EXTREME PRECIPITATION: PREPARING FOR AN UNCERTAIN FUTURE

Background Information

Museum of Science

Northeastern

Arizona State University

ECAST
EXPERT AND CITIZEN ASSESSMENT OF SCIENCE AND TECHNOLOGY

Section 1: Introduction to Resilience Planning

Engineers, farmers, business owners, and other community stakeholders have dealt with the impacts of weather and climate related events for centuries. Communities around the world are thinking about how to become more prepared and resilient to hazards such as sea level rise, extreme precipitation, heat waves, and droughts in a changing and uncertain future world. Increasing population and land use, combined with a changing climate, make these kinds of hazards increasingly relevant to civic planning. Most urban and regional planners are now conducting studies of their cities to identify threats to economic, environmental, and social development from weather and climate related hazards.

An increasing number of city planners are creating local "resilience plans," which go beyond identifying vulnerabilities to also assess the potential benefits, costs, and tradeoffs of a range of proposed resilience strategies. For example, New York City recently issued a report called "One New York: The Plan for a Strong and Just City," which states that "a changing climate, a growing population, aging infrastructure, and an evolving economy with increasing inequality pose challenges to our city's success and quality of life. Recognizing that we determine New York's future by how we shape our response to these challenges, our work includes actions to mitigate climate change while also preparing for the risks it presents, ensuring quality of life for generations of New Yorkers to come." [1] A few examples of actions outlined in the plan include: transforming buildings to be more flood-resistant, preparing neighborhoods across the city for better emergency management, and increasing the number of trees in the city to increase resilience against urban heat waves.

This packet provides basic information about an array of resilience strategies for dealing with the hazards of extreme precipitation and sea level rise. This information is provided to help you feel comfortable discussing elements of resilience planning for these hazards, which are faced by many communities. We will not be testing you on this information, but instead making sure everyone at your table has the same amount of information at the beginning of the event. The US National Oceanographic and Atmospheric Administration (NOAA)'s "US Climate Resilience Toolkit" is a valuable resource that helps planners think about actions that cities can take. At the upcoming forum, you and your fellow participants will follow the same steps that these resilience planners use to prepare their communities for weather and climate related hazards.

[1] OneNYC report, online at https://onenyc.cityofnewyork.us/visions/resilience.

Your group will learn about the vulnerabilities to a community, consider the tradeoffs of several possible resilience strategies that could help the community to adapt, and then create a resilience plan by thinking about the impacts, opportunities, and challenges that these kinds of strategies will present for different kinds of stakeholders. We hope you will learn about the difficult and complex decisions that face resilience planners in communities around our nation and our world.

The Five Steps to Resilience.
Source: NOAA Climate Resilience Toolkit.

Section 2: Vulnerabilities to Extreme Precipitation

Extreme Precipitation Overview

With the changing climate, many places in the world are experiencing changes in normal weather patterns. While some places are facing prolonged drought and intense heat waves, others are being impacted by rising sea levels and stronger storms. Experts around the world are thinking about ways to prepare cities, states, and countries for their changing climates and how it can affect citizens, the environment, and the economy.

The United States has been experiencing an increase in extreme precipitation events for decades. Extreme precipitation is when a place has significantly more than the normal amount of rain or snowfall in a few days, rather than spread out over many days during the year[2]. The northeast has had the most drastic increase with a 71 percent increase in extreme precipitation events since the late 1950's[3].

This rise in extreme precipitation events is connected to the increase in the average global surface temperature. This leads to more evaporation, and more air in the atmosphere[4] – like a giant humidifier. According to the National Wildlife Federation, over the next 100 years, every time the average temperature rises 1.8° F, the amount of water the atmosphere can hold increases by seven percent[5]. As more water becomes trapped in the atmosphere, an average rainfall can turn into an extreme precipitation event that leads to devastating floods.

The number of extreme precipitation events is predicted to continue increasing over the next century. Therefore, it is important to consider the impacts of intense rain or snow, and how we can become more flexible, adaptable, and prepared for future extreme weather events[6].

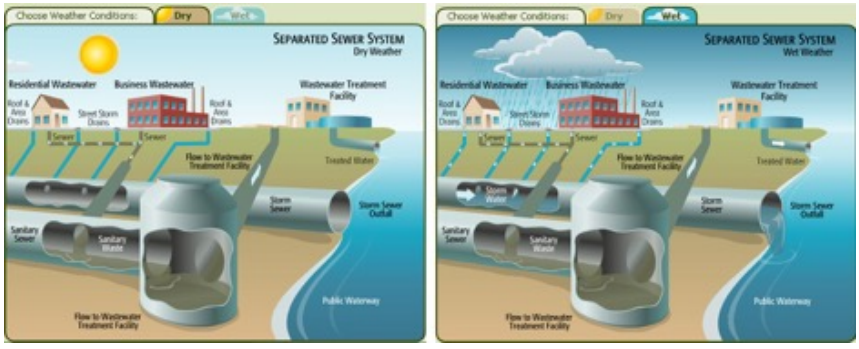
The following section outlines the social, economic, and environmental impacts extreme precipitation could have on a city. This will introduce you to some of the problems city officials are facing when considering resilience plans.

