Beyond Resilience: Case Studies

The Institute for Social and Environmental Transition-International catalyzes transformative changes toward a more resilient and equitable future. Through research, training, and implementation activities, we improve understanding and elevate the level of dialogue and practice as society responds to natural resource, environmental, and social challenges. We serve as a framework for equal collaboration among individuals and organizations in the North and South.

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Beyond Resilience: Case Studies

Authors listed in alphabetical order:
Michelle F. Fox, Richard Friend, Rachel Norton,
Marcus Moench, and Kanmani Venkateswaran

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Photo by: Richard Friend

Author
Marcus Moench

Introduction

The case studies presented in this document illustrate some of the core challenges and opportunities inherent in developing resilient urban water management systems. While most work on urban water management focuses on the role played by government and quasi-government organizations (such as utilities, flood control and drainage organizations, and municipal governments), in many locations markets and actors at the household and community levels operate and manage core parts of the urban water system. Each set of actors plays a different role and each has different strengths and limitations in relation to the other actors and the overall functioning of the urban water system. Building the resilience of urban water systems in the face of climate change, rapid urbanization and other stresses requires, we argue, a deep understanding and appreciation of these roles and their limitations. In addition it is important to understand the inherent synergies, conflicts and functional gaps created by the interaction between different actors.

The case studies in this publication have been selected and analyzed in ways that illustrate the above issues and, in doing so, identify innovative opportunities for responding to the growing challenges inherent in urban water management. The case studies have been developed in conjunction with analytical discussions of resilience concepts highlighted in our working papers: "Refining the Resilience Narrative" and "Beyond Resilience." Our goal with this series of products is to increase understanding of the benefits and limitations of applying resilience concepts in the face of rapid urbanization and a changing climate, both of which are increasingly contributing to flooding, water scarcity and water contamination. As rural areas begin to urbanize, cities continue to expand, and climate change alters the hydrological cycle and the ways we access and use water, effective strategies for overcoming urban water management challenges will become ever more vital for both continued economic growth and ensuring human health and wellbeing.

Major Challenges

These cases demonstrate that resilience often emerges as a consequence of a series of smaller scale (and often unplanned) responses and solutions rather than as pre-designed interventions. At the same time major, and we would argue, inherent, gaps exist in incentives and scope of action of the different actors involved. As a result, there are three major challenges to improving urban water management and building resilience:

- increasing recognition of the roles played by different actors and the incentives driving the actions they take;
- developing policy and other mechanisms to coordinate and mediate these roles; and
- identifying innovative mechanisms for addressing critical water management needs that fall outside the incentives and capacities of urban actors.

An introduction to actors, urban administrative entities, and markets

Each of the case studies begins with a breakdown of the role that actors, urban administrative entites, and markets play in each location. The purpose of these categories is to highlight opportunities and barriers in achieving resilience.

Actors at the local level

Actions taken by actors at the household level tend to be autonomous–they are decided upon at the household or individual levels and are not regulated by higher administrative levels. These actions can be highly adaptive to existing stresses. In response to stresses, actions can also be taken at the community level. Community-level actions tend to have benefits for the community as a whole. Scaled-up, the actions of household and community level actors can have major impacts on systems and create transformative changes.

Urban administrative entities

Urban administrative entities represent various levels and sectors of government. These entities are responsible for ensuring that the populations in their administrative jurisdictions have access to basic, necessary services such as water, electricity, waste management, and so on. These entities also play regulatory roles to ensure that growth and development follow government laws, policies, and plans.

Markets

Markets are centers of exchange, particularly of rights, services and goods. Markets can be formed intentionally or emerge in response to the needs of a population. Importantly, they are key in determining who has access to much needed resources within urban water management systems with implications for resilience for those who are left without access.

These case studies demonstrate the lived reality and daily challenges that society faces in managing and accessing water in the context of rapid urbanization and major governance challenges. The innovative, and yet complex, responses that emerge from these situations highlight opportunities to share and apply resilience concepts to diverse contexts around the world.

Photo by: Michelle F. Fox

Globally, rapid urbanization, climate change and increasing pressure on basic water resources pose fundamental challenges for urban water management. As the case studies presented in this document illustrate, despite widely differing contexts, strong commonalities in these challenges exist across many regions. These commonalities relate to the basic dynamics and roles played by urban administrative entities, markets, and actors at the household and community level.

Boulder, Colorado, USA
A look at the interactions between different sets of agents at different scales during the 2013 Floods in Boulder, Colorado and their implications for overall system resilience and social equity

Photo by: Richard Friend

Karnali River Basin, Nepal
An exploration of flood control planning and how it can create maladaptive system-level dependencies

Kathmandu, Nepal
A review of the resilient and desirable aspects of Kathmandu's water system in addition to it's highly undesirable paradigms

Gorakhpur, India
An exploration of the diversified and integrated resilience building initiatives arising in response to urban flooding

Mekong Region
An examination of how resilience might contribute to improved water management in a rapidly urbanizing region

Author
Richard Friend

The Mekong Region

Regional integration

In this case study, we use the Mekong region as a reflection point to the rapid growth and increasingly interconnected world that is emerging today. The Mekong region—generally referred to as comprising Cambodia, Lao PDR, Myanmar, Thailand, Vietnam and parts of southern China—contains four major trans-boundary river basins—the Mekong, Irrawaddy, Salween and Red rivers. Traditionally these countries have been largely agricultural but within the last decade the whole region is witnessing a dramatic transformation, becoming increasingly urbanized, industrialized and inter-connected. The region is also identified as being highly vulnerable to the impacts of climate change.

Actors, urban administrative entities, and markets in the Mekong Region

Actors at the local level

The combination of poor upstream water management, disconnected land-use management, exposed urban services, and increasing flood hazard have exacerbated urban flood impacts, especially for the poor living along riverfronts. While these people must adapt and are adapting to increased flood risk, the cost of adapting is increasing the rate of and perpetuating the cycle of urban poverty.

Urban administrative entities

In the midst of rapid, major transformation, haphazard planning and land-use change have situated key economic assets in highly vulnerable areas and created issues of both water shortage and excess for populations across the Mekong region.

Markets

Markets are rapidly emerging, but are emerging in highly exposed areas. This pattern places the growth of the region at risk.

Photo by: Richard Friend

Dramatic change follows a long period of colonialism, conflict, civil war and unrest. Partly in response to this period of unrest, there has been a push for regional economic integration. Much of the initial investment in regional integration came from the Asian Development Bank (ADB) under the Greater Mekong Sub-region (GMS) programme, which has provided support for regional transport and energy linkages. More recently, the process has accelerated with the approaching establishment of the ASEAN Economic Community (AEC), which will facilitate trade and movement of goods and people. With all of these investments, and continued flow of regional and international private capital, cities at critical intersections of transport networks are growing at a phenomenal pace.

Such dramatic transformations have significant implications for water resources. The Mekong has long been the focus of global interest in water resources. Much of this interest has focused on the water-food-energy nexus, and the tensions of balancing hydropower demand for growing urban and industrial needs with the needs of traditional agriculture, fisheries, and ecosystem services. However, the full significance of the transformative change driven by urbanization on water resources has only recently become the focus of attention.

Urbanization is transforming ecological landscapes, modes of production and exchange—and power and values (Friend and MacClune 2013).

Climate change provides an added dimension to this story. The Mekong region is particularly vulnerable to climate change, and much of the urbanization and industrialization that is taking place in the region is located in hazardous spaces along the coasts, deltas, river basins and flood plains that by their nature are exposed to storms and flooding. Moreover, much of the land that is targeted for urban development has formerly been agricultural land, with a growing regional concentration of food production in some of the most climate vulnerable areas of the region—the deltas of the Mekong, Irrawadddy and Chao Praya. This trend has important implications. Each of the countries is losing agricultural production land, while concentrating more of its agricultural assets in the most vulnerable locations. Any shocks to agricultural production would have enormous implications for local and national consumers. As the region contributes to global rice production the effects of production failures would be even more far-reaching, affecting urban rice consumers in Lagos and Manila.


Photo by: Richard Friend

The history of urbanization and industrialization in Thailand reveals important lessons, and potential future risks. Much of the urban and industrial development in Thailand occurred around Bangkok in the lower reaches of the Chao Praya basin—in land that had traditionally been used for rice production and that, by its ecology, floods every year. But the development of these locations was also contrary to land use planning; what had once been designated floodways became converted to residential and factory areas as national economic policy shifted. Indeed, the international airport of Suvvanabhumi, is located in what was known as King Cobra Swamp, part of an area that had historically been important for rice production, much of which is below sea level. As this development unfolded, many observers pointed publicly to the risks. These concerns were largely ignored.

The consequences of these investment decisions became apparent in 2011 during a period of intense flooding. As the floodwaters came south in an enormous mass, there were desperate efforts to protect the economic assets of the key factories, and the airport, where the water was flowing. This meant diverting this mass of water against its natural flow, eventually flooding areas on higher ground in order to save economic interests.

Since 2011, the main focus has been on providing further infrastructure protection, rather than looking at the underlying dynamics of flood risk. This history and sequence of responses indicates the risks of path dependency. Having created critical economic assets and physical infrastructure in vulnerable space, the only response is to build a way out of vulnerability. But in doing so, the risks of failure in another serious flood become all the greater.

A case from Udon Thani, Thailand

Udon Thani, in Northeast Thailand, provides an important case study that is emblematic of the emerging challenges around water resources, urbanization and climate change.

The city of Udon Thani was originally settled as a border military post, selected because of rich water resources in the wetlands and river systems and abundant fisheries. For many years Udon Thani was considered a remote, poor province,

well known for exporting labor to Bangkok and the Middle East. The economy was based on rice agriculture, and the largest water resource infrastructure, the Huay Luang dam, was built specifically to provide irrigation for rice cultivation.

