



Floods in Boulder: A Study of Resilience

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Executive Summary

On September 9th, 2013 heavy rain started falling along the Front Range in Colorado. When the rains stopped five days later parts of Boulder County, which was hardest hit, had received nearly a year's worth of rain. Rivers and creeks, swollen well beyond bank-full in many locations, had destroyed roads and bridges, torn out culverts and downed trees, flooded homes and businesses, and resulted in the evacuation of several towns. Boulder County and 14 surrounding counties were declared federal disaster areas. Statewide, over 18,000 people were evacuated, more than 1200 by helicopter.

Yet in spite of the destruction, a common refrain from residents and government officials alike was how lucky they had been. Though rivers peaked in the middle of the night, though the scale of the event was unprecedented, only 10 lives were lost, most systems were maintained, and the response and recovery have been strong, well-coordinated and effective.

What made the area resilient to the devastation? This study demonstrates that the following actions in three major categories increased resilience:



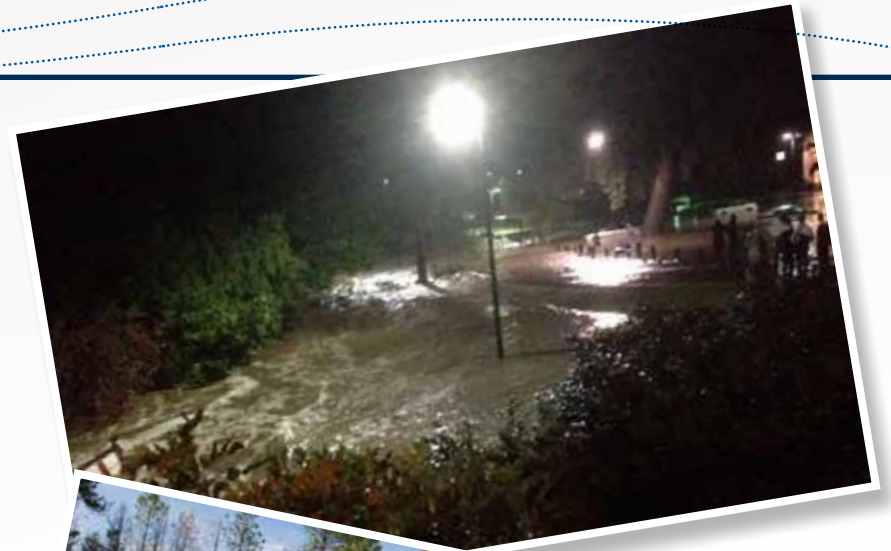
Physical Systems



Human Systems



Legal and
Cultural Norms





Executive Summary: Physical Systems

Plan for physical system failure —

Virtually all physical systems will eventually fail; designing them to fail in non-damaging, and ideally beneficial, ways is critical to resilience. Many of the rivers and creeks in Boulder County are bordered by Open Space or Greenways, providing recreational opportunities and preserving ecosystem biodiversity. During floods these trails and paths “failed” in their primary roles, taking on the role of floodwater conveyance. This allowed space for creeks to overflow, entrain and carry large debris, and scour and deposit sediments with little impact to built infrastructure and to the benefit of the natural ecosystems.

Prevent failure of critical physical systems through redundancy —

Redundant systems, such as a back-up diesel generator at the Boulder Water Treatment Plant, can prevent the loss of critical systems. However, main and back-up systems must have different sources of vulnerability. Though having multiple roads providing access into the mountains appears redundant, six of the seven roads between the plains and the mountain communities in Boulder County failed because they were at the bottoms at canyons next to rivers and creeks and were washed away. The transportation system was not as redundant as it appeared because so many roads had the same point of vulnerability. Further, as a result of the loss of roads, it proved almost impossible to transport the diesel required to keep the backup generator at the Boulder Water Treatment Plant in operation. This highlights the need to consider the potential for cascading failures in assessing resilience.

Build in diversity — Many of the physical systems that failed during the flood would benefit from a more diverse, distributed, multiple-small-solutions approach. For example, many homes outside the floodplain in the City of Boulder suffered substantial damage from sewage upwelling in basement drains. The City has determined that refurbishing the entire sewage system would be prohibitively expensive. Yet to date there has been only limited discussion of other options such as incentives for homeowners to install backflow devices to prevent sewage backups into homes in the future. Opportunities to strengthen system performance through small, distributed solutions should be sought whenever possible.



Executive Summary: Human Systems

Support individual capacity — Flood preparedness, response and recovery were strongest where individuals had access to basic resources and were able to act with creativity to address the problems at hand. For example, the sewage and potable water systems in the City of Boulder were maintained primarily through the ingenuity and resourcefulness of staff that felt free to take needed action without fear of reprisal. A network of civilian ham radio operators became the backbone of the communications network for many mountain communities. Many of the operators received training, funded by the county, following the Four-Mile Canyon Fire in 2010.

Develop networks — Strong collaboration between county non-profits, the faith community, and local governments dramatically aided the initial response to the floods and continues to facilitate ongoing, rapid recovery. Strong community groups, originally developed for other purposes, rapidly came together to aid both those within and those outside those groups. Virtually any type of network becomes a resource in a disaster situation, improving resilience.

Maintain broad access to resources — Access to outside resources, such as private sector stores and vendors in the Denver Metro Area, the national disaster clean-up industry, outside volunteer groups, strong financial institutions, insurance and other sources of outside financing all sped response and recovery. In some cases, waste from one purpose can become a resource for another; Boulder County was able to use organic flood debris as mulch and fill, creating a cyclical system rather than a series of linear problems.

Develop avenues for learning — Much of the resilience seen in the flood response and recovery were the result of modifications made to improve upon less resilient preparation and response to previous disasters. The economic downturn in 2008 left many organizations in the non-profit and faith communities with declining revenue and increased demand. The networking and collaboration developed to address needs at that time dramatically strengthened the community as a network and provided a strong foundation for rapid communication and collaboration during the flood recovery phase. A large wildfire in the County in 2010 provided useful lessons for emergency personnel, highlighting areas where better communications, early warning techniques, resident capacity for preparedness and response, and response and recovery coordination were needed. The progress made in all of these areas was readily apparent during the flood event. Where learning is inhibited, such as due to threat of litigation or due to workload challenges and a desire to just return to “business as normal”, it is critical to build in forums at all levels and across sectors and communities that foster learning from the disaster event, the response, and the recovery.