Social impacts

The societal impacts of an extreme weather event might seem obvious. Tornadoes, hurricanes, and intense storms can all lead to property damage, injuries or fatalities, and an interruption of communication and electrical systems. Extreme precipitation might not always affect people as immediately as a natural disaster can, but an abnormal amount of rain or snowfall in a short amount of time can create a multitude of problems.

[2] https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation
[3] http://www.climatecentral.org/gallery/maps/extreme-precipitation-events-are-on-the-rise
[4] http://glisa.umich.edu/climate/extreme-precipitation#footnote21_h1r8ecb
[5] http://online.nwf.org/site/DocServer/Climate_Change_and_Great_Lakes_Water_Resources_Report_FI.pdf (pg. 6)
[6] https://toolkit.climate.gov/regions/northeast

Flooding is one of the major issues to consider when thinking about extreme precipitation. Heavy amounts of rain or snow can cause sewer and wastewater treatment plant overflows, cause rivers to rise above their banks, and block roads with deep pools of water.



Henderson, Kentucky Water Utility

Some cities have a combined sewer system that collects stormwater runoff and sewage from homes and businesses in the same pipe system that runs to the wastewater treatment plant. While this system may have been adequate years ago, now the systems are becoming consistently overwhelmed during heavy rainfalls, causing the untreated water to overflow into basements, streets, and nearby waterways[7]. Many cities have restricted the construction of combined sewers and are building sanitary sewers instead to help keep the system from overflowing. Sanitary sewer systems use a separate pipe system that collects wastewater and carries it to the wastewater treatment plant, and another system of pipes collects stormwater and filters it into the ground or the nearest waterway[8]. Although this helps to take stress off of the system and decreases the likelihood for a sewer overflow, sanitary sewers are not a perfect solution. They could still take on extra water during heavy rainfall events and overflow, or the pipes could crack and allow the wastewater to be released. However, sanitary sewers can be a worth-while investment to keep the city from being contaminated by wastewater, with the proper city planning.

Keeping wastewater from entering buildings and water ways is important because the untreated water carries various bacteria and viruses that can cause anything from stomach aches to serious diseases if ingested[9]. Not only can the water itself cause health problems, but if indoor flooding is not properly taken care of, mold can grow and cause respiratory issues for those living or working in the building that was flooded.

[7] https://toolkit.climate.gov/regions/northeast/people-and-communities
[8] https://toolkit.climate.gov/topics/built-environment/water-and-wastewater
[9] https://www.epa.gov/sites/production/files/2015-10/documents/sso_casestudy_control.pdf

Boston Water and Sewer Commission

In 2014, Vermont experienced a downpour of rain that overwhelmed one of the state's aging, but recently upgraded, wastewater treatment plants. Due to a malfunction at the plant, approximately 100,000 gallons of partially treated wastewater were released into a local river[10]. Tests showed the concentration of E. Coli (*Escherichia coli*), a bacterium commonly known to cause gastrointestinal illnesses, in the river was 10 times the maximum amount recommended for human exposure, according to the Vermont Department of Health. Planning for incidents like this, where partially treated wastewater can enter waterways used recreationally and/or as drinking water sources, is just one important aspect of becoming more resilient against the impacts to health and wellness during and after extreme precipitation events.

Sewer overflows can become a huge issue in some cities, but are not the only problem arising from extreme precipitation. When the infrastructure that connects people is disrupted, it can leave them without electricity, transportation and communication.

Most roads and powerlines were built based on historic weather data because predicting future weather conditions can be difficult. However, this means that the infrastructure is vulnerable to extreme precipitation events that were not planned for years ago[11]. Without proper drainage, roads flood and become impassible to residents and emergency personnel. Flood water can last for days, seeping into homes, covering roads and blocking any way for people to escape or receive aid. Some people may even try to pass through flooded streets in their cars, which can be extremely dangerous. In high water, cars will break down and leave people stranded with no choice but to get out of their cars and try to get to high ground. However, rushing water is strong, and six inches of moving water can make an adult fall[12]. To avoid incidents like these, cities may need to update their road systems to increase water drainage, and be sure that if a flood is coming, all residents can be properly informed.

[10] http://www.burlingtonfreepress.com/story/news/local/2014/07/11/storms-challenge-wastewater-treatment-plants/12539441/
[11] http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf (pg. 53)
[12] http://environment.nationalgeographic.com/environment/natural-disasters/floods-safety-tips/

Severe storms and flooding can also damage power and communication lines[13]. Without electricity, air conditioning units, refrigerators, and traffic lights won't function. If the electricity is down, people could overheat, become sick from eating spoiled food, and even get into car accidents. Damaged communication lines can also cause major issues. People will not know if they need to evacuate, where they need to go, if their loved ones are okay, and if it is safe to leave their homes. These problems often affect vulnerable populations, such as low income families who might be located in isolated areas, as well as the elderly and children who are more susceptible to infections and overheating.