Over the last few years Udon Thani has gone through a dramatic transformation. Situated on critical transport connections that link Northeast Thailand with China, Laos and Vietnam, the province is now positioning itself as a gateway for industry, trade and services to the Mekong. It has enjoyed the highest GDP rates, and some of the highest increases in land values, in all of Thailand.

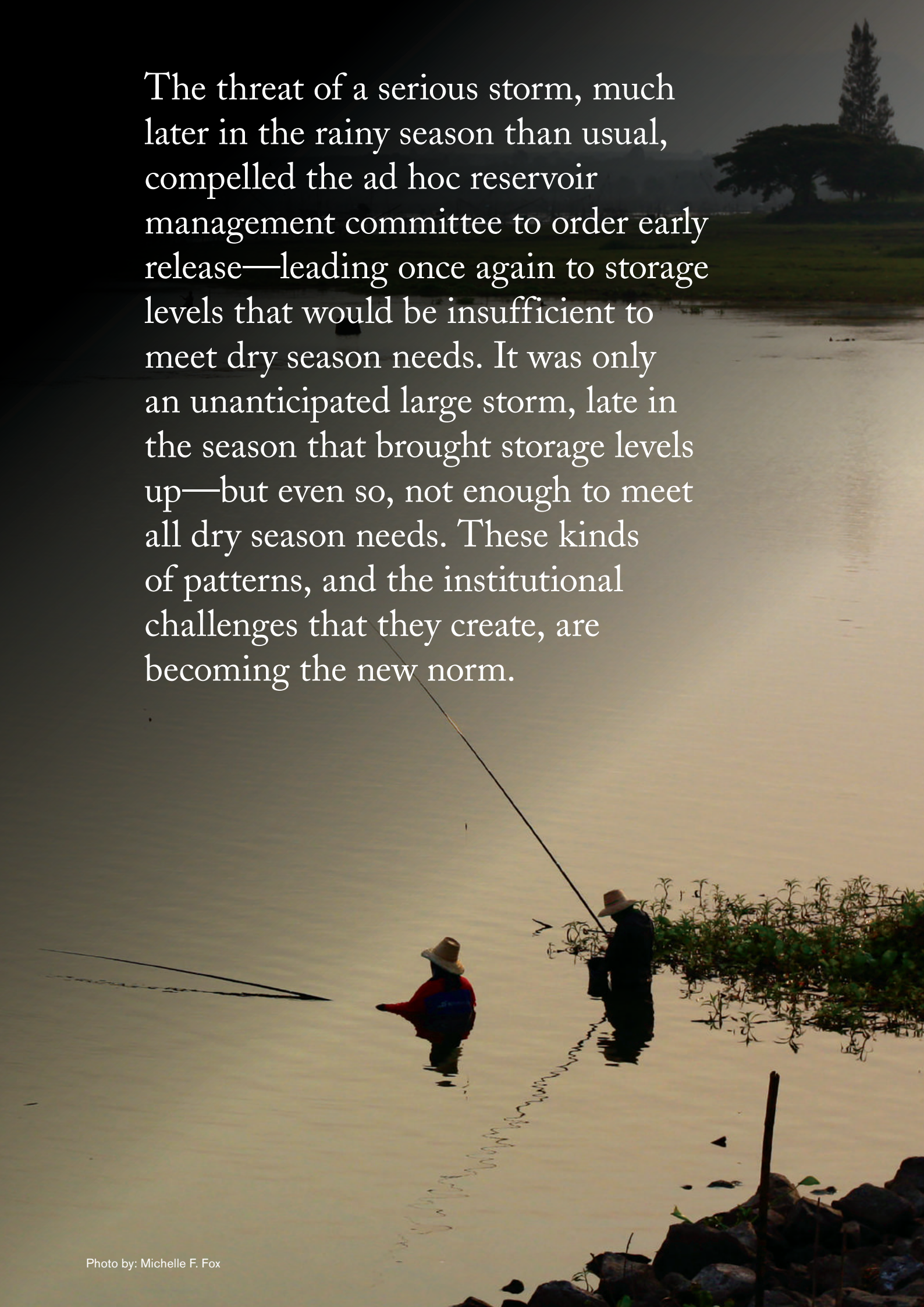
With this dramatic transformation has come serious pressures on water resources, their management and distribution. Demand for water has grown, with domestic users and industry now competing with agriculture. As the city has expanded it has followed a pattern similar to that in other parts of the region—the city has preferentially developed low value, often public, wetlands and agricultural land. This means new construction is located in highly vulnerable areas, much of the natural drainage has been impeded, and potential water sources have been lost. The construction of a network of roads to link to this development has further impeded natural drainage.

Udon Thani has experienced both excess and shortage of water. In 2001 the city experienced serious flooding, and since then, more regular localized flooding. But the greatest challenge has been around water allocation. The Houay Louang dam is over 40 years old—designed for different purposes, and for a different climate regime. In recent years rainfall has been unpredictable, creating an enormous challenge for the Royal Irrigation Department who are responsible for managing the reservoir. The pressure they face is to ensure that they store sufficient water in the rainy season to meet water demand in the dry season. In 2011 storage of the reservoir was only 40% of capacity. An extended dry period meant that in the following dry season of 2012 not enough water was available to meet demand. An ad hoc management committee had to ensure water allocations for domestic use, but in doing so, could not meet agricultural demand. Rice farmers simply had to do without irrigation water. The situation intensified later in the year. In a bid to ensure they had sufficient storage capacity, the reservoir managers stored early in the rainy season. But the threat of a serious storm, much later in the rainy season than usual, compelled them to order early release—leading once again to storage levels that would be insufficient to meet dry season needs. It was only an unanticipated large storm, late in the season that brought storage levels up—but even so, not enough to meet all dry season needs. These kinds of patterns, and the institutional challenges that they create, are becoming the new norm.

Similar problems appear in many other parts of the Mekong Region. Much of the water storage infrastructure is old, and was designed for different purposes and different climate regimes. Historically, the region has tended to favor large-scale infrastucture to manage water resources, but this has been a history mired in controversy and conflict, often associated with devastating impacts on local ecosystems, fisheries, and livelihoods. The dependence on large-scale infrastructure solutions may not be adequate for emerging climate uncertainties and risks. Land use and water resource planning and management, as in many other parts of the world, is fragmented among different government agencies and tiers of local administration, with different agendas and interests competing against each other. There is little consideration of ecological values, or of the benefits of maintaining natural hydrological systems or of enhancing natural water bodies. The institutional challenges require bringing different stakeholders together in informed public dialogues; but critically, to rethink the future rather than merely manage emerging trajectories.

In summary

To address these challenges, ISET-International and local partners (under the USAID-funded Mekong Building Climate Resilient Asian Cities (M-BRACE) project) supported a program of work that promoted Shared Learning Dialogues (SLD) to open space for re-imagining urban futures, assessing vulnerabilities and identify solutions.



The threat of a serious storm, much later in the rainy season than usual, compelled the ad hoc reservoir management committee to order early release—leading once again to storage levels that would be insufficient to meet dry season needs. It was only an unanticipated large storm, late in the season that brought storage levels up—but even so, not enough to meet all dry season needs. These kinds of patterns, and the institutional challenges that they create, are becoming the new norm.

Photo by: Michelle F. Fox

Much of the effort was focused on learning and institutional strengthening. This engaged local citizens from rural and urban areas across the Huay Luang basin to assess their own water resources and identify flood and water shortage issues, bringing the whole network of citizens together in dialogue platforms. Empowering citizens to better analyze their own situation, while learning from other stakeholders in different parts of the basin is a necessary feature of water management across different scales. These efforts highlighted upstream and downstream interactions, while also identifying affordable opportunities to improve drainage and to manage existing water bodies to improve storage. At the same time, supporting local government to co-develop a scenario based modeling tool helped bring different state actors together—and now provides a mechanism for strategizing and planning collaboratively across the responsibilities of different agencies. Reshaping these urban water and land futures is also a matter of design. In collaboration with a team of architects, ISET-International has supported local government to identify green infrastructure solutions for non-motorized, water-based transport routes, while also enhancing natural storage and drainage.

The work in Udon Thani, under the M-BRACE program, was made possible by the generous support of the American people through the United States Agency for International Development (USAID) and the Rockefeller Foundation as part of the Asian Cities Climate Change Resilience Network.

The contents are the responsibility of ISET-International and do not necessarily reflect the views of USAID or the United States government.

Our partners for the research conducted in Udon Thani include: Udon Thani Rajabhat University, Thailand Research Fund, Khon Kaen University.

Mekong Region

Boulder, Colorado USA

While the Greater Mekong Sub-region and Boulder, Colorado are worlds apart in dealing with issues of urban flooding and population growth, they present surprising similarities and reveal global patterns about the application of resilience concepts. In both regions, common themes about individual and group action, the need to learn and act on that learning, the willingness to rethink and re-plan, and the sometimes competing roles of authorities vs. individuals in responding to and mitigating future water system impacts can be seen. Drawing out these common threads and global lessons can speed us in our quest for resilience.

Authors
Michelle Fox
Rachel Norton

Boulder, Colorado

A tale of two cities

In September of 2013, over the span of eight days Boulder, Colorado received the amount of rainfall it normally receives in a year. The resulting floods devastated nearby towns, washed out roads, and took both the wastewater and water treatment facilities of the city to the brink of failure. Though an urban flood event was not unexpected—the City of Boulder is the number one flash flood risk in Colorado—the severity of the rain and extent of the flooding exposed vulnerabilities and caused unplanned for events to occur across the county.

Had it not been for advance planning, strong community relationships and the flexibility of institutions the floods would probably have resulted in even more widespread, longer-lasting impacts.