Executive Summary: Legal and Cultural Norms

Adapt legal requirements to enable response and recovery — During and following the flood, Boulder County cities, towns and the county as a whole modified many existing policies and legal requirements around waste disposal, construction permits and other flood-related issues to enable rapid response and reduce the financial burden on residents. However, laws about construction in floodplains continue to delay re-construction in many places where rivers and creeks have moved; the legal frameworks have not yet been updated to reflect new realities on the ground and until they are, government staff are unable to approve building permits.

Promote a culture of collaborative self-help — Many citizens in the U.S.A. have an expectation of government assistance during disasters. Yet, the government has only so much capacity; in large disasters, they are overtaxed just addressing critical infrastructure and life-threatening issues. The larger the disaster, the more residents will need to rely on themselves and their neighbors. The Boulder County mountain communities have learned this lesson well; Boulder County as a whole is now looking at ways to transfer these lessons to the plains communities and build a stronger culture of neighborhood collaboration and self-help.

Promote imagination - The scale of the 2013 flood completely overwhelmed Boulder County communications and response capacity, splintered communities, shut down transportation, taxed infrastructure systems to and beyond the breaking point. Yet, true “disasters” are the things we didn’t see coming, the things that are too big to plan for. We need to get good at imagining the unimaginable, and thinking about how existing systems, people, laws and policies can be easily, cheaply adapted for those events.

I. Introduction

Between September 11 and 18, 2013 Boulder, Colorado received over 17 inches of rain, about 85% of the annual average, all in one week. The rains resulted in severe flooding throughout the county that severely damaged or destroyed 688 homes and damaged an additional 9,900; damaged 150 miles of county roads; and killed ten people. The storm parked in the area and poured down rain for days on end, affecting not just Boulder County but 14 counties in the region. The rains and flooding were of historic proportions, and taxed the ability of communities across a wide swath of Colorado to respond.

The range of destruction was wide. Some towns were only affected in isolated parts, while others like Lyons and Jamestown in the foothills of the Rocky Mountains were devastated.¹ (Endnotes can be found on page 44.)

In many ways the City of Boulder and the wider Boulder County were well prepared for disaster. Yet the floods still caused millions of dollars in destruction and displaced many people, in some cases entire towns. What factors contributed to resilience, and what factors undermined it? This study looks at this question, breaking it down into three main categories.

The study method included interviews with key people in local government, civil society, and business, as well as academics studying the disaster. Interviews were supplemented with review of rainfall and hydrological data, press reports, and participant observation of the relief and recovery efforts.





Physical Systems

How did the built infrastructure hold up, such as roads, water and sewage, storm-water drainage, and how did ecosystems help or hinder people to weather the storm?

We look for these characteristics of resilient physical systems:

Flexible and diverse — able to deliver services under a wide range of conditions or over a wide spatial distribution;

Modular — with redundancy and with spare capacity to deliver unexpected service demand or meet extreme events;

Designed to fail in predictable ways — if system components are overtaxed, they can fail safely without taking down the whole system.



Human Systems

Did emergency response systems function as planned, how did public authorities respond, where did civil society organizations contribute, and how did individuals act spontaneously in light of what they saw happening?

Here are the characteristics we look for in human systems:

Responsive — motivated and able to take timely action when required, including changes in organization structure;

Resourceful — when priority actions for adaptation are identified, they can mobilize financial, human or other resources and implement those actions;

Able to learn — they can identify and anticipate problems, and lessons from past failure and feedback are internalized in system improvements.



Legal and Cultural Norms

What laws, regulations, and even cultural expectations contributed to an effective response, and which ones got in the way?

In general, resilient laws, regulations, and norms are:

Accessible — rights and entitlements to use key resources or access urban systems are equitably distributed;

Transparent, accountable and responsive — decision-making processes, particularly in relation to urban development and urban systems management, follow widely accepted principles of good governance;

Informed — private households, businesses and other decision-making agents have ready access to accurate and meaningful information to enable judgments about risk and vulnerability and for assessing options.

Instructions for Use

This report presents a snapshot of events and responses during the September 2013 flood in Boulder County, Colorado, USA. It is not comprehensive – much more could be said on the degree of resilience of Boulder County’s social-ecological systems during the floods. What this report does provide is a collection of short, field tested examples of resilient systems, resilient organizations and individuals, and resilient legal and social frameworks and a discussion of what it is that makes those resilient. It also describes factors which limited the ability of people and systems to weather the storm.

Though focused on cities and counties in the United States, this report has lessons of value globally. Improving communication, finding ways to use high hazard lands in socially valuable ways that simultaneously decrease risk, focusing on ways to build the capacity of individuals to act on their own behalf, providing the support and incentive for government and non-profit staff to be innovative in the face of disaster – these are applicable anywhere.

The challenge to using this report is not to use it as a literal template, but to use it as an illustration of the characteristics of resilience. For example, in Boulder six roads into the mountains turned out not to be resilient; they were all at the bottoms of canyons and all failed. What would that mean in your context, for your roads? Do you have what you think of as redundant or backup systems, but when you look closely you realize they all have a common point of failure? For example, is your power system reliant on one hydroelectric plant, one main power line, one set of tracks to bring in coal? What would happen if that hydroelectric plant or power line or set of tracks was rendered unusable? It is by asking these questions, of our own systems, and then acting on the results that we build resilience.

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II. Analysis: Physical Systems

The eastern half of Boulder County is a relatively flat plain lying at an elevation of about 5000 feet (1500 meters) above sea level. The western half of Boulder County lies in the Rocky Mountains; over a distance of about 15 miles (24 km) the land rises from the plains to the continental divide at elevations of 10,000-14,000 feet (3000-4300 meters) above sea level.

Unlike in the eastern or southern U.S.A. where soils absorb water and topography slows and retains runoff, floodwaters in Boulder County runoff rapidly from rocky slopes and across heavy clay soils, quickly accumulating in drainages and creeks. Consequently, intense rainfall can quickly turn small creeks into raging torrents.