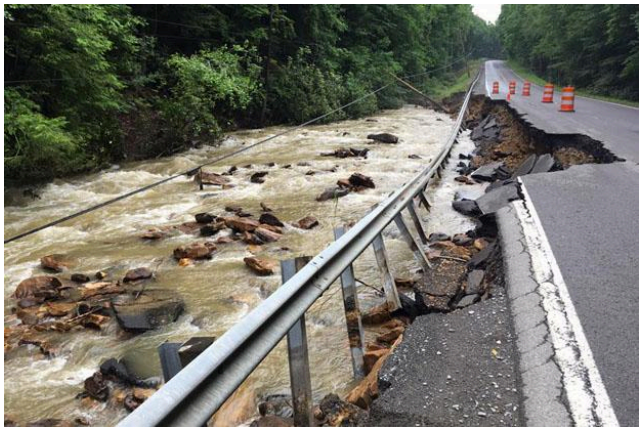
Kaldari, public domain via Wikimedia commons

Rain is not the only culprit when it comes to infrastructure damage. Snow can also affect roads, power lines and homes. With winter weather becoming more mild, snow events are usually wetter, which causes dense, heavy snow to falling on trees, houses and powerlines, and possibly causing severe damage.

In April of 2016, Houston's "Tax Day Flood" was considered a 1 in 500-year event[14] with an average of 12 – 16 inches of rain falling in 12 hours, and continuing for two full days[15]. Rivers flooded several feet past their maximum flood zones, almost 7,000 homes sustained flood damage, hundreds of thousands lost power, and eight people were killed after their vehicles flooded on the road[11]. Many residents did not know the rain was going to be so intense and had to be rescued from their flooded homes by inflatable rafts and boats, and moved to higher ground. If this storm was a 1 in 500-year event, what's next? After losing lives, and sustaining nearly $5 billion in property damages[16], Houston and similar cities may need to start planning for even more extreme precipitation events in the future.

[13] http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf (pg. 10)
[14] http://www.chron.com/news/houston-texas/houston/article/Historic-Texas-flooding-events-and-Houston-this-7255052.php
[15] https://www.scribd.com/doc/310404129/Immediate-Flood-Report-1-April-17-18-2016-1
[16] http://www.cnn.com/2016/04/19/us/houston-texas-flooding/

Economic impacts



NOAA Climate Toolkit

Major precipitation events often lead to major floods if the area is not prepared. Water levels can rise and move quickly, leaving little time for residents to properly block the incoming water with sandbags, or if necessary, evacuate the area. Rushing water can accumulate debris from trees, buildings, and roads and infiltrate homes causing millions of dollars in damage. With some storms like tornados, the impact is swift and definitive. However, extreme precipitation can lead to flooding that lasts for days, and will take even longer to dry out of buildings and homes. The cleanup after a severe flood could cost hundreds of millions of dollars, and impact the city or state's economy for the long run.

Hurricane Katrina was one of the most catastrophic hurricanes to impact the United States[17]. In August of 2005, New Orleans was hit by a category 3 storm that broke most of their protective levees and flooded 80 percent of the residential city[18]. With anywhere from one to 10 feet of flooding along the gulf coast, more than 1,800 people were killed, and one million people were displaced from their homes, the majority of whom couldn't return until a month after the water receded[19]. The city is still trying to build back their infrastructure and recover economically from the devastating flooding that infiltrated office buildings and neighborhoods. With an economy based on tourism and exporting petroleum, New Orleans was hit hard. Businesses were forced to relocate when the damp walls grew mold, the Port of New Orleans was damaged, and oil production and refining operations were shut down. The Gulf coast is one of the major oil producers in America with about 25 percent of the nation's oil coming from their refineries. After Hurricane Katrina, 95 percent of the Gulf's oil production had to stop due to employee evacuations, which increased gas prices across the country[20]. It has taken many years, but New Orleans is recovering. The number of tourists declined by over half after the storm, creating a gap in the amount of revenue the city was producing. However, a decade later, the number of tourists nearly returned to pre-hurricane levels, and those that are visiting are spending even more money than before[21]. New Orleans will never be the same as it was before Katrina. It has been rebuilt to be safer, stronger and more resilient in the future.

[17] http://content.time.com/time/specials/packages/article/0,28804,2070796_2070798_2070785,00.html
[18] http://www.cnn.com/2013/08/23/us/hurricane-katrina-statistics-fast-facts/
[19] http://www.datacenterresearch.org/data-resources/katrina/facts-for-impact/
[20] http://abcnews.go.com/Business/HurricaneKatrina/story?id=2348619&page=1
[21] http://fortune.com/2015/08/27/hurricane-katrina-new-orleans-tourism/

Environmental Impacts

Just as extreme precipitation can affect social and economic aspects of society, it can also affect the environment. Intense rain and snow events often lead to runoff that pollutes local water sources used for irrigation and drinking water, and destroys habitats. With the highest amount of extreme precipitation events occurring in the Northeast and Midwest United States[22], city planners and leaders are being challenged to construct ways to protect their vital rivers and lakes from the effects of extreme precipitation.