Actors, urban administrative entities, and markets in Boulder, Colorado

Actors at the local level

During the flood, autonomous actions at the household level, such as temporary flood walls and pumping water out of basements, pushed floodwaters into public spaces and also into downstream homes. Relationships between households in neighborhoods, however, helped speed up household recovery even though repair and maintenance services were backed up. In recovery, autonomous actions taken to prevent future flooding are changing the nature and location of risk in ways that are not being recognized by government or broader entities.

Urban administrative entities

Households were by and large unprepared for the floods, without backup systems for electricity and water. This is largely because the Boulder government has otherwise been able to provide reliable and adequate access to core urban services. The lack of redundancy at the household level is a challenge for Boulder's resilience during short-term crises.

Markets

Market forces play a major role in determining who has access to what. Autonomous actions at the household level push floodwaters into public spaces and also into the homes of those that are unable to afford to implement such measures. Thus the market ultimately influences who participates in protecting their households and thus who is more resilient during and following floods.

Photo by: Michelle F. Fox

An un-resilient city

While certain characteristics of the city proved protective, the floods also revealed another Boulder, one where social position and economic status influenced residents' ability to respond to and recover from the floods. In this Boulder, the city was constrained in its response and recovery in part because of inherent inequities, but also because 1) the scale of the event was unprecedented and unanticipated, 2) groundwater dynamics during the flood were unexpected and poorly understood and 3) there was little recognition of the critical role of emergent and autonomous behavior. These factors set up a physical landscape where flood impacts were particularly severe in lower income neighborhoods and for basement apartment dwellers. In the recovery process, household-level autonomous actions are creating a setting where those with more resources are sometimes rebuilding in ways that increase risk for their neighbors.

During the flood, autonomous adaptation actions included deflecting water away from personal property. This led to both increased flow in and damage to public property and, in some cases, damage to downstream properties. Water was "deflected" from basements by purchasing pumps and pumping it into the yard or street, from where it then flowed into other basements. In recovery, many badly impacted properties are installing "flood gardens", raised berms or planting beds that will deflect future floodwaters. Such actions, however, are limited to those who can afford pumps, and those who own their residences and have the resources and capacity to develop and implement landscaping plans (or have the good fortune to have landlords who are responding due to market pressure). Problematically, government-level planning does not account for these types of behaviors. In parts of the city, these actions are changing the 100-year floodplain in small but cumulatively significant ways, and these changes are not going to appear on flood maps. Overall, the market is both changing the nature and location of risk, and influencing who can participate in protecting their homes and thus who will be more resilient in future floods.

Aside from the "who" that could participate in emergent and protective behaviors, the "where" also influences the resilience of urban water systems. Lyons, Colorado, which lies in the northern part of Boulder County, demonstrates the tensions between development regulations and market forces. Lower income individuals in Lyons live in floodplains because of the access to jobs and services their geographic proximity provides. Living in floodplains makes them more vulnerable to floods (Blaikie et al. 2014), but living in less risk-prone neighborhoods is either too expensive or too far from jobs. This leaves these individuals, often without flood insurance, with little choice but to live with flood risk.

Issues of social equity, driven by market forces, also arise in the manner through which undocumented individuals, primarily Hispanic people and immigrants, navigate the recovery process following floods and other disasters—an aspect that has been largely left out of the resilience discussion. Negotiating with FEMA and insurance agencies, for example, requires the know-how to navigate complex bureaucratic systems and it assumes a certain amount of agency on the part of individuals, which is often attenuated by a person's legal status or English language fluency (Bolin & Stanford, 1998). Undocumented immigrants impacted by the floods, for example, do not have the same access to state and federal recovery resources because of their societal status. They are set apart from the target population governing institutions seek to help through disaster relief. Even when governing institutions make specific attempts to provide assistance to these "missed" populations, they often fail to reach, or even identify, their target groups. Different approaches, potentially through community endeavors, are needed to reach these populations.

A resilient city

In spite of shortcomings, there were many successes in the Boulder flood response and recovery. This case shifts the focus slightly to look at both the role of regulations, and also the actions that emerged at the community and household level, ultimately contributing to the overall resilience of Boulder's urban water management system.

At a household and community level, people stepped up to mitigate their own homes and help neighbors, in some cases coming together to create wider organizations to channel volunteer labor and address flood issues. One such group, Boulder Flood Relief, used the lessons they had learned from the Occupy Wall Street Movement to respond to emergent needs. Their flexibility and ability to sidestep many of the liability issues more established relief organizations were faced with allowed them to respond rapidly to arising needs and to send volunteers into the harder hit areas. While traditional urban water management, funneled through government and aid agencies, was hamstrung, autonomous groups were able to adapt and ultimately contribute to the resilience of the system in a unique and novel manner.

Concurrently, established organizations and community groups that were not normally focused on emergency aid, such as Parent Teacher Associations, art guilds, ski clubs, and neighborhood associations adapted their resources and utilized previous relationships to provide support during the floods (MacClune, Allan, Venkateswaran, & Sabbag, 2014). Such groups served as points of connection for individuals and as conduits for vital information and key resources.

The question of how best to take advantage of and prepare for emergent groups during times of crises is growing. Increasingly, formal response agencies are seeing the potential inherent in these emergent groups, but also the challenge of harnessing that potential in the midst of a dangerous and rapidly changing disaster landscape. In the wake of the 2013 floods, a newly formed resilience group in the Boulder County is working form the connections now to better support and leverage the potential of emergent groups during the next disaster.

Innovation and relationships

While relief groups coalesced and self-organized in response to emergent needs at the individual and household level, this same level of responsiveness, resourcefulness, and a fair amount of luck, helped avert the failure of the Betasso Water Treatment Facility and the City of Boulder's Wastewater Treatment Facility.

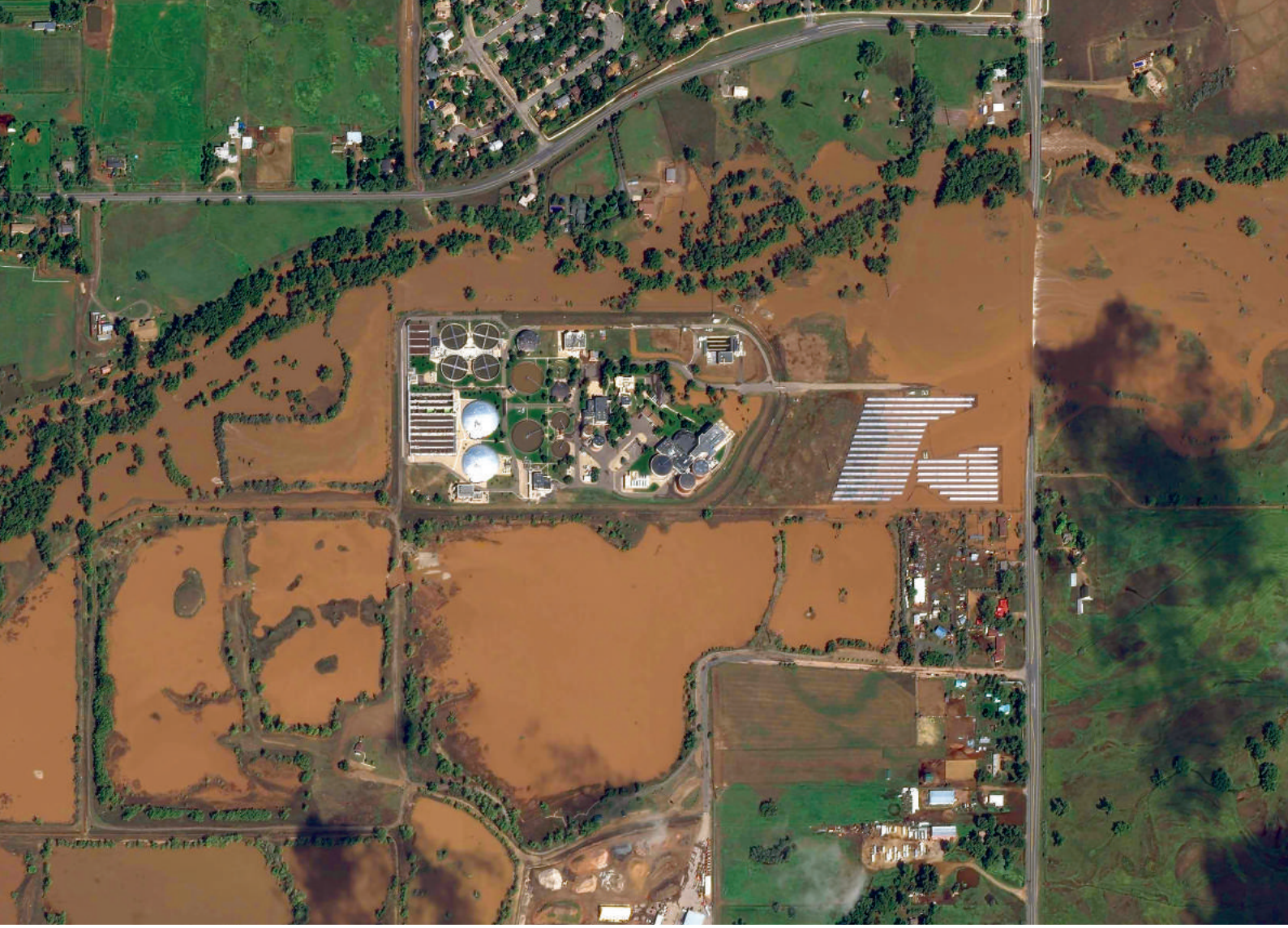
Jamestown Flood Bowls

Jamestown, Colorado is a small town nestled in the Rocky Mountains with a population of only ~200 people. In September of 2013, Jamestown was devastated by the "Boulder Flood of 2013", which destroyed much of their town. In response, Joy Boston, a ceramic artist, had an idea to use art as a way of bringing the community together to heal from this terrible disaster. The Jamestown Flood Bowls project was not only a means to cope and heal as a community, but also to build social cohesion—an element that is critical to a community and individual's capacity to recover from a disaster.