This combination of topography and soil characteristics makes Boulder County at particular risk from floods and flash floods. In this landscape, we received nearly a year's worth of rain in five days. Unsurprisingly, there was extensive damage to storm-water drainage ways, utilities (water, wastewater, power), roads and bridges, and public buildings. Impacts to private property included damage to homes, vehicles, livelihoods, and in some cases to water supply and septic systems. Many of the private property impacts were located outside of the official floodplain mapped by the government². These impacts were caused by groundwater and sewage backup, irrigation ditch failure, landslides, and rivers and creeks changing course. In hindsight, however, most emergency personnel reflected that the real surprise is that damages weren't far worse and loss of life far higher.

In this section, we review how core physical systems — early warning systems, storm-water drainage, sewage, potable water, transportation, communications — held up, where resilient planning played a role in minimizing damage, and where we were just lucky.





Storm-water Drainage

Communities in Boulder County have been working for decades to mitigate potential flooding. The City of Boulder, for example, has a Greenways Program³ for drainages that fulfills many objectives simultaneously. The objectives of the program are:

- Protect and restore riparian, floodplain and wetland habitat;
- Enhance water quality;
- Mitigate storm drainage and floods;
- Provide alternative transportation routes or trails for pedestrians and bicyclists;
- Provide recreation opportunities; and
- Protect cultural resources.

Under the Greenway Program, main creeks in many communities have been left as open corridors. Multi-use paths have been integrated into these corridors to provide recreational benefits and to garner support for maintaining a wide footprint of undeveloped land to either side of the creeks. Where creeks intersect roads, oversized underpasses have been built with paths to accommodate cyclists, runners and walkers. Funding for this construction comes from local and state flood control and transportation dollars and federal transportation money. On the edges of towns and cities, particularly around the City of Boulder, floodplains have been bought by the City and County and designated as “Open Space”, crossed by hiking trails and/or leased for grazing cattle.

During the floods, mitigated areas — the paths, underpasses and Open Space — “failed” as planned. Initial functionality for recreation and transport was replaced by the secondary function to route storm-water. Particularly in the City of Boulder, this avoided substantial potential damage.

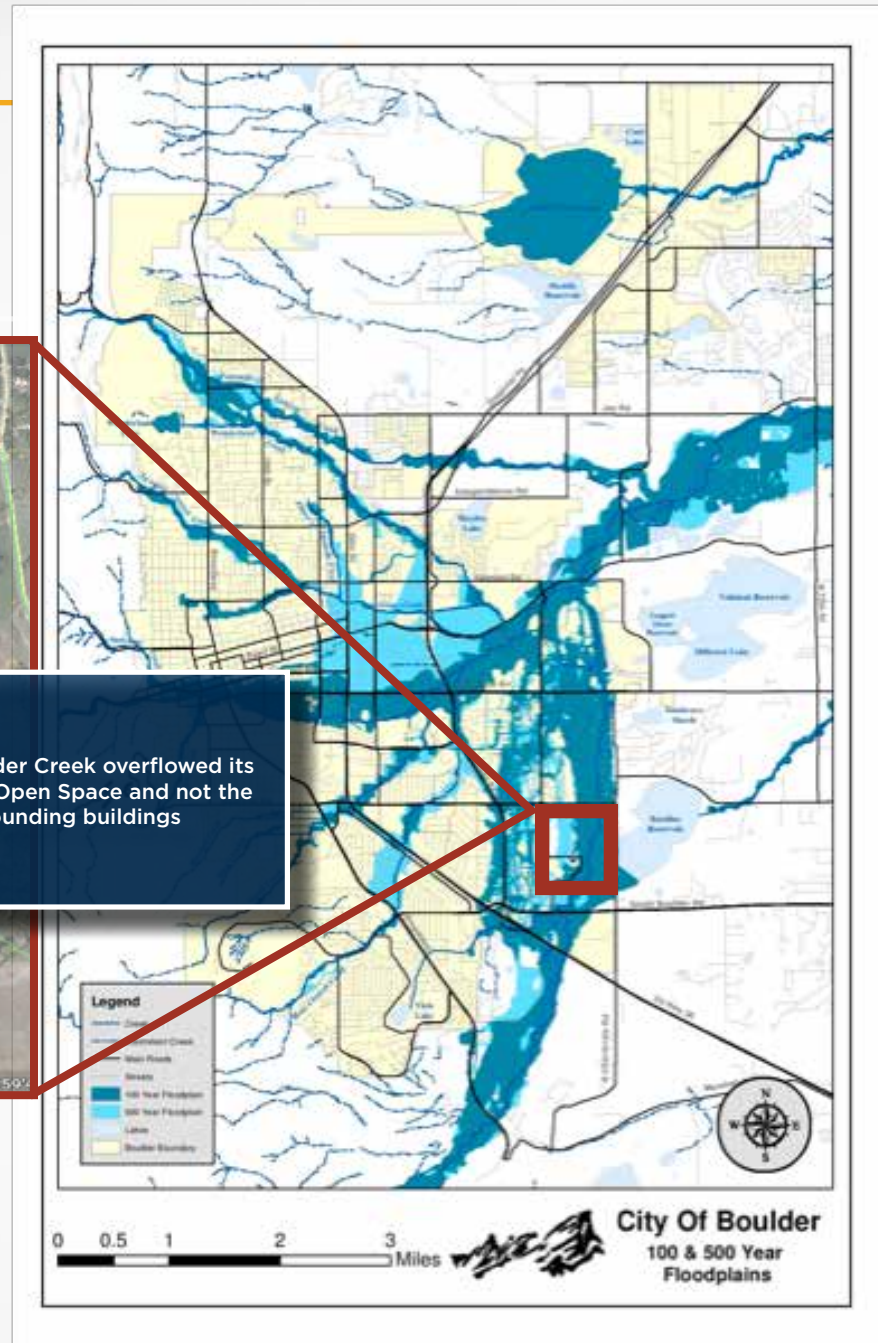
However, this type of mitigation can only be undertaken where the City has secured access rights along the full corridor. Consequently, smaller drainages — where land is a patchwork of publicly and privately held parcels — have not yet been mitigated.



Floodwaters flattened grass and covered the bike path along the Goose Creek Greenway, but no buildings were damaged, and the water quickly passed through.

In these neighborhoods, flooding was substantial. In places, families woke up to find streams running through their homes, slopes failed, and transportation routes were impassable. Overall, there was greater damage and impact in the city where the Greenways systems are in planning and design processes and have not been built out.