NOAA Climate Toolkit

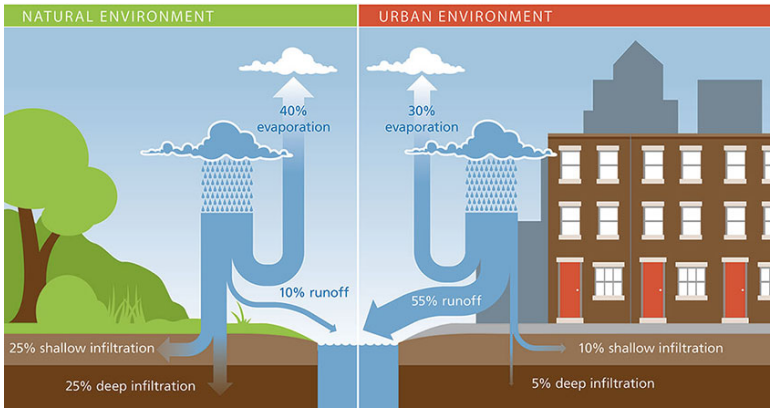
Over time, humans have changed the course of rivers to fit the needs of a growing population. Many rivers have been narrowed, redirected and dammed in order to have space for farming and building. Bodies of water naturally ebb and flow with the change of season, and some even need a periodical flood or two to remain balanced. However, many floodplains (or flat land next to a river that is prone to flooding[23]) have been shortened and built upon, creating problems for the people who live there. With fewer, more intense precipitation events, the river can rise multiple feet above the flood levels, inundating dry land and pavement that can't absorb the excess water. Levees and dams have been built to try to control flooding and protect riverside neighborhoods, but in the cases of extreme precipitation, these barriers often fail, and allow water to flow into streets and homes. When this flooding occurs, it disrupts habitats, creates polluted runoff, and increases sediment and nutrient concentrations - all of which can impact downstream water quality. Before human influence, natural bodies of water could recover from incidents of pollution and disruption. However, with so much physical and chemical change, and an increase in extreme weather, these natural fresh water systems could be impacted for the long term[24].

One problem that many river ecosystems are facing is the impact that rushing flood water has on the fish populations. Some communities depend on fish as a food source and to bring in money. In Alaska, salmon fishing is a $1 billion industry[25]. Recently, a 1 in 100-year storm caused major flooding of a river, killing almost all of the salmon and their eggs. The flood also wiped out most of the invertebrates, and completely destroyed the beetle and shrimp species living in the river. The salmon were finally back to normal population numbers six years later, but the other species struggled to bounce back from the flood[26]. Many other rivers and lakes

[22] https://toolkit.climate.gov/topics/water-resources
[23] https://www.nationalgeographic.org/encyclopedia/flood-plain/
[24] http://www.britishecologicalsociety.org/flooding-in-the-uk-ecological-impacts-and-an-ecosystem-approach/
[25] https://www.wildsalmoncenter.org/2016/10/17/salmon-floods-learning/
[26] The-Impact-of-Extreme-Events-on-Freshwater-Ecosystems_FullReport.pdf (pg. 34)

are experiencing the same problems. Rivers in the Northwest are experiencing intense amounts of rain and snow melt that leads to rivers flooding and "scouring" the bottom of riverbeds, killing most of the fish eggs laid there. Precipitation is also happening earlier in the spring, changing the normal peak flows for rivers that affect typical fish migration and mating rituals.

Another problem facing freshwater ecosystems is stormwater runoff. When extreme precipitation is followed by periods of drought, the pollution that runs into the water can cause harmful algae blooms that lead to de-oxygenated "dead zones." In Lake Erie, water levels are currently lower than average and are expected to continue to drop in the next few years. Heavy rainfalls are flooding cities and farms, carrying nutrients and wastewater into the lakes. With less water in the lakes, the water quality can be highly affected by the pollution, and lead to an increase in problematic algal blooms[27]. Walleye fishing is a popular recreational sport in the regions surrounding Lake Erie, but with the changing lake ecosystem, the walleye has become threatened. The walleye's main prey item is highly susceptible to dead zones, and could be killed in a large bloom, eventually leading to a decrease in the walleye population that the economy depends on[28].



Philadelphia Water

The entire nation is experiencing changes in weather patterns. In some places, extreme heat or drought is the biggest issue. In others, it is sea level rise or extreme precipitation. City officials everywhere are thinking about ways to deal with all of these changes to protect the people who live there and the environment they depend on from the repercussions of a changing climate.

Section 3: Potential Resilience Strategies for Extreme Precipitation

The effects of a changing climate can be devastating, but there are ways to protect our cities from hazards like extreme precipitation. While scientists might be able predict what the weather will be like a week from now, it's extremely difficult to predict what the weather might be next year, in 50 years, and in 100 years. However, city planners and leaders will have to use these predictions to plan for more intense storms, heavier rainfall, warmer winters, and drier summers.

[27] http://www.nwf.org/Wildlife/Threats-to-Wildlife/Global-Warming/Effects-on-Wildlife-and-Habitat/Great-Lakes.aspx
[28] http://www.nwf.org/Wildlife/Threats-to-Wildlife/Global-Warming/Effects-on-Wildlife-and-Habitat/Walleye.aspx

The following section outlines a select number of possible strategies that can be used to help prepare cities for extreme precipitation events. While there are many ways for cities to prepare, this section will give you an overview of some of these options and the social, economic and environmental impacts of each. This information will prepare you to make your own resilience plan for the city, based on the discussion you will have with your table on the day of the event about the strategies and their impacts on the city.