Initially, the flood bowls (pictured here) were gifted to flood recovery volunteers. Months later, Joy and her neighbors continued to make and sell the bowls in order to fundraise for the town's recovery effort.

YouTube

To see a video on the Jamestown Flood Bowls, please see: www.i-s-e-t.org/resources/other/jamestown-flood-bowls.html



Clear waters and stormy skies

A protective berm was installed at the City of Boulder Wastewater Treatment Facility in the mid-1980s, and back-up systems for service and electricity provide the wastewater facility with internal redundancy, but external redundancy is lacking. Given that there is only one wastewater treatment facility for public offices, private businesses, government labs, schools and universities, industry and over 100,000 citizens, protecting it from failure is and was vital. As the flood waters rose, the volume of wastewater entering the facility sky-rocketed but the berm held off the floodwaters that rose along all four sides of the facility and power and communications were maintained. Everything was going as planned until something peculiar happened.

On the 3rd night of the flood, after days without rest, the crew noticed that the water entering the facility was remarkably clear. Normal wastewater has a grayish brown look to it, but the water entering the facility was visibly NOT wastewater. Unsure of what to think of this, the crew began considering the possible causes. That's when the panic set in—"do we have a break in our pipeline?" Crews set out to investigate, ready to cover miles of pipelines.

Not long into their investigation, they found that the main pipe that delivers wastewater to the facility had become unearthed. The 42" pipe, which had been buried under several feet of dirt and earth, now rested in rushing floodwaters, completely exposed. The power and incredible force of the floodwater had carved out the pipe. If this 47-year-old pipe failed, the otherwise resilient facility would have to be shut down, and if the Boulder Wastewater

Photo by: Chris Douville

Management Facility were taken offline, there would have been cascading effects seen throughout the region. City residents would have been evacuated, and it would have taken weeks to repair and restart the plant.

Lean on me

As the staff at the Boulder Wastewater Management Facility worked to keep the facility online and processing wastewater, up in the mountains the staff of the Betasso Water Treatment Facility were working to keep water flowing into the city.

Relationships between firefighters and homeowners in the neighborhoods west of Boulder were vital in ensuring that the Betasso Water Treatment Facility remained online for the duration of the flood. When power was first lost in the facility, the back-up generator kicked in, as it should have, to keep the system running. While this redundancy averted the initial failure of the facility, employees at the facility soon realized that their store of diesel at the facility wouldn't last.

Transporting diesel to the facility would normally not be a problem, but the flood had washed out all the established roads to the treatment plant. Getting diesel up the mountain became more than just a matter of transport, that transport needed a route. Using their knowledge of the mountain roads and building off their relationships with homeowners in the area, firefighters were able to navigate back roads and access private property to successfully deliver the diesel to the water treatment facility.

Had these relationships not existed, getting diesel to the back-up generator in Betasso, after the roads

leading to the facility had been washed out, would have been nearly impossible and would have lead to the failure of the city's water treatment system. While seven roads leading up to the mountains could be considered redundant, in this case, because of their location next to creeks, the six roads that failed were all susceptible to the same vulnerability—flooding (MacClune et al., 2014). This failure in infrastructure could very well have led to the failure of the city's water treatment system were it not for the resilience of the human systems who stepped in when physical systems were lost.

The flexible role of institutions

Unlike at the water treatment facility, intervention at the Boulder wastewater facility required Federal support. Fortunately in the early days of the flood, the wastewater facility established direct contact with FEMA and the U.S. Army Corps of Engineers. This allowed facility staff to respond swiftly, bypassing traditional decision-making processes and enabling the facility to do what it needed to in order to fortify the exposed main pipeline. What would, absent a disaster, have taken months of proper permitting took only a few hours to approve. A local engineer had a plan. They would fashion a concrete cradle around the pipe to hold it steady and protect it from additional damage from floodwater, debris or erosion. Backhoes and concrete trucks were deployed immediately, in the middle of the night, and within hours the pipe was secure.

At the end of the day, it's hard to say who or what exactly preserved the wastewater main, and as a result saved the plant and the city. Due to the foresight of managers and city planners, the facility was well equipped to face the battering that the flood delivered. But there was still the wild card that no one had considered. The ability of the wastewater facility staff to act responsively, with a somewhat out-of-the-box solution to fortify the exposed pipeline, speaks to the flexibility of institutions, resourcefulness of people, and how innovation plays a critical role in urban climate resilience. This also highlights that the role that individuals can play in the management and preservation of a city-wide water system.

In summary

Overall, the Boulder case indicates that even in one of the wealthiest, highest capacity municipalities in the United States, dynamics similar to those facing other urban regions are present. Poor populations tend to be disproportionately affected and have the least ability to recover from urban flooding events. Planning, while important, cannot account for the range of possible futures. Furthermore, despite extensive research, critical system dynamics remain poorly understood. Uncertainty and surprise are, consequently, inherent. When events occur, government institutions cannot meet all needs and emergent responses are common.

Individuals, households and business act to protect their assets and those of their neighbors with unpredictable consequences for others downstream. At a higher level, organized groups emerge or existing ones shift their functions to meet the immediate needs they perceive. Major institutional gaps exist between the formal responses and mandates of government organizations, neighborhoods, households, and emergent organizations.

Boulder, Colorado USA

Karnali River Basin, Nepal

Between Boulder and the Karnali basin in Nepal, flood planning has taken two very different routes. Boulder has largely focused on more adaptation-oriented solutions, including institutional flexibility and relationship building, which were instrumental in maintaining resilience during the September 2013 floods. In the Karnali, there is greater focus on engineering nature to control flooding without due consideration of how people interact with built systems. Failing to account for how individual perception and behavior exacerbate or mitigate risk, as illustrated in the following case study, can ultimately undercut the supposed resilience provided by flood protection structures and greatly exacerbate flood risk. This is particularly true in the Karnali Basin as populations increase, the region urbanizes, and development is increasingly drawn to the rivers.

Author
Kanmani Venkateswaran

Karnali River Basin, Nepal

Flood control

The Karnali River basin in mid-western Nepal is enormous, draining almost a third of Nepal. It begins in the high Himalayas and drains into the Nepali and Indian Tarais (or plains). The rivers in this basin, especially the Karnali River, carry a lot of sediment, exacerbating both flood risk and flood damages experienced by communities along the river.

Actors, urban administrative entities, and markets in the Karnali River Basin

Actors at the local level

The presence of embankments has, in many respects, inhibited household and community-level adaptation to floods. As the Karnali region urbanizes and migrant populations increase, people and development are moving into the floodplain just behind embankments, under the notion that the embankments will protect them indefinitely.

Urban administrative entities

Government response to flooding in Nepal has been to build embankments as a means to protect infrastructure, people, and agriculture. Yet, there are few regulations over residing and building in the floodplain and those that exist are not being implemented.

Markets

As embankments are built, and development and people move towards the embankments, markets will emerge. These markets, in turn, attract more development and more people, intensifying urbanization in a highly flood-prone area.

Photo by: ISET-Nepal

In August 2014, intense cloudbursts over the lower Karnali basin caused major flooding, affecting nearly 150,000 people and 15,000 households and taking the lives of 99 people in the districts of Dang, Surkhet, Banke, Bardiya, and Kailali. As the lower Karnali continues to urbanize and more people and development move into the floodplain, it is likely that floods will become more and more catastrophic.

The Nepal government's response to flooding across the country has largely been to introduce major flood control structures such as embankments and spurs along rivers. One of the major flood control projects in the Karnali involves building 43 km of embankments along the east side of the Karnali River with a road on top; this project will cost 11 billion Nepali Rupees (roughly $110 million USD). The west side of the Karnali is already heavily embanked. While the government is seeking to protect communities from floods by introducing such structures, these structures are not helping make communities, especially marginalized communities, more flood resilient. Moench (2010, p. 977) states, "because interventions at a system level can catalyze patterns of change that are difficult if not impossible to reverse, they can create path dependencies that are ultimately maladaptive". In the Karnali basin, this statement resonates.

In the 2014 floods, several communities faced unexpected flooding as a result of embankment breaches and breakages. Embankments, in effect, allow communities, particularly those that are marginalized, to remain and even form in flood-prone areas. While communities that have lived along the Karnali for several decades are aware of the flood risk posed by the river, migrant communities by and large are not. The Nepali Tarai has seen an influx of people from the foothills, seeking fertile lands and greater economic opportunity. A significant number of these migrants are landless due to "the combination of corruptive land distribution to settlers, diminishing land availability, increasing immigration, and high natural population growth" (Shrestha, 1989, p. 370). Their landlessness means that they cannot live on government lands or on public lands, and are pushed to areas that are risk prone and largely unregulated, i.e. floodplains. The ability of these newcomers to adapt to floods is greatly hindered by their lack of experience with the type of flooding that occurs in the Tarai and knowledge of the river and its behavior during floods. The embankments only serve to add a false sense of security that further hinders adaptation.

The 43 km of embankments currently being built will greatly exacerbate this problem in part because the road that is being built on top will catalyze development. Research has shown that development thrives along roads due to greater access to markets and income-generating activities (Barwell, 1996; Eberts, 1991). Multi-use protection structures, in many situations, have been successful and have the tendency to garner community buy-in. Boulder, Colorado's flood protection system, for example, consists of a series of paths that function as floodways and bike paths. During the 2013 floods in Boulder, these paths safely 'failed' in their function as bike paths and were able to drain water back into the creeks (MacClune et al, 2014).