This type of mitigation has limitations, as does any mitigation effort. In the City of Boulder, flows were in the 1-in-25 to 1-in-100 year event range. In Lyons flooding was well above a 1-in-100 year event. The sheer volume of water led the river to carve new channels through town. Spaces devoted to parks, private music venues, open space and playing fields rather than homes and city buildings substantially reduced what could have been even more catastrophic damage. Nonetheless, many homes within the floodplain were heavily damaged or completely destroyed; Lyons lost 20% of its housing stock. Furthermore, much of the lost housing belonged to lower-income sections of the population. These people are among those least able



Shown on the right is the City of Boulder 100 and 500 year flood map. Areas in blue were flooded during the September 2013 floods. The photograph on the left illustrates the area highlighted in red on the flood map. South Boulder Creek extended to the east and west of the creek but for the most part did not flood infrastructure until it ran into residential neighborhoods in the north east section of the photographed area. (Please see page 47 for a larger image of the flood plain map.)



to recover, yet they are often central to the economy and culture of a community. In Lyons, this sector includes a large concentration of artists, musicians and service workers. Lyons has worked hard to build and nurture this community, and is now challenged to provide housing opportunities that will allow them to return to the town.

In Jamestown, where flows were roughly a 1-in-300 year event and where the mountain topography forced homes and roads either into the floodplain or onto steep slopes at risk of landslide, it is not clear that there were floodway mitigation options that would have made a substantial difference. Part of the challenge for Boulder County is that the mountains are a patchwork of old mining claims that have been declared legal building sites. Many of these are in very high-hazard areas — areas with limited access, on steep slopes, or along creeks. In the current County regulatory framework, these would never be declared buildable sites. However, by State law, because the land was subdivided decades ago and they are now privately owned, to declare them unbuildable now would be equivalent to the government taking private property. Nonetheless, these properties are inherently vulnerable and when they fail they often create secondary risks for others. The question of how individual land owners develop and manage their property, and the types of risks and costs this can create for their neighbors and for local taxpayers as a whole is an issue for Boulder County and also for many other communities.

In the aftermath of the flood, drainage continues to be a major concern for city and county staff. Creeks and drainages are choked with sediment and debris in some places and compromised by erosion in others. Some creeks have moved and are now running along unstable new channels. With groundwater levels still high from the fall rains, water managers are racing to clear drainages prior to the spring runoff season.

Another challenge moving forward is to figure out the new drainage landscape. Where do the 100- and 500-year floodplains now lie? Should cities and counties allow people to rebuild in the same location? Unfortunately, the time required to update flood-plain maps is much longer than the timeframe on which residents want or need to rebuild. In some cases residents and local government staff are struggling to make the best decisions possible with limited information; in other cases residents are unable to proceed while local governments struggle with regulations, leading to rising frustration and conflict.



Wastewater

Wastewater treatment plants and piping in communities throughout the county were heavily impacted by the floods. The Lyons and Longmont plants were shut down, and in both communities sewage pipes were badly damaged; repairs are ongoing six months later. In Boulder, the wastewater treatment plant was kept up and running primarily as a result of the resourcefulness of the operators. During the flood, wastewater volume went from 10 million to 50 million gallons a day. Operators used retired holding tanks for temporary storage and kept the biological processing of the heavily diluted wastewater stream running through ingenuity and experimentation. During the second or third night of the flood, staff discovered that riverbed erosion had fully exposed one of the main sewage intake pipes to the plant where it crossed a major river. In the middle of the night, city employees were out with heavy equipment damming the river and building a concrete cradle to protect the pipe. Had city employees not had the freedom to take independent action and the incentive to problem solve in an emergency situation, the City of Boulder might have lost sewage treatment and had to be evacuated.

Homes on private septic systems didn't necessarily fare any better. Many private systems were badly damaged during the flood. Some hard hit areas that are located on the outskirts of cities are in negotiation with those cities about connecting the the municipal sewer system.

Though the sewage treatment plant in Boulder stayed operational, the elevated volume of water in the system caused backflow issues in lower-lying sections of town. In numerous homes in the eastern part of the city, sewage upwelling into below-grade drains caused significant damage to basements and garden-level apartments. Many of the impacted apartments were home to lower-income families and university students. Though some landlords were responsive and quickly repaired damages, some portion of these residents were forced to find replacement housing, and others continue to live in damaged and now moldy and otherwise hazardous residences.

To date official discussion of sewage backflow has been minimal. The city government is concerned that if it initiates a dialogue about sewage disposal, it will open itself up to lawsuits. Unfortunately, this limits the ability of both the city and residents to learn from the impacts of the flood and work together to



reduce potential future impacts. City utility staff have determined that upgrading the sewage drainage system city-wide is prohibitively expensive. Other possible solutions, such as backflow devices on individual homes or drains were only starting to be publicly discussed six months after the flood. Truly out-of-box thinking, such as modular municipal sewage systems treating individual neighborhoods, such as those that are being considered in Victoria, Canada, or moving to composting toilets, which could be coupled with a private-sector waste collection and secondary composting to assure public health and safety, are not on the table. Indeed, composting toilets – which have dramatically improved in recent years – could potentially present an elegant solution to sewage backups (and in other times, to water supply challenges) by removing sewage from the wastewater stream entirely. Such systems might be a highly feasible option for severely impacted neighborhoods, though they would certainly have their own set of issues. Nonetheless, they remain illegal within Boulder city limits. Consequently, in the next big flood in the City of Boulder, sewage backups are likely to again be a problem. In this case, the legal framework and associated threat of litigation inhibits learning and reduces the future resilience of the area.



Potable Water

Potable water systems throughout the county were also badly damaged. In Lyons the water distribution system was torn apart by floodwaters and erosion. In Jamestown the potable water plant needs to be rebuilt and 50% of the distribution network was lost. In other communities, potable water plants are still operational but water intake points are no longer connected to the river.

The City of Boulder is fortunate to have both a main and a secondary potable water plant. The secondary plant was shut down early in the flood, however, due to loss of power and excessive turbidity in the intake supply. The main plant stayed operational during and after the flood, but as with the wastewater treatment plant, its functionality was maintained only through the ingenuity of city staff.