KEEP IT OUT - Improve Water Management Systems

Sewer Separation

Combined sewer systems, or systems that carry sewage water and stormwater together to the wastewater treatment plant, often overflow during a period of heavy rainfall and cause a mixture of sewage and stormwater to flow into homes, streets, and waterways. Some cities have already updated their systems to include areas with sanitary sewer systems, or systems that carry wastewater and stormwater separately. However, updating the sewer system can be costly and extremely inconvenient for older cities. For some cities like New York City and Philadelphia, this process might not be feasible. Replacing the sewer lines can disrupt a city's road system for years, causing frustration and annoyance among commuters. Updating the system would help decrease the probability of future wastewater backups into homes, roads and waterways, but some cities may have to consider other modes of adaptation for extreme precipitation.

KEEP IT OUT

Keep It Out involves improving water management systems through actions such as separating sewer systems, updating the local wastewater treatment plant, building stormwater basins, and protecting public transit systems.



ECONOMIC ★½

Sewer separation is costly and extremely inconvenient for older cities, likely costing billions of dollars and causing widespread disruption. Replacing aging infrastructure and removing dams is also expensive. Retrofit projects, such as barriers to protect water from entering subway tunnels, are a cost-effective management option but are only a temporary solution.

ENVIRONMENTAL ★★★★

Protecting wastewater treatment plants makes it less likely for plants to flood during storm events, preventing pollution from entering waterways. Stormwater management also helps prevent nutrient pollution, which leads to unwanted consequences such as algal blooms and fish kills.

SOCIAL ★★★★

Even though construction of stormwater management systems is disruptive, separating sewer systems prevents wastewater from entering homes and buildings, protecting residents from pathogens and mold. If built strategically, recreation can be incorporated into stormwater management strategies, like allowing outdoor theaters to collect water during a flood.

Read through this box to learn more about the Keep it Out strategy. You will use this information during your discussions at the forum.

Wastewater Management System

Some cities have prepared for an increase in heavy precipitation by updating, relocating or protecting their local wastewater treatment plant. When planning the nearly $4 billion update to the Boston, MA wastewater treatment plant (located on Deer Island in the Boston Harbor), the Massachusetts Water Resources Authority investigated the plant's possible vulnerabilities to extreme weather events and sea level rise, ultimately deciding to raise the most important parts of the plant 1.9 feet to avoid inundation[29]. Iowa took an alternative approach by decommissioning their flood-prone wastewater treatment plant along the river in Iowa City.

[29] https://www.epa.gov/arc-x/boston-raises-wastewater-facility-avoid-inundation

They increased the capacity of a second plant located off the floodplain to accommodate the city's needs, and plan to turn the newly vacated land from the decommissioned plant into a recreational park[30]. Washington, D.C., had limited options for improving their wastewater treatment plant and decided the best option, even when considering the uncertainty of weather events, was to build a 17 foot seawall (three feet more than the recommended height) to protect the Potomac River facility[31]. These changes can be costly and time consuming, but in many cases, improve the long-term quality of public health and the environment.

Stormwater Management System

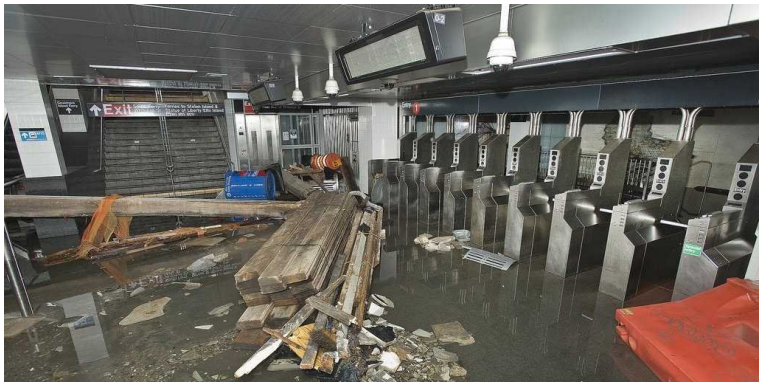
With or without a sanitary sewer system, there may still need to be plans in place for dealing with excess water during extreme precipitation events. It is difficult to predict the amount of rain the area will receive a month, a year or a decade from now, so it is possible for even newly built stormwater pipes to be overwhelmed. If the pipes become overwhelmed, and flooding occurs, there are options to make sure the water does not damage homes, buildings, and important infrastructure.

One model for this type of stormwater management is Rotterdam in the Netherlands. Rotterdam is not only surrounded by water, but has experienced unpredictable and increased rainfalls. To keep the water and debris from damaging buildings during extreme rainfall events, they have created ways to capture the water and flood areas of the city that are built to recover from such flooding[32]. Parking garages, parks, and city squares are equipped to retain water and slowly drain away in order to keep water from flooding the streets[33]. The amount of rain needed to flood these structures may only come a few times a year, so the majority of time they will be used for their original purposes.

De Urbanisten

[30] https://www.epa.gov/arc-x/iowa-city-iowa-closes-vulnerable-wastewater-facility
[31] https://www.epa.gov/arc-x/blue-plains-wastewater-facility-washington-dc-reinforces-facility-against-floods
[32] http://www.rotterdamclimateinitiative.nl/documents/2015-en ouder/Documenten/20121210_RAS_EN_lr_versie_4.pdf (pg. 48)
[33] http://www.waterpleinen.com/Watersquares.pdf

Upgrades to public transit and/or highway systems



New York City Dept. of Transportation

Without functioning public transportation systems and highway systems, residents might be stranded in their homes and emergency officials could be delayed or blocked from reaching people who need help. In 2012, Hurricane Sandy flooded New York City and its transit systems. Subway stations were completely underwater, train tracks were destroyed, and roads were badly damaged. The only thing holding back water in some cases was plywood and sand bags stacked in front of subway entrances. Luckily, most of the subway services were up and running five days after the storm, but some other aspects of the transit system cost billions[34] of dollars to fix. By building sea walls to protect tracks and roads, using metal and plastic subway station coverings, and raising transportation signals, cities can become more resilient to extreme precipitation and avoid paying to fix damages later[35]. These updates can be expensive and disruptive to daily commuters and other city-goers, but could help save valuable infrastructure in the long run.