The Karnali embankments, however, are poorly conceived. They are being designed for the 2014 flood volume but are not taking into account sedimentation rates, which may be as high as 10 cm/year, or the recent intensification of rainfall events that has been seen over the past two decades. Consequently, there is evidence to believe they will be undersized relative to the historic 1-in-100 year flood with one or two decades. The road being built on the embankment crest will bring people and development into an extremely flood-prone area. And, the embankments are only being built for a lifespan of 20-25 years, with no long-term maintenance or replacement plan. This is extremely problematic. The design is short-term, but embankments and roads cannot be short-term investments. Roads and embankments permanently change development and settlement patterns and consequently require long-term planning and commitment. These embankments, without substantial re-planning and ongoing investment, are on the path to catastrophic failure. When they fail, people will be deeply impacted by the resulting deaths, injuries, property losses, infrastructural losses, loss of market access, livelihood losses, and so on.

What is evident so far is that the Nepal government's embankment construction follows the age-old paradigm of engineering nature to control it and then not giving due consideration to how people interact with built systems, and subsequently the kinds of

"...interventions at a system level can catalyze patterns of change that are difficult if not impossible to reverse, they can create path dependencies that are ultimately maladaptive"

(Moench, 2010, p. 977)

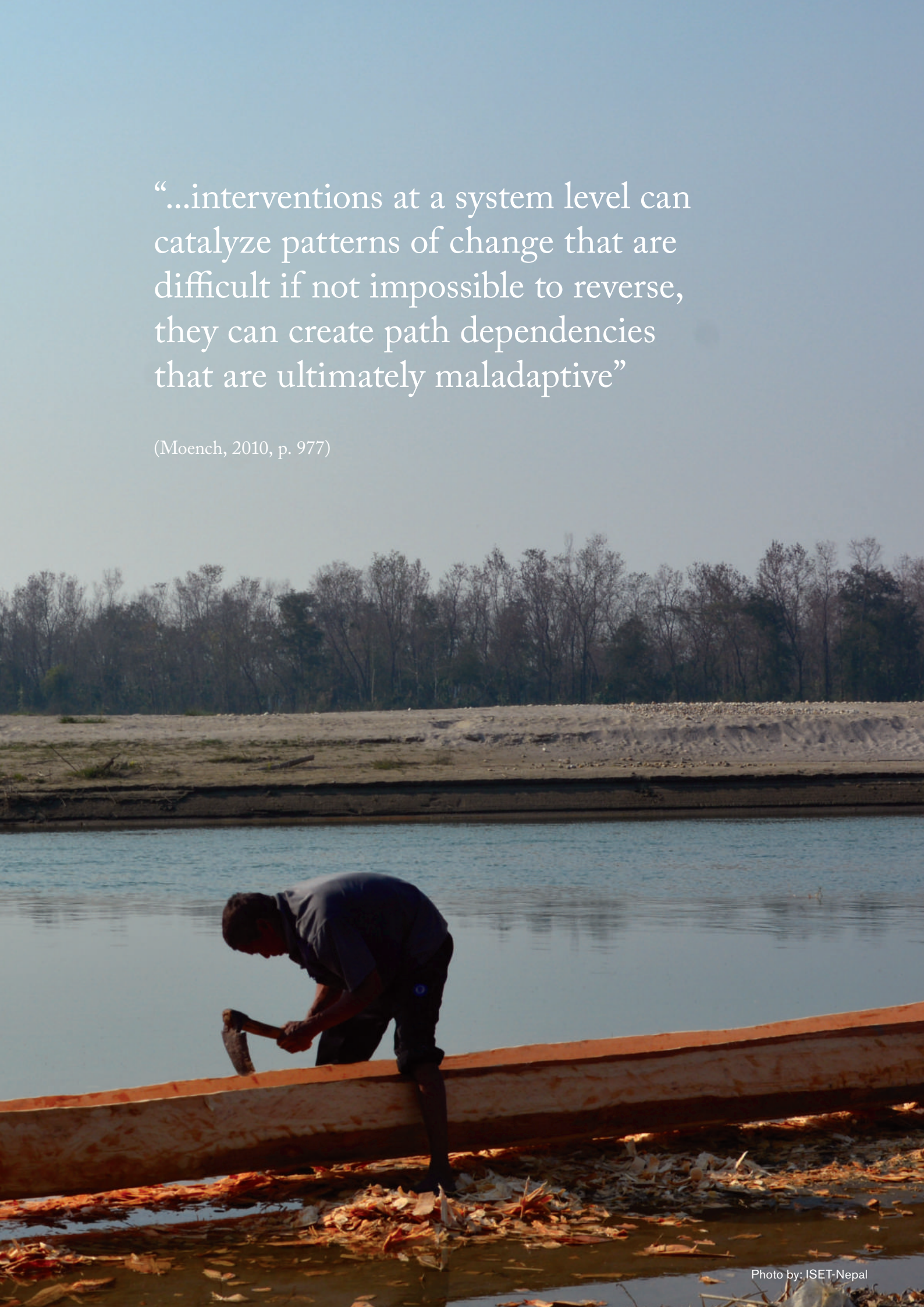


Photo by: ISET-Nepal

Photo by: A. Pandey, ISET-Nepal

autonomous and spontaneous actions that will arise. In this case, the autonomous actions consist of people moving to the floodplain, and towards the embankments. As markets emerge in response to growing needs and demands, urbanization will intensify with even more development and in-migration, leading to more market growth, and so on, all in a highly flood-prone area. To avoid catastrophe, the potential for this type of autonomous response should be taken into consideration in the planning and design phase of these embankments, and regulations developed and enforced to control urbanization and development in such risky areas. So far, the status quo is to enforce hierarchical structures and design systems in Kathmandu with little knowledge about local realities and tendencies.

In summary

From a conceptual perspective, the Karnali case illustrates how resilience depends on path-dependent characteristics within systems. The creation of long-lived infrastructure, particularly when it combines multiple functions such as flood control and transportation, influences the location and characteristics of emerging urban areas. Markets depend on transport and market actors will generally locate themselves where they have good access to roads and other facilities. Urban areas will emerge as a result. If, as in the Karnali, embankments provide a false sense of security from floods, the incentive for communities and household level actors to avoid high-risk areas or invest in actions such as the raising of houses and other assets will be minimal. At the same time, government actors will face strong pressure for rebuilding or strengthening embankments when failure occurs. Overall, this creates an on-going incentive to maintain systems that are rigid, inflexible and subject to catastrophic failure during extreme events while undermining the incentives for more diversified, flexible and resilient approaches.

Karnali River Basin, Nepal

Kathmandu, Nepal

Government instability, poor governance conditions, and weak regulation have led to conditions that have exacerbated the risks faced by communities. In the Karnali Basin in Nepal, landless populations have been pushed into highly flood-prone zones and excluded from decisions that have major ramifications for their vulnerability. In the Kathmandu Valley of Nepal, these conditions have led to widespread water scarcity. In response, many people access water through private tanker-based water markets or diversify their water access to include both groundwater and surface water sources. Over-extraction and contamination of these sources is becoming increasingly problematic. This case illustrates the way in which some adaptive solutions may contribute to short-term resilience while critically undercutting resilience in the long-term.

Authors
Kanmani Venkateswaran
Rachel Norton
Michelle Fox

Kathmandu, Nepal

Emergent responses

The Kathmandu Valley, Nepal has major water scarcity problems. Rivers are heavily polluted and municipal water supplies are only able to provide 100–155 million liters of water/day to a population that currently requires 320 million liters of water/day (KUKL, 2010) and is growing at an unprecedented rate of 6% per year. The valley's water problems are largely attributed to a combination of rapid urbanization, political instability, and weak governance. In response, water markets have grown and households in Kathmandu have maintained a highly diversified array of strategies for accessing water including traditional stone taps, wells, local surface supplies and water harvesting.

Actors, urban administrative entities, and markets in Kathmandu, Nepal

Actors at the local level

In the face of poor access to safe, adequate, reliable water, households and communities in the Kathmandu Valley have diversified their access to water.

Urban administrative entities

The government is unable to provide the Kathmandu population with adequate and reliable access to safe water and, to a degree, public pressure to increase water access has subsided as households, communities and the private sector have stepped in to diversify water supplies. Access to high quality water supplies in the long-term, however, is uncertain as pollution and overdevelopment affect resources within the Kathmandu Valley and efforts to import additional water proceed slowly.

Markets

Private sector response to water scarcity in the Kathmandu Valley has been enormous, resulting in the growth of large tanker-based water markets. These add flexibility and some degree of responsiveness during disruptive events. Water tankers were, for example, especially crucial for providing water to the Kathmandu population after the earthquake. Yet, water access through markets is not available to everyone, in particular the urban poor.

Photo by: Richard Friend

"Building resilience can provoke reflection and be up-scaled across a management regime enabling transitional and potentially transformative change, but it could also slow down more profound change as incremental adjustments offset immediate risks while the system itself moves ever closer to a critical threshold for collapse"

(Pelling, 2012)

Traditionally, Kathmandu households and communities depended on a system of stone water taps, ponds, and lakes to provide them with water. The construction of the Tribhuvan Highway connecting the Nepali Terai, Kathmandu, and India in the mid-sixties spurred urbanization in Kathmandu. Between 1955 and 2008, the population grew by 499% (Bhattarai & Conway, 2010). Maoist violence in rural areas between 1996 and 2006 further fueled rural-urban migration. This rapid urbanization resulted in major land-use changes. Water bodies such as ponds, lakes, and rivers were encroached on, and roads and buildings were built rampantly with little government regulation. The few remaining traditional water systems were unable to provide the growing Kathmandu population with enough water.

Urban services such as water, sanitation, wastewater treatment, and solid waste management have not expanded enough to accommodate the population explosion. Poor waste management has led to major contamination of all Kathmandu rivers, with sewage, industrial waste, and solid waste being dumped directly into rivers without treatment. Although large investments have been made to construct a series of sewage treatment plants along Kathmandu's rivers, most of these plants have never been functional.

Municipal water, extracted from aquifers, is also unable to keep up with urban water demand. The municipal water that is available is extremely unsafe to drink without treatment and filtration.