The main City of Boulder water treatment plant is located in the mountains six miles west of and a thousand vertical feet above Boulder. Its location on a ridge protected the plant from damage from floodwaters. However, power and access to the plant were both lost during the peak of the flood. Equipped with a backup diesel generator and with a dedicated 2-person, 24-hour staff, the plant weathered the first day or two quite well. However the roads to the plant, located at the bottoms of canyons, were lost by the second day of the flood. As diesel and chlorine reserves ran low, and as operators were worn ragged and needed to be swapped out, it took substantial creativity, extensive knowledge of informal mountain roads, and the cooperation of private landowners to identify alternate routes to the plant. As with the sewage treatment plant, failure of the water treatment plant could have meant the evacuation of the city. Because distribution lines would have had to be flushed and disinfected prior to any re-initiation of distribution, potable water would have been lost for the duration of the flood and for at least a week after re-accessing, repairing and restarting the treatment plant. For a city of 100,000, this would have resulted in huge economic impacts.





Transportation

One of the hardest hit public sectors was transportation. Almost all the roads west of Boulder and Lyons follow creeks up mountain canyons. All of these roads were impassible by the second day of flooding. The rivers-turned-raging-torrents tore chunks out of the roads and filled the canyons wall-to-wall with water. Only one east-west road into the mountains remained passable in Boulder County by day five of the floods. Many mountain communities were evacuated by National Guard helicopter. Closure of canyon roads resulted in large numbers of displaced residents; their homes were intact but they couldn't access them until the roads were rebuilt.

One of the key issues with the mountain transportation network was in the location of roads – all but one lie at the bottoms of canyons. Consequently, though there were at least seven different routes from the plains into the mountains in Boulder County, six of those were all subject to the same hazard and failed. It is fortunate that Sunshine Canyon Road follows the ridge-top and thus avoided damage, or many thousands more people would have been displaced until the roads were repaired to the point they could be reopened two months later. This point highlights that backup and redundant systems really are not redundant if they all have the same failure points. It also helps identify entry points for strengthening system resilience – in the case of Boulder County, strengthening both Sunshine Canyon Road up the ridge and rebuilding one of the canyon roads to withstand 1-in-100 or 1-in-200 year flood conditions, though very expensive, would significantly improve transportation resilience.

On the plains, impacts to transportation during the floods were widespread. Many roads, designed to route up to 2-year rainfall events, were overwhelmed. Many intersections and sections of road were closed, creating hazards for residents and emergency responders. Transportation closures throughout the county cut off access to most of the pre-designated flood shelters, requiring emergency managers to rapidly identify and open new sites.

Once the rains stopped, most of the plains roads were usable again. Damage was highest in unincorporated Boulder County, where roads lacked curbs and were of less durable construction. In many places, particularly driveways and private access roads, culverts washed out taking the road with them.



In the Town of Lyons, the main bridges connecting sections of town remained intact; they were well engineered and built to withstand flooding. Unfortunately, most were built for the 100-year flood and were too small to accommodate the full volume of the flood that came through this community. Substantial portions of the river ended up flowing around the bridges eroding the road on one or both sides and rendering the bridges impassable. This happened in other places on a smaller scale with undersized culverts forcing water over roads. In some areas, this may have contributed to rivers and creeks changing course and cutting new channels.

Within two months of the flood most of the county roads were temporarily rebuilt and open to local traffic. Particularly for mountain roads, county employees were required to think outside the box. In many cases roads had to be rerouted quickly but safely. The County Transportation Director noted that the employees who really excelled at this rebuilding task were those who had risen up through the ranks, developing substantial on-the-ground experience in the process, rather than those who had official educational credentials and book learning. This highlights the value of a diverse staff, trained in a variety of ways and with a range of credentials. It also highlights the value of a flexible county organization, which gave staff the chance to be innovative and solve problems on their own, resulting in a rapid recovery.



Ecosystems

The areas in the foothills on the western side of Boulder County are sparsely populated and heavily forested. The forests cannot generally be described as “healthy:” a century of fire suppression has created an ecosystem of trees packed too tightly and with insufficient variety in age. However, the forest cover holds soil and debris in place, minimizing erosion and landslides. Of great concern to emergency managers were areas that had recently been burned by wildfire which were vulnerable to erosion in the rains. The Four Mile Creek Fire in 2010, which burned 10 square miles of land and 169 homes in the hills and mountains directly above the City of Boulder was the most recent and worrisome of areas. Beginning immediately after the fire, foresters had worked to remediate the fire damage by creating check dams and re-vegetating the area with native plant seed. County Emergency Management staff noted:

“Two inches of rain in an hour used to go unnoticed in the Four-Mile burn area; immediately after the fire half an inch of rain causes debris flow. A year later, three-quarters of an inch of rain caused debris flow. In 2013, we had three-quarter and one inch an hour rains and nothing happened. We were thrilled, but concerned that it really hadn’t recovered that much and it was just luck.”

This luck didn’t hold for the 2013 flood. The rain that fell in September 2013 was so extreme that no practical amount of mitigation would have prevented erosion and landslides. In fact there were numerous landslides – one of them fatal in Jamestown. Every drainage was clogged with debris. Though erosion was higher in former burn areas, the amount of erosion was certainly reduced by the existence of ground cover. Without that protection, the loss of life and property would have been far worse, not just in the burn area but also in areas downstream as debris washed off the hills, clogged creeks and rivers, and increased the chance of the water carving new channels.

Interestingly, though the built environment was heavily impacted by the flood, many natural ecosystems benefitted. The Boulder County environment is one of intermittent, intense rains, high spring runoff punctuated by low fall and winter river flow, extreme winds, extreme temperatures, intense sunshine, and occasional extreme droughts. Native plants and animals have adapted to and in many cases



thrive on these conditions. This is particularly true of river environments, which benefit from floods, even extreme ones. Floods create new habitat for fish, stir up sediments and wash plants into the channels releasing nutrients, and generally play a revitalization role. Man-made regimes of controlled, relatively steady flows are generally less healthy for rivers and streams. Consequently, the September 2013 floods had little effect on our fisheries; indeed in the long run they may improve them. This positive outcome was aided by Greenways and open space along channels that allowed rivers to modify their beds, deposit and erode sediments, and take up and transport substantial plant material. Though problematic for spring runoff, these processes are beneficial for fish and other stream life, which in turn are a key component of the tourist economy. The rapid recovery of the fisheries bodes well for economic recovery.