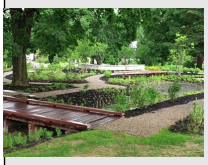
Some people may be opposed to these options because they can be inconvenient and costly, such as moving cars to the upper levels of a parking garage during a storm, or investing in infrastructure updates. However, investments in new building projects that create space for water could keep the city safer and save money on damages in the long run.

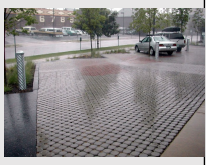
[34] http://www.businessinsider.com/heres-how-nycs-subway-system-has-come-back-from-hurricane-sandy-2013-10
[35] http://www.nyc.gov/html/sirr/downloads/pdf/final_report/Ch_10_Transportation_FINAL_singles.pdf

SOAK IT UP– Create Solutions to Increase Water Drainage

SOAK IT UP

Soak it up involves creating solutions to increase water drainage by using the earth's natural resilience capabilities. These strategies include vegetative solutions such as green roofs and rain gardens, as well as using porous pavement to allow water to filter into the ground.





ECONOMIC ★★★★

Green infrastructure is cost effective and has the potential to attract residents and businesses to an area due to its aesthetic quality. New building projects such as constructing roads and sidewalks with porous pavement may create jobs.

ENVIRONMENTAL ★★★★★

Green infrastructure reduces runoff into waterbodies and treats runoff water by filtering pollutants. At the same time, it allows nutrients to be recycled and taken up by plants, leading to increased plant growth. In addition to helping absorb excess water during extreme rainfall events, green infrastructure can help lower carbon emissions, increase oxygen production, and lower urban heat.

SOCIAL ★★★½

Parks, green roofs, and rain gardens create opportunities for recreational space. This strategy also avoids the disruptive construction to install larger storm pipes. Some of the potential hazards from increased vegetation include infectious pathogens carried via rodents, ticks and mosquitoes, as well as increased pollen allergens.

Read through this box to learn more about the Soak It Up strategy. You will use this information during your discussions at the forum.

Enhanced natural hydrology/vegetative solutions

Cities across the nation have been going "green" for years by conserving and using alternative energy. However, many cities are now adapting a new form of "green" that includes increasing the amount of green infrastructure along roads and sidewalks, in suburban neighborhoods, and through the urban sprawl. Green infrastructure can include anything from green roofs, bioswales and rain gardens - anything that increases green ground cover rather than the typical grey infrastructure of the city.

As one of the oldest cities in the United States, Philadelphia's aging combined sewer system has been overflowing and polluting the waterways for years. To help create a healthier community that's more connected to nature, Philadelphia is working hard to create more green infrastructure in their urban environment by building rain gardens, stormwater wetlands, green roofs, stormwater tree trenches and more[36]. Uprooting streets to rebuild the sewer system would be nearly impossible in such a dense city like Philadelphia due to the cost and general inconvenience of blocking off streets. Instead, city planners and leaders can look to green infrastructure to help absorb, drain, and filter any excess water from an intense rainstorm, and take some stress off of the sewer system. While green infrastructure may not solve the flooding problem, it is cost-effective, creates more recreational space, absorbs more CO2, and is immediately effective, rather than taking years to build like new pipes would.

Reducing runoff through porous pavement or other changes in land cover

While green infrastructure can help to keep the city cooler while increasing water and CO2 absorption, cities still need grey infrastructure to safely and properly operate. This grey infrastructure is impervious, meaning water cannot filter through, and instead runs off into the nearest drain or waterway, or ends up flooding the road. By building roads and sidewalks with permeable materials, water will be able to soak into the pavement and filter down into the ground or stormwater system. Porous pavement typically costs more to install, requires monthly cleaning, and can't be used in high traffic areas due to clogging issues, but it also limits

[36] http://www.phillywatersheds.org/what_were_doing/green_infrastructure

runoff, filters stormwater into the ground which takes stress off of the sewer system, and does not freeze because the snow melts into the pavement. Porous pavement cannot be used in high traffic areas like highways, but it can be a good solution for places that have to be paved and are vulnerable to flooding. Porous pavement tends to be used on the side of the road for parking and in parking lots to soak up excess water.

On a household level, homeowners can purchase rain barrels, or a more complex version called a cistern, to collect stormwater runoff from their roofs and use it to water the garden, wash the car, or simply allow it to filter into a rain garden. Experts typically suggest that homeowners have two 55-gallon rain barrels because a storm that produces one inch of water in a rain gauge can lead to over 500 gallons of water falling on a 1,000 square foot roof[37]. A rain barrel usually costs less than $100 and could save money on water bills in the long run if the collected water is used efficiently.