In the context of poor government capacity to provide safe, reliable, adequate water, households and communities have taken actions to diversify their water supply. These actions include digging boreholes deeper and deeper, digging wells, installing illegal taps and pumps into municipal water lines, and buying water from the private sector. The private sector has seen an explosion of water markets with the growth of bottled water and water tanker companies. Companies specializing in water storage facilities and rainwater harvesting have also emerged. These diversification options have been adopted across Kathmandu—primarily among those that can afford it—and have transitioned access to water in the valley.

While these solutions have made household access to water in the valley much more resilient, they are only incremental solutions that offset water scarcity in the short-term and do not deal with the sustainability of water reserves in the long-term. Soaring public demand in conjunction with a lack of private sector regulation and poor waste management has resulted in the overexploitation and contamination of groundwater and surface water sources. Groundwater, especially, is unable

Photo by: Richard Friend

to recharge, partly due to the clay composition of the aquifer and partly due to surface sealing caused by rampant construction in the floodplain (Pandey et al., 2010). While more resilient solutions such as rainwater harvesting do exist and are slowly growing, they are not being adopted widely as installing rooftop systems can be cost-prohibitive. Rainwater is also broadly perceived as 'dirty', and rainwater harvesting as outdated.

This question of long-term water resilience is ultimately seen by most local residents to be the government's responsibility. At the same time, however, large parts of the Kathmandu water system are effectively owned and operated by actors outside the government. Households own most wells and water harvesting facilities, the approximately eight hundred small tanker companies in operation (some with their own wells) are private sector, ponds and the traditional water spouts are held by community or religious institutions. Overall, the Kathmandu water "system" is a composite of different actors operating different infrastructure elements and tapping different sections of the resource base.

One of the Nepal government's primary solutions to water scarcity in the Kathmandu Valley is the Melamchi Water Supply Project, a 'megaproject' costing over $300 million, which will pipe water to Kathmandu from the rural Melamchi Valleys. This project has been racked by delays and budget issues. Both the rural and urban poor will be largely excluded from the benefits that this project will bring. In the Melamchi Valleys, landless farmers do not have the land certificates and citizen cards required to obtain compensation for loss of their land, water, and livelihoods. In Kathmandu, water tariffs will likely increase, having devastating effects on the urban poor that are connected to the municipal water supply. Those that are not connected will not receive water from the pipe and will be left to alternative sources of water that may be contaminated and/or limited (Domènech, March, & Saurí, 2013).

This highlights the question of resilience for and by whom; while the Melamchi Water Supply Project will bring water for many in Kathmandu, many others will be excluded. Yet, as a response, small-scale resilience to water through diversification is not enough. While these alternative water sources offset immediate problems with water access, they (1) allow the government to deflect responsibilities over ensuring water access for all and (2) further lead to the deterioration of the overall water system through the resulting pollution and depletion of surface and groundwater sources. Ultimately, the multiple systems that are maintaining water

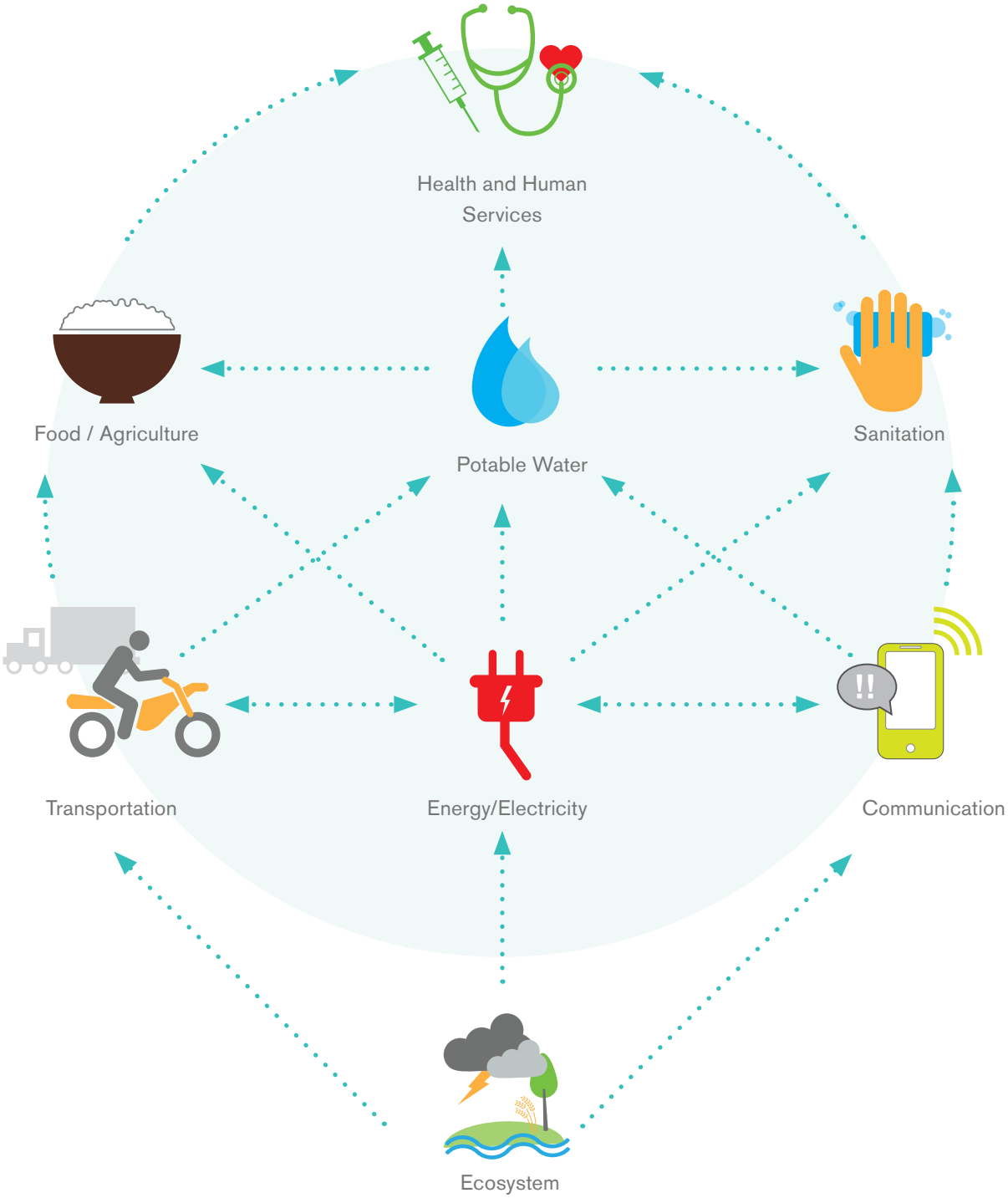

Photo by: Richard Friend

resilience in Kathmandu have also created a highly undesirable situation, "ever closer to a critical threshold for collapse" (Pelling, 2012). If and when the water system collapses, millions of Nepalese will be left without access to safe water.

The 2015 Earthquakes

The April and May 2015 earthquakes in Nepal killed over 8800 people, injured more than 23,000 and destroyed housing and other structures across a large area. Over 2.8 million Nepalese have been impacted and will require food, water, shelter, sanitation, and health services in the coming months. Hoffman and Oliver-Smith note the "processual" character of disasters (2002) with the impacts of an event, such as an earthquake, cascading across both time and space. This implies that while the earthquake in Nepal, as the triggering event, occurred within a specific time frame and impacted a specific geographic area, the disaster unfolding in Nepal will not be limited to just the immediate shock of the earthquake. Rather, in the days and months to come, we may very well see cascading impacts from this event across the impacted areas with continued landslides, floods and disease outbreaks as the result of environmental and structural fragilities.

Water distribution and supply is becoming the focal point of many disaster relief efforts (Office of the Resident Coordinator, 2015). In our analysis of the water system in Kathmandu above, we emphasized both its resilient and non-desirable aspects with water markets and rooftop water harvesting emerging in response to the formal water supply system's unreliability and cost. While this diversity of sources has provided the Nepalese living in the city with options following the earthquake, it is highly vulnerable. The widespread tanker markets, for example, helped deliver water following the quake. At the same time, the highly polluted nature of most water sources in the valley and the lack of sanitation facilities could lead to the spread of disease. Rooftop rainwater harvesting looks like a local option to reduce dependency on imported supply and avoid contaminated water sources, but it depends on infrastructure, which may take time to repair. Thus, just as the resilience characteristics



System dependencies allow for cascading impacts of a natural disaster to play out across space and time. If a disruption to, say electricity, communication, or transportation is encountered all services that depend on these services will become compromised.

Photo by: Richard Friend

of the current water system emerged in response to the stress of poor management, how and what the water system looks like in response to the earthquake are questions that should be addressed both in the short and long term recovery plans.

In summary

Overall, the Kathmandu case illustrates how elements that contribute to the resilience of a system can also perpetuate highly undesirable situations and, just as with overly rigid systems, may exacerbate the impacts of ongoing disasters or create the conditions for later disaster. In addition, it illustrates the role of different actor sets in operating elements of the urban "water system." In this case, urban water supplies are delivered directly by homeowners through wells and water harvesting systems, through markets by tanker and bottle, through community based religious or neighborhood organizations, and by the municipality through the piped system. Each of these elements operates relatively independently and in parallel with the others in a way that contributes to resilience, but the lack of a primary responsible party leaves no one monitoring or addressing the growing degradation of water quality and the urban ecology.

Kathmandu water scarcity is a governance issue

The Kathmandu Valley was once rich with water resources. In an interview with Suman Shakya of SmartPaani, a rainwater harvesting startup operating in the valley said, "You used to be able to just drill a hole and there would be water." Traditional water systems like stone taps and ponds were once abundant, but with rapid urbanization, infilling of ponds, and ground sealing, water resources have become constrained. This is compounded by a lack of proper treatment facilities and waste water management. People in the Kathmandu Valley face challenges of water scarcity on a daily basis. The problem that they are facing in this case is the result of poor governance and not climate change.

