning. The hydrologic and hydraulic models developed as part of the Stormwater Resiliency Flood Map are serving as a valuable input to this planning to prioritize locations.

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