INFORM THE PUBLIC – Enhance Public Safety, Communication, and Knowledge

Over the last decade, new, more complex, and accurate satellites have been able to better predict what kind of weather might affect a region, but even this new equipment can't forecast far into the future. Not only can future predictions be difficult, but weather patterns can change quickly, meaning what was predicted to be a small rainstorm can turn into an extreme precipitation event within the same day. No matter how prepared the city is for an extreme precipitation event, it is still possible that the built-in strategies and infrastructure will fail, leaving the public in danger. Because of this, public safety, communication, and knowledge must be top priorities when planning for an emergency event.

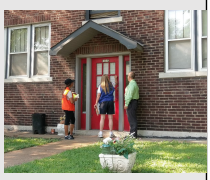
Relocating or reinforcing electricity and communications lines

Society today relies on energy for keeping food cold, heat or air conditioning on, maintaining external communications, and for providing traffic signals. If houses, businesses, and emergency centers are not prepared for flooding, it's likely that their power will be cut off for hours or days due to flooding, ice, or wind knocking out power lines and boxes. To prepare

INFORM THE PUBLIC

Inform the Public involves enhancing public safety, communication, and knowledge about extreme precipitation events. This means keeping the power on so that communities are not isolated, as well as making sure the public is educated about the risks and knows where to go in case of an emergency.





ECONOMIC ★★★

Damage to electricity systems is costly to repair, and burying lines is expensive and makes lines difficult to access if there is a problem. However, there is little to no cost to implement shelter and education programs but a large benefit from preventing loss of life.

ENVIRONMENTAL ⊘

Inform the public has little to no measurable environmental impact. A problem may result from managing trees or burying power lines, which could disrupt habitats and cause damage to tree roots.

SOCIAL ★★★★★

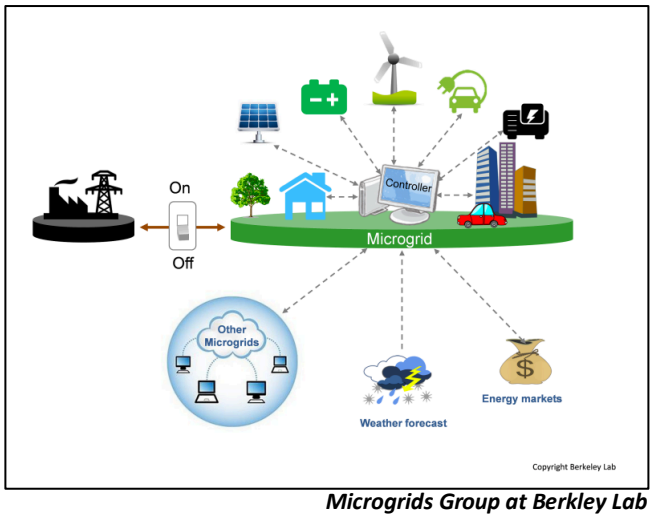
Protecting or relocating power and communication lines protects residents by keeping them connected to one another. When combined with education, this improved communication helps to keep people informed about the risks of extreme precipitation so they can remain safe. Additionally, refuge centers provide shelter, safety, and protection for people during storms.

Read through this box to learn more about the Inform the Public strategy. You will use this information during your discussions at the forum.

[37] http://www.mapc.org/resources/low-impact-dev-toolkit/cisterns-rain-barrels

for more extreme weather in the future, some cities are moving power lines underground, installing power boxes above the flood level, and even creating microgrids that can be fully functional even if disconnected from the city's main power grid.

Moving communication and electrical lines underground can help keep the lines safe during extreme winter weather, but the lines can still be corroded by flooding, and can cost up to 14 times more than installing traditional above ground lines[38]. They are also more difficult for workers to reach, meaning it could take up to 60 percent longer for issues to be fixed[39]. Powerlines are not the only element of infrastructure that is vulnerable to extreme weather. For a small price, electrical boxes, panels and controls could all be elevated above the flood level to avoid being inundated with water and interrupting service. Some regions are even creating microgrids that can allow certain sections of a city to disconnect from the main power grid and run on its own energy generation source in order to maintain critical services if the larger grid is affected by extreme precipitation or storms. In Connecticut, the Department of Environment and Energy awarded various towns up to $3 million to create microgrids that will support police and fire stations, cell towers, schools, gas stations and emergency centers[40]. After Hurricane Sandy, 7.9 million homes and businesses were without power[41]. While microgrids can cost millions of dollars to install, in the wake of a devastating storm, they can keep important household utilities on and businesses can keep working, ultimately keeping the city safe and operational while the main power grid is being repaired.



Microgrids Group at Berkley Lab

These changes can be beneficial to society by allowing residents to maintain their everyday lives, but they can also be costly. Some regions may start becoming more resilient against extreme weather and extreme precipitation simply by monitoring and trimming trees around power lines. By keeping the lines free from branches, it is less likely that heavy snow, ice, or winds will cause branches to break and fall on the lines, and is a less costly, but less effective, option than moving powerlines or creating microgrids.