YouTube

To see our video on the compounded issues of climate change and poor governance, please see: www.i-s-e-t.org/resources/other/ktm-water-scarcity.html

Kathmandu, Nepal Gorakhpur, India

The previous case studies have focused, in some cases, on the role of relationships and flexible institutions in building adaptive systems and, in other cases, on the role of structural interventions in building mal-adaptive systems. Our final study of climate resilience in Gorakhpur, India takes us in yet a third direction and elucidates the powerful effect that a series of small-scale actions can have on building city and community resilience as a whole.

Authors
Michelle F. Fox
Rachel Norton

Gorakhpur, India

Community Mobilization

This case study of resilience in Gorakhpur, India demonstrates how many small actions at multiple levels—community, individual and governmental—across a city can lead to more rapid transformation and resilience. The approach taken by the Gorakhpur Environmental Action Group (GEAG) and ISET-International takes into consideration ecosystem dynamics and the need to build social cohesion in the face of annual flooding and community fragmentation as increasing numbers of rural migrants flood the city.

Actors, urban administrative entities, and markets in Gorakhpur, India

Actors at the local level

In Mahewa Ward in Gorakhpur, in the face of extremely poor urban services, community members have banded together to implement a series of one percent solutions as a means to improve their access to basic needs such as water, sanitation, transportation and information.

Urban administrative entities

The government in Gorakhpur has been unable to provide core urban services to its population. The urban poor in particular, such as those living in Mahewa Ward, have been excluded from what little service provisions there are. Community-level initiatives have effectively pressured the Gorakhpur government into implementing similar initiatives at a much larger scale.

Markets

Efforts to improve the state of peri-urban agriculture in combination with market forces have contributed to protecting peri-urban farmlands and in securing a critical buffering system that protects the city's infrastructure from threats of annual flooding.

Photo by: Michelle F. Fox

Photo by: Michelle F. Fox

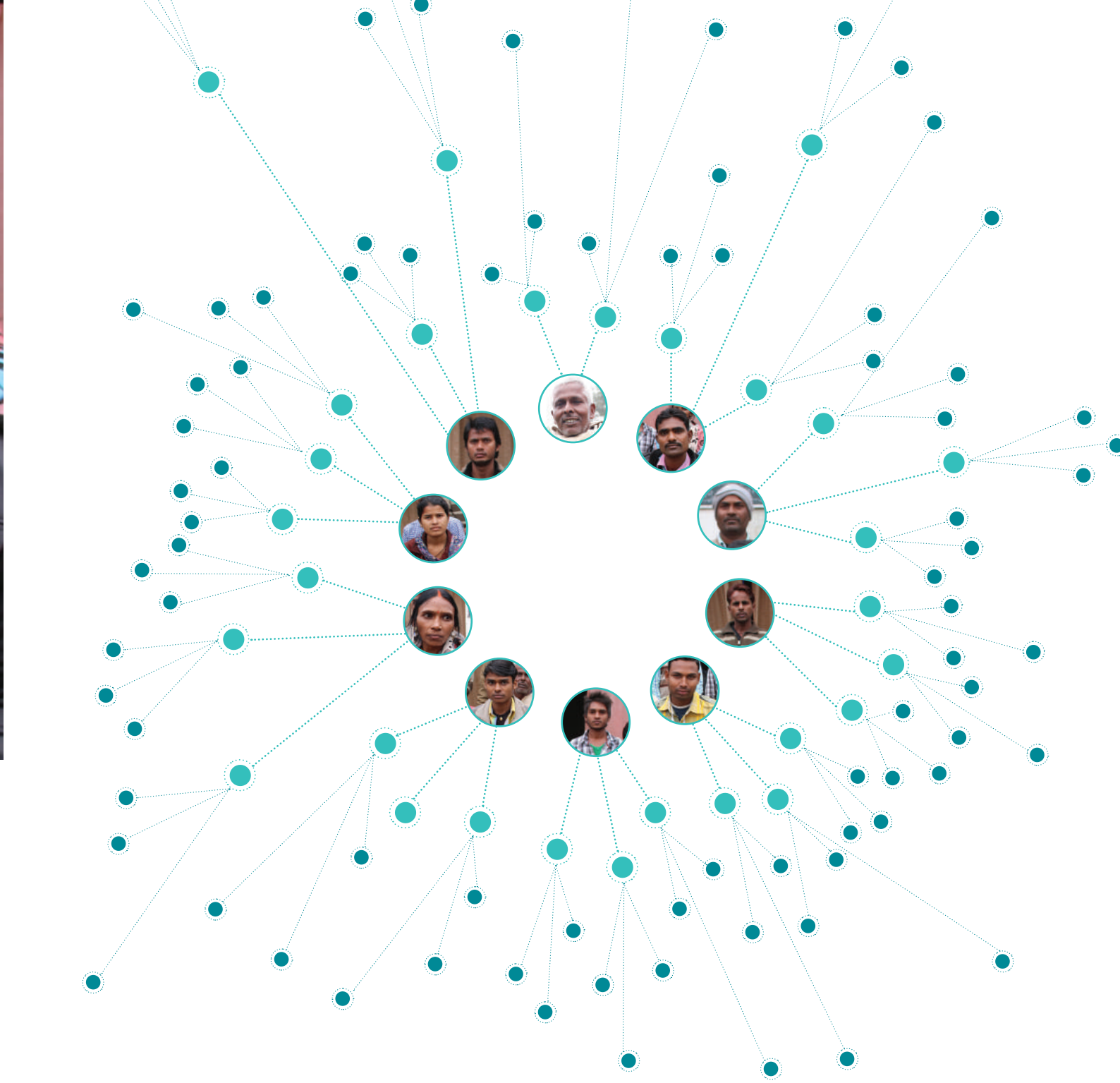
Even as population and climatic pressures exacerbate vulnerabilities and suffering, particularly for the low-income communities who encounter waterlogging for months out of the year, Gorakhphur's municipal government lacked the capacity and financial resources needed to effect local change. In response to this gap, and to the increasing demands placed on the city, GEAG and ISET-International supported a series of small initiatives—actions such as supplying weather information to farmers, building flood resistant homes and schools, or paving roads in low-income wards—which are creating ripple effects throughout the city. Moreover, the increasing community engagement resulting from this work has effectively created political pressure on the state to replicate these projects in other wards within the city.

These innovative actions, implemented at the community and household level, illustrate the way a diverse array of solutions might aggregate and contribute to a resilient urban water management system. While each of these steps are partial and only provide a small piece of the puzzle, they contribute to the overall resilience picture. Education, the creation of physical infrastructure, changes in governing practices, and collective and individual actions are all examples of one percent solutions to pressing environmental and social issues.

Climate resilient agriculture, and access to information

One of the one percent solutions implemented in Gorakhpur is supporting peri-urban agricultural initiatives as a component of flood management. Not only these actions, but the entire peri-urban environment has traditionally been largely disregarded by the government, whose focus is on the urban and rural areas, not the grey area in between.

The core of this peri-urban agricultural initiative is a Farmer Field School opened by GEAG in a peri-urban area of Gorakhpur. Through the school, farmers receive training on "ecological"



At the Gorakhpur Farmer Field School, GEAG is engaging 30 model farmers. Through both planned and unplanned information sharing, another 619 farmers are also adopting climate resilient agriculture. This program has had direct and indirect impacts on a population of 18,000 people.

farming practices such as seed saving, use of organic fertilizer, composting techniques, and 5-day weather forecasts. This is a substantial improvement on the previously available 1-day weather information through the local newspaper, television, and radio, and lack of formalized information on agricultural techniques.

Thirty "model farmers" actively participate in the Farmer Field School training program and with the success of these model farmers, local community members are also adopting the same ecological farming practices. In total, an estimated 500 "link farmers" are scaling the project autonomously across the city. Weather information is being disseminated even further. Over 1,000 farmers have been trained and receive direct SMS messages with 5-day weather forecasts. These farmers then share these forecasts with their own social networks to reach a total of 5,400 people.

These farming practices and weather information have manifold results for the farming families and the entire ecosystem of the city. Farmers have been able to turn their failing crops into profitable businesses. Instead of selling their produce at wholesale markets on the outskirts of town, farmers are now selling their crops at a premium in the city and are turning their crops into other products like jam and jelly. Grown with organic materials, fertilizer and compost, the food offers high nutritional value to the entire city. With the profit and savings from their crops, farmers are able to reinvest in their children's education, their homes, or in hosting community events. While hosting community events may sound like a luxury, doing so helps to build community networks that enable people to bounce back after a disaster. Through this program farmers now have a reason to keep their land, which would otherwise be sold to developers. Market forces have thus contributed to protecting peri-urban farmlands and in securing a critical buffering system that protects the city's infrastructure from threats of annual flooding. In this way, benefits of this program are impacting multiple scales and sectors within Gorakhpur.

Paving the streets in the Mahewa Ward

The Mahewa Ward is located on a former landfill in the urban area of Gorakhpur. The roads were once filled with litter, waste, and debris. Due to lack of drainage, wastewater and sewage would stagnate in the muddy streets, stirred by vehicles, pedestrian traffic, and animals and would eventually end up in homes, spreading disease and germs. Notably, because of the extent of the physical and social vulnerabilities within the ward, GEAG and ISET-International selected Mahewa as the area for piloting Asian Cities Climate Change Resilience Network (ACCCRN) interventions.

The structure of ACCCRN rests on collaboration with community groups so that individual community members are making the decisions needed to build their own resilience from the ground up. However, at the beginning of the ACCCRN work in Mahewa Ward, there were no existing community groups to mobilize. The work in Mahewa therefore began with GEAG and ISET-International facilitating shared learning activities in the community with the goal simply of forming connected community groups. These groups then identified critical issues, such as sanitation, drainage and the creation of all-weather roads, which were of high priority to them.