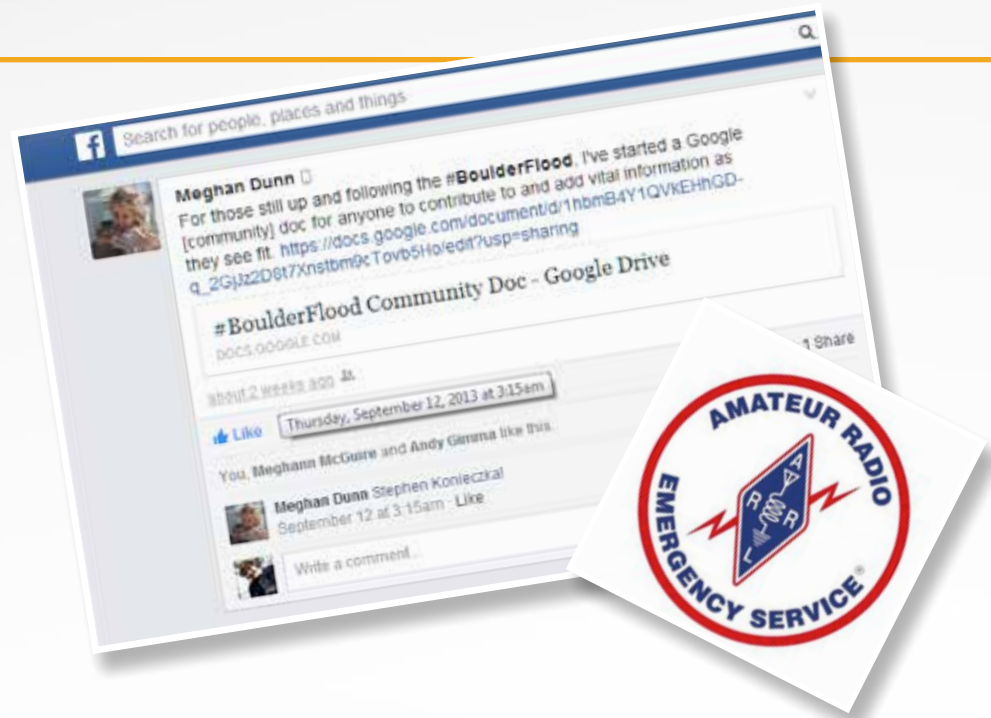
Communications and Power

Except in the Town of Lyons, communications and power infrastructure remained intact and functioning throughout most of the plains communities during the flood. Many of the mountain communities also retained communications and electrical power, though gas lines in many places were lost when the roads were lost. Intact power and communications made an enormous difference in what was possible in terms of disaster response and substantially minimized impacts to residents.

In those mountain communities where communications and power systems did fail, first responders used radios for backup communication. The channels they typically use were rapidly filled up with thousands of calls, however, far more than in any previous disaster. This clearly indicates the need for and value of alternative methods of communication that are not reliant on power and cell towers. This was an area recently strengthened based on learning from prior fire disasters. Many of the mountain residents had requested and received country support to train as ham radio operators. This civilian network of communications support was highly valuable during the floods. More than five-dozen Boulder County Amateur Radio Emergency Service (BCARES) volunteers provided critical communication for Red Cross shelters and state and local emergency operation centers.

In communities where power and communications remained intact, the Internet provided many highly valuable avenues of communication. Websites were able to post updates. Facebook was used by individuals, neighborhood groups and emergent aid groups to exchange information and coordinate support and assistance. Twitter was used by a wide range of players, from individuals to police to emergency workers to understand rapidly changing conditions and needs and coordinate aid. However, it was also an avenue for spreading unsubstantiated rumors and fueling fears. Several government employees noted that during the flood they spent substantial time monitoring and responding to social media posts to dispel fears, correct misperceptions and communicate information.

This highlights the double-edged sword that is social media. It has the power to be incredibly useful, but requires monitoring and course-correction to maintain that usefulness. Many agencies are already monitoring and using social media to enhance disaster response, but there is substantial room for additional growth. In particular, social media could be used to push messages about preparation



and provide basic information prior to disaster events that could significantly reduce impacts. For example, pushing information to schools about individual flood prevention measures might have encouraged homeowners to take simple actions like cleaning out gutters or checking sump-pumps that in turn could have significantly reduced flood impacts. Monitoring of social media during disasters can improve understanding of what is happening, help identify geographic and sectoral areas of need, point to the existence of emergent organizations that can help, and allow organizations with authority the opportunity to correct misperceptions and disseminate useful information.

Had power losses during the flood been more widespread, eliminating cell phone, television, most radios, and internet coverage, it is possible that impacts, particularly to human health and lives, might have been higher. It is certain that coordination of initial recovery efforts would have been delayed, possibly intensifying damages. The resilience of the power and communications systems throughout the majority of the county is to be commended.



Physical Systems – *What this means for resilience*

1. *Redundant* systems, such as a back-up power supply for the potable water plant in the City of Boulder, maintain system functionality when linked systems fail. However, this requires that the main and redundant components be independent and, ideally, have different vulnerabilities. If they both rely on, for example, the same power system and that power system goes down, they will both fail. This was illustrated in the failure of six of the seven main roads between the plains and mountain communities in Boulder County – all roads in the bottoms of canyons next to creeks failed. Through sheer luck there was one route that followed the ridge tops that remained intact. However, this was not a design consideration when the roads were built.
2. Previously established Greenways and recreational paths along creeks and rivers were designed to “fail” in their primary role, instead taking on a secondary flood conveyance role. The extra space along the river corridor and under bridges provided by the Greenways allowed for *safe failure* of the creeks; creeks were able to overflow their banks, entrain and carry large debris, and scour and deposit sediments with relatively little impact on built infrastructure.
3. Having a *modular, diverse* collection of communications systems was critical to both response and early recovery. In many mountain and some plains communities, communications systems reliant on power (cell phones, phones, televisions, internet) were lost early on. An established network of emergency personnel with access to and protocols for radio usage and a more informal network of ham radio operators established following the 2010 fire were critical to maintaining communication with the county at large and with one another. This greatly aided disaster assessment and evacuation efforts.
4. Physical system function was maintained and/or reestablished most effectively when staff were given the freedom to take independent action and innovate. This operational *flexibility*, coupled with a diversity of staff types and training, allowed systems to be operated effectively under a much wider range of conditions than they were initially designed for. In the City of Boulder, this was particularly evident in the cases of the potable water and wastewater treatment plants, both of which would likely have been shut down had staff not been proactive in highly unconventional ways.



II. Analysis: Human Systems

Flood preparation, response and recovery are implemented by many different players functioning at many different scales. In this section, we explore the actions and roles taken by individuals; non-profit organizations; city, county, state, and federal government; emergency responders; and the for-profit sector.

Autonomous and spontaneous activity

Governments undertake substantial planning and rulemaking in an attempt to guide action. However, in the end individuals look at their situation and make decisions about how they are going to react. Spontaneous action prior to, during, and after the floods fell into a few categories:

1. Mitigating flood risk on personal property prior to the disaster
2. Mitigating flood on personal property during the disaster
3. Finding alternative accommodation if necessary
4. Volunteering to help others within the neighborhood
5. Creating spontaneous organizations to deal with the immediate issues.

1. Mitigating flood risk on personal property prior to the disaster —Knowing that Boulder is a high risk flood area, some homeowners had made adjustments to their homes or land to reduce their risk: berms to divert water, swales to direct it off the property, culverts to allow streams to pass underground, sump pumps in basements. For the most part, homeowners undertook these adaptations on their own, assessing their own risk, their own cost, and their own benefit. Rarely were these adaptations done with an eye to upstream and downstream impacts, or in coordination with other property owners. Many of these features pushed flood waters into roads or public property. While this type of flood mitigation can, in part, be controlled through enforcement of building codes, if public infrastructure is built in anticipation of these types of autonomous behavior, resilience is increased.

Some of these adaptations had been built but had not been adequately maintained prior to the floods. In some neighborhoods in the plains, people had not maintained their sump pumps; some homeowners had even removed their sump pumps. This maladaptive behavior reflects the long-term nature of these risks: for many homeowners on the plains, there had been no severe flooding for fifty years, so the risk seemed very low. Other homeowners were unaware that there was potential risk. This finding echoes similar experiences in disaster management elsewhere – if it isn't used regularly, it won't be maintained. Specialized disaster response equipment like sump pumps, satellite phones and vehicles that have no other use tend to fail in disasters unless actively maintained since they are not required for regular use.

2. Mitigating flood on personal property during the disaster — Those whose homes were affected took action to stem the flow of water into their homes and to salvage property. In most cases, this involved such activities as modifying roof gutters to carry water farther from house foundations, digging ditches to divert water, pumping water out of basements, shoveling out mud and debris, and carrying furniture and valuables out of flooded areas. Local hardware stores recorded a huge increase in the sale of pumps, shovels, and similar equipment in the first days of the disaster, and lines in the hundreds for these items were common.

There were also more elaborate responses. In a number of places, neighbors banded together to divert the flow of water away from their homes. They did this by using the mud carried by the water to create temporary berms in the streets or in their yards, diverting the water from their property. In one area adjacent to Open Space, they were able to divert the water back into the Open Space so it wouldn't damage homes. But more commonly people unknowingly diverted the water from one home to another, farther downstream. In this case, individual action made sense for one home, but not another – it simply displaced the damage from one place to another. One observer noted that it would have been very helpful if there



had been trained volunteers who knew how to build spontaneous structures to a) be effective and b) minimize downstream damage.

These responses also pointed to a gap in information about the impacts of the flood. It was easy to see what was going on at a particular house or apartment, and the information provided by the City and County was good for the whole area. But information between those levels was difficult. Word of mouth was supplemented by Facebook and Twitter, but the accuracy of the information was difficult to assess, as always in the case of disasters.

3. Finding alternative accommodation if necessary – Flood shelters were available in a variety of areas as part of pre-planning coordinated by the Red Cross.⁴ However, as is the case in most emergencies, the majority of people chose to stay with friends or relatives. People without well-developed, well-resourced social networks were more dependent on the shelter system, especially those who were homeless before the flood. It is important to note that homeless people in the City of Boulder have strong social networks, yet those networks do not have a lot of resources to spare in the event of an emergency.

Groups that were vulnerable before the floods became more so afterward. In the town of Longmont alone, the number of homeless children in the school system went from 900 to 1300. This does not count the families that moved out of the area after losing jobs or homes.

4. Volunteering to help others – Every affected neighborhood saw neighbors helping neighbors. Whether carrying furniture, boxes of possessions, or waterlogged carpet and drywall, or providing showers and hot meals, or taking in those displaced, there was an outpouring of help from neighbors and friends. Most often, this voluntarism was informal and spontaneous.

Other spontaneous efforts included a Relief Exchange, where people could leave or pick up items to help those who lost things in the flood, as well as many fundraising events, especially among musicians from the area. Funds included the Lyons Musician Relief Fund and the Foothills United Way Flood Relief Fund. These fundraisers were organized specifically for flood relief, and had no previous life or plans to continue beyond a single event. They raised millions of dollars for



individual relief, most of which was distributed by existing charitable foundations. The existence of these funds sped the recovery period for many people, and allowed many to remain in the area as opposed to having to move away.

5. Creating spontaneous organizations to deal with the immediate issues – In addition to volunteering for neighbors and friends, there were important instances where self-organized groups developed to provide more systematic, almost institutional assistance.

In Lyons for example, where the town was split by floodwaters into six unconnected islands by floodwaters, a volunteer used Facebook and took advantage of a cell tower installed by FEMA to set up three-person emergency operations teams on each island: a medical person, a communications person, and a technical person. These people had no previous emergency response experience but quickly stepped up and within hours Lyons had a clear structure for helping people with basic needs



on each island. Backup teams were established to avoid burnout, and before taking on a job individuals were requested to identify who they would hand their job to next.

This type of spontaneous action is often called *emergent behavior*. People start to take action that they haven't before because it looks like the right thing to do. In many cases during the flood – creating volunteer management systems, local government staff building dirt roads in the rain when the paved roads were washed away, local non-profits stepping up to help even though they don't normally work on disasters – flexibility in management within organizations allowed people to get creative and solve problems on their own.

The flood also saw the rise of *emergent structures*, that is, new organizations formed spontaneously to help out. In the City of Boulder two groups started up to put volunteers in touch in a systematic way with those who needed help.

A group that came to be called “Mudslingers” (pictured to the right) started spontaneously in the first week of the disaster in an informal meeting in someone's living room. Attendees were frustrated because they had approached the City to volunteer, but were told the City could not get involved with volunteers because of the liability. During that meeting, people self-organized into a group that could match volunteers with people who needed help. They went around the room to see who had special skills, and who wanted to play what role. One volunteer set up a website to show volunteers where and when to show up, one person volunteered his organization, The Living GREEN Network, as a fiscal sponsor to receive donations and purchase tools and equipment, and others took other roles. Five to six people volunteered for a Leadership Team to make decisions for the group. The group set up a Facebook page to help communicate among volunteers, and set up an ad hoc office in donated office space. Some people specialized in handling phones and email and posting on Facebook. Local hardware stores donated tools and equipment, and businesses and individuals gave about \$30,000. One leader noted that if the City had made available office space and played a facilitating – not coordinating – role, that would make organizing volunteers easier.

A similar group, Boulder Flood Relief, started up around the same time. Boulder Flood Relief was started by veterans of the Occupy movement in Occupy Sandy, Occupy Portland, and Occupy Boulder. The group arose from similar impulses as



the Mudslingers: to find a way to put volunteers together with those in need of help. Following the organizational principles of the Occupy Movement, the group agreed to maintain a horizontal organizational structure with little hierarchy. This meant that important decisions affecting Boulder Flood Relief as a whole were usually brought to consensus among a core group of volunteers. Most smaller decisions were made by volunteers on the spot without having to ask the group. For instance, the procedures and systems for volunteer dispatch and the website were defined and implemented through on the spot decisions by volunteers who saw something that needed to be done and did it. The principle was to empower people to go directly to the source of the problem without worrying about whether the organization will approve or not. This can lead to problems when important tasks are put off or when coordination is required, but it makes for quick decisions.

Participants noted that in the early days of the disaster, they got little attention from the established disaster response community, partly because they were



Since emergent groups will appear in response to most disasters, maximizing their effectiveness while minimizing risks would multiply the resources available to established organizations.

unknown with no track record, and partly because they were a legal liability for established non-profits. As a result they had to figure out their own organization, management systems, volunteer database, sources of tools and equipment, etc. For the first week, the group worked without legal status, insurance or adequate personal protective gear. As a consequence the group was able to mobilize hundreds of volunteers quickly and help hundreds of homes, but the individuals involved took on considerable liability. With time, as the group established itself as well organized and reliable, it got pro bono legal help to reduce its risk, and became part of the broader network of relief organizations. It developed legal waiver forms for volunteers and homeowners, incorporated to reduce liability to individuals, and set up Bylaws and a Board of Directors. Given the outpouring of support, it also received \$30,000 without doing much fundraising other than putting a donate button on the website.

The entire Boulder Flood Relief operation ran using social media and cloud technology. Any documents needed were created and stored on Google drive, and volunteer matching was done on the web site, Twitter, and Facebook. Participants noted some surprise at how the established disaster response agencies tried to do group work only by email, which seemed cumbersome and inefficient. They also noted that early on in the flood response phase they were faced with needing to collect and store data on those needing assistance. They developed their own tools and systems for this, which later in the recovery phase they found were incompatible with the systems used by established disaster response and humanitarian relief organizations. They noted that, had they received logistical support from established organizations early on, both they and the established organizations could have benefitted significantly.

Over the course of several weeks, the emergent self-organized groups established credibility with existing aid and humanitarian organizations — it became clear that the emergent groups were reasonable, had skills and capacities, were going to last beyond just a few days or weeks, and wanted to be part of the recovery process — and the emergent and existing organizations began working more collaboratively. Staff from established disaster response agencies observed that cooperation with informal, emergent groups could allow bigger agencies to respond more flexibly; they could pass on requests that fall outside their established organizational procedures to the emergent organizations which have more freedom of movement in their responses.

In many disaster situations, self-organized groups form among those who are poorly served by the disaster response. This was not the case in the Colorado floods; here, new groups were primarily formed by volunteers trying to help, rather than by those directly impacted. As a result, the groups tapped into a set of people who were well resourced and often highly skilled (computer professionals, lawyers, accountants, etc.). The majority performed the physical labor that most disaster response requires, but the groups were able to call quickly on the more specialized skills they needed. For example, Boulder Flood Relief quickly dealt with some its legal issues when one volunteer stepped up to handle its legal registration at no cost. Another volunteer with computer experience set up the group's database of volunteers and requests.



These self-organized groups were a resource that could have been more effectively used earlier if professional disaster response organization staff had been trained in how to identify and work with them. Since such groups will appear in response to most disasters, maximizing their effectiveness while minimizing risks would multiply the resources available to established organizations. For established organizations, training in how to identify and call on these self-organized group when their own organizations' constraints make response difficult, how to help self-organized groups get up to speed quickly, and how to quickly assess the capacity of self-organized groups would be to the benefit of established organizations, government entities, self-organized groups and disaster victims. Easy to use systems that display, in real time, which appeals for help have received responses could greatly aid coordination between groups. For self-organized groups, ready-made tools for volunteer management, inventory and finance, quick legal advice, and even office space could significantly increase effectiveness.

Whether these self-organized groups will continue after the disaster is unclear. There is precedent for emergent groups to continuing to operate beyond a disaster and recovery in useful ways. Professional emergency personnel in the area cite the contribution of the Inter-Mountain Alliance (IMA), a group of mountain community leaders originally convened in mountain towns in 2010 to discuss lessons learned from the Four-Mile Fire⁵ in 2010. Each one of the mountain townships west of Boulder is represented either by their elected officials or community leaders. Two years later, the group enthusiastically meets once a month to discuss a variety of topics. The continued operation of this self-organized group has served to mitigate future wildfire risk (through its popular "Saws and Slaws" events, where volunteers thin forests and then have cookouts together afterward), generate participation in improving local disaster response plans in coordination with the Boulder Office of Emergency Management, improve early warning systems, and engage the BCARES (Boulder County Amateur Radio Emergency Services) to design the Mountain Emergency Radio Network. This radio network was also an invaluable resource during the flood to communicate with mountain communities cut off by washed out roads. Disaster response organizations like the Red Cross can help connect these groups with official emergency management staff where possible, help provide capacity building and training, and include them in resilience planning.

Autonomous and spontaneous activity – *What This Means for Resilience*

1. Even before disaster strikes, *people make choices* about what to do with their houses and neighborhoods based on their perception of risk, the rules set by law or local practice, and their sense of cost and benefit. Some people chose to protect their houses, but most did not, since there had been few severe floods in the area in many years.
2. During the crisis, people did what they could to *divert water from