Improvement to emergency management

Not all of the solutions to protecting a region against flooding work 100 percent of the time. Levees can break, porous pavement can become clogged, and green infrastructure can be inundated with water. In cases like these, it is likely that people will need to leave their homes

[38] http://www.elp.com/articles/powergrid_international/print/volume-18/issue-2/features/underground-vs-overhead-power-line-installation-cost-comparison-.html

[39] http://www.cnn.com/2014/02/12/us/winter-storm-power-lines/

[40] http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/40cb9336a459e06185257bb20052b8ff/$FILE/Microgrids%20Funding%20Chart%20Final.pdf

[41] http://www.cnn.com/2013/07/13/world/americas/hurricane-sandy-fast-facts/

behind and evacuate the area. But where do they go, and what roads to they follow to get there? Having a safe place for people to go in the case of extreme weather, and creating easy to follow directions to get there can be the difference between life and death during a destructive flooding event.

Educating the community about storm shelters and evacuation routes can be relatively simple and cost efficient, but preparing the building to become a storm shelter can be expensive. The building will likely need to be updated or built to withstand any sort of storm or flood that could occur in the next 100 – 500 years, which means it will have to remain structurally sound, maintain power, and be able to house hundreds to thousands of people safely for multiple days. However, if the shelter is not properly prepared for an extreme event, it can lead to a dangerous and unhealthy situation for those seeking shelter with nowhere else to go.

Getty Images

Hurricane Katrina forced thousands of people to flee from their homes and seek shelter from rising flood waters at the Superdome, the New Orleans Saints football stadium. With no air conditioning or running water, a ripped ceiling, and a limited food and water supply, the stadium was underprepared and overwhelmed, barely a refuge for the 40,000 people who sought shelter there[42]. The stadium seems like a natural choice for a shelter, as it is in centralized location and has a large capacity, but it was not prepared for a storm of this magnitude. To adequately prepare a building for a hurricane or other extreme weather events, FEMA recommends building above the floodplain, keeping important utility components above ground, making the building accessible even when surrounded by water, and ensuring that there is enough food, water, and bathrooms available for number of people the building is designed to hold. Hurricane Katrina developed quickly, giving first responders little time to prepare the Superdome. Creating a shelter to keep people safe for multiple days can be a costly project, but when faced with extreme circumstances like Hurricane Katrina, it could save thousands lives.

Social Connectedness & Public Education

A storm can turn into a flash flood, hurricanes can gain power quickly, and power outages can happen at any moment. Due to the unpredictable nature of extreme storms, being able to reach people to inform them about any emergency measures that need to be taken can be critical to protecting those living in the region. Having a system that can relay messages to cell phones and landlines, along with internet and television alerts can be a relatively inexpensive

[42] http://www.nola.com/superbowl/index.ssf/2013/01/superdome_series_catching_up_w_2.html

way to keep people safe. These alerts can keep people off the roads in case of an extreme winter weather event, and in the case of extreme precipitation, it can cue them to evacuate and what routes are safe to use. Systems can also be programmed to send city wide, or region specific notifications so only those in affected areas will be notified when necessary, and can be sent in multiple different languages. Being able to communicate in different languages, reach people on multiple platforms, and limit the number of irrelevant warnings by streamlining the notification process are all important factors to consider when designing an alert system.

City officials can alert people with emergency notifications, but how do they know what to do once they get the notification? That's where public education comes in. Through educational campaigns distributed through pamphlets, door to door efforts, social media posts, and television advertisements, people can learn how to prepare for extreme weather events, and how to remain safe during them. According to the Centers for Disease Control (CDC), more than half of flood-related deaths occur due to vehicles driving into hazardous flood waters, followed only by the number of deaths that occur due to people walking in or near flood waters[43]. Just 12 inches of moving water can sweep away a small car, and just six inches can cause an adult to fall. Even though signs are often posted around flooded streets, some people will ignore the signs, assuming they are only precautionary. Educational campaigns such as Turn Around Don't Drown®, can help people better understand flood safety and remember simple facts that might be forgotten in an emergency situation[44]. Having these systems in place to notify the community about potential hazards and what steps to take to remain safe can be a cost-efficient way to keep citizens safe in many extreme weather situations.

With this information, you are now prepared to think about how to build a resilience plan for extreme precipitation based on the social, economic, and environmental impacts of the strategies you choose. On the day of the event, you will use this knowledge and your own values to discuss how stakeholders will be affected by your choices, visualize what happens to the city when you they are implemented, and make changes based on your results.

[43] http://tadd.weather.gov/
[44] http://www.nws.noaa.gov/os/water/tadd/

Section 4: Participant Role and Preparation for the Event

The forum you are participating in will be used in eight science museums across the country. Each museum will recruit participants with a wide array of demographics, values, and ideas to create a space that reflects who the people are that live in the region and will be affected by the climate hazards being discussed.

As a participant in this forum, you will be asked to share your opinions, discuss your ideas, and collaborate with your table to make a resilience plan for the city. The first two sessions of the day will involve a fictional city that is grappling with creating a climate resilience plan for one of the hazards you will be discussing. Each fictional city is based on a real place that is currently thinking about ways to become more resilient against the chosen hazard. We chose to use fictional cities in order to create a replicable and unbiased program that can be used in many places around the country and remain relevant to the people who live there. During the last session of the day, you will be able to discuss a topic that is important to city planners who live in your region. This will allow you and your table to think of ideas and options for a resilience planning process that affects your region, and then relay that information to local planners.