In response to this community driven initiative, GEAG invested money and piloted a street-paving project with gutter systems to improve drainage and move wastewater away from homes, and a solid waste removal and composting project to assure that drains would remain clean and provide the co-benefit of compost for household gardens. These community efforts effectively shamed the local government into action. Within several months, the city paved the remaining streets in the ward and in several others, dramatically improving conditions.

In addition to the community building, drainage and paving work in Mahewa, GEAG worked with Mahewa and other Gorakhpur communities to: implement awareness campaigns centered on informing the community about general health, ranging from discussions of the benefits of hand-washing and vaccines to the spread of communicable diseases; develop low-cost, flood

Photo by: Michelle F. Fox

Photo by: Michelle F. Fox

resilient houses; and build the capacities of low-income women through connecting them to local microfinance institutions.

Individuals are also taking action on their own behalf to address flooding in Mahewa. Prior to the ACCCRN engagement, and continuing today due to ongoing need, one of the primary household level flood-resilience strategies is to raise homes 1-3 meters in response to typical annual flood depths. This is, for the most part, largely successful in mitigating flood risk. However, similar to the construction of flood landscaping in Boulder and the purchasing of water in Kathmandu, only those who can afford these actions benefit from them. Thus, here also the market plays a role in contributing to flood management in Gorakphur.

Community building creates lasting benefits

The capacity building support that GEAG has offered will outlast any infrastructural change. The multi-layered approach to building resilience demonstrates that building resilience is not about simply ending poverty, building smarter buildings, or providing solutions to wicked problems. Building resilience is about training, mobilizing and connecting communities, and empowering individuals with knowledge and resources to take action when a disruption to their system occurs.

While GEAG provided support and training, the community members have provided the momentum. When we asked the communities what the greatest benefit of the program was their responses were largely centered around themes of awareness, empowerment, leadership, and hope. The communities have been armed with a greater understanding of how, by working together, they can influence decision-makers to act on their behalf. They understand the value of the ACCCRN programs and the behavior changes that have been initiated. Wellness practices, like hand washing and receiving vaccinations, are being adopted at increasing rates. And now, when an issue in the community arises, community members know which municipal corporations and government offices to go to for support, demonstrating a collaborative system of urban water management that involves actors at the community and governmental level.

The programs have created lasting change. Because of the demonstrated success of programs like the climate resilient agriculture, people request the recommendations and advice of the community leaders. In turn, community members now realize that they can make real change happen. It's step-by-step, it may be slow, but they are looking

to the future and identifying the changes and interventions that can be made to ensure that the community continues to grow stronger.

In summary

The Gorakhpur case illustrates the role actions within communities, households and markets can play as central parts of an urban water management system. While each action (such as improvements in drainage) may only represent "one percent" of the urban management equation, more comprehensive approaches can be catalyzed by recognizing and facilitating action by different sets of actors.

In the absence of effective regional flood control systems, raising the plinth level of houses is among the few courses of action individuals, households and businesses can take on their own in response to flooding. In this case it is highly effective in reducing regular asset losses. It is, however, expensive. As a result the poor remain vulnerable. Programs to provide funding for them to raise houses in the same manner as their more wealthy neighbors could, at least in part, address this. However, addressing issues individual household by individual household is rarely the optimal or most cost-effective option.

At the community level, building institutions can help to address problems within neighborhoods and, perhaps more importantly, create the conditions necessary to catalyze government support. Finally, where markets are concerned, facilitating businesses such as urban farming can help to create the economic conditions necessary to maintain open space or other land uses that mitigate flood impacts. Each of these elements, though perhaps minor on their own, are elements in a mosaic of activities that can transform urban water management.

It's more than just flood mitigation

When we talk about *resilience*, we often say that it's about bouncing forward and not just bouncing back. The engagement with peri-urban farmers in Gorakhpur is doing just that; the program strengthens the flood holding capacity of the city, while also improving the quality of life for farmers and their families.

YouTube

To see our video on the climate resilience agriculture project, please see: www.i-s-e-t.org/resources/other/more-than-just-flood-mitigation.html

Photo by: Michelle F. Fox

Author
Marcus Moench

Conclusion

The case studies presented above illustrate that water management outcomes, and the urban water management system itself, are co-produced by a diverse array of actors in households, communities, and markets as well as by municipal and other government entities. While the relative balance of activity between different actors varies greatly, even in highly developed, planned, and regulated locations such as Boulder, Colorado, entities other than the government play major roles. This poses significant challenges for how urban water management and resilience are conceptualized. While globally most attention focuses on formal institutions for water management, such as municipal water supply utilities or flood control organizations, we argue this perspective is limited and often ineffective.

Developing mechanisms that build capacity, strengthen and coordinate incentives facing each actor set, and mediate the roles they play can build resilience in the face of uncertainty and change.

Particularly in contexts where rapid processes of urbanization or climate change are occurring, though formal institutions should play a central role, they will always be playing catch-up. No matter how much is invested in information and planning, there will always be a margin of uncertainty and surprises are inevitable. Additionally, governments, even in wealthy locations, lack the capacity to deliver all the water management services that are required. Autonomous and emergent behavior by households, neighborhoods and other entities plays a major role in both shaping the urban water system and enabling responses when disruptive events occur. Markets, whether those shaping land use or for the direct provision of water services, also shape and operate elements of the urban water system. Consequently it is essential to recognize these elements as core elements of the urban water system.

Recognition of the role households, communities, market actors, and local organizations play could, in many areas, lead to re-evaluation of strategies for urban water management. Activities by each of these sets of actors can contribute to diversification and flexibility and thus to the overall resilience of urban water systems. Developing mechanisms that build capacity, strengthen and coordinate incentives facing each actor set, and mediate the roles they play can build resilience in the face of uncertainty and change. Furthermore, tracking the role each set of actors plays is required to identify critical gaps. Globally, mechanisms for resolving conflicts between water management actions at the household level, within urban water markets, and with municipal entities are rare. Similarly, as the Mekong Region and Udon Thani cases illustrate, regional mechanisms for managing water systems to meet urban needs are rare.

It is important to recognize that all approaches to urban water management have major limitations where equity is concerned. Water markets are driven by the ability of users to pay; those who buy large quantities in bulk almost always pay the lowest price. This is also the case where protective measures, such as raising houses or purchasing land in protected locations, are concerned; those with money can buy greater security. These equity concerns are not limited to financial equity. In most areas, cultural and other minorities have limited access to wider cultural resources. This is frequently most evident in the operation of government entities. Globally, wealthy and culturally dominant locations tend to have better access to municipal water supplies, flood protection and other water management services.

As a result, arguments that increasing the capacity of government to deliver water services will increase equity appear flawed. What may be needed instead is greater attention to the driving factors associated

with each set of actors in urban water management and the development of mechanisms to increase equity tailored to each. The case of Gorakhpur, for example, illustrates how community organization can increase the power of marginalized groups in obtaining water services from the government. Similarly, regulation by a combination of communities and the government could potentially address some of the equity concerns associated with the water market system in Kathmandu. Overall, approaches that recognize the range of actors involved and the elements of the urban water system they operate appear essential for both resilience and equity.

Finally, the cases demonstrate that resilience, desirability and equity are not inherently related. Many elements of the water system in Kathmandu are highly resilient. It is highly diversified both in terms of sources and water delivery mechanisms. Many of these mechanisms are very flexible and responsive in relation to events such as the recent earthquake. At the same time, the very resilience of these elements allows fundamental problems of water quality and environmental degradation to remain unaddressed.

Similarly, in Boulder Colorado, extensive long-term efforts to manage the water resource base by diversifying sources and improving flood management have created a system with many aspects of resilience that is, for the individuals who can afford to live there, highly desirable. It is, however, also highly exclusive. As Boulder becomes more resilient it is also becoming wealthier and less affordable. The purchase and creation of open space and bike paths, for example, contributes to the overall resilience of the city and makes it an attractive place to live. As Boulder continues to diversify its economy, the influx of higher paid workers into the city who want to live in Boulder is driving housing prices up, which in turn is pushing those in the middle and lower classes out of the city to join the two thirds of the workforce that commute into the city (Boulder Economic Council, 2012). We may very well see this same phenomenon occur in the Mekong region as green space initiatives to reduce vulnerabilities to flooding, may, down the road, ultimately lead to population movements that further the vulnerability of the already vulnerable.

Overall, though popular discourse frames resilience positively and sees it as contributing to social equity, resilience itself is only an aspect of a system. Resilience does not imply economic equality. To slightly expand an old adage, water can be thought of as a bipolar molecule: it flows uphill toward money and power when there is too little of it and downhill away from money and power when there is too much of it. Resilience also is not inherently the same as desirability or sustainability. In fact, factors that contribute to the resilience of a system can have undesirable consequences both socially (in terms of equity) and, as the Kathmandu case demonstrates, environmentally. As we strive for resilience we need to be aware that it is only one of multiple characteristics and we need to be thoughtful and intentional about the rest of the system values we build in.

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Globally, rapid urbanization, climate change and increasing pressure on basic water resources pose fundamental challenges for urban water management. The case studies presented in this document illustrate some of the core, common challenges and opportunities inherent in developing resilient urban water management systems across widely differing contexts. While most work on urban water management focuses on the role played by government and quasi-government organizations (such as utilities, flood control and drainage organizations, and municipal governments), in many locations markets and actors at the household and community levels operate and manage core parts of the urban water system. In this respect, water management outcomes, and the urban water management system itself, are co-produced by a diverse array of actors and not just government entities. The relative balance of activity between different actors varies greatly. Building the resilience of urban water systems in the face of climate, rapid urbanization and other stresses requires much greater understanding and appreciation of the roles of the different actors and their limitations and strengths in relation to other actors and the overall functioning of the urban water system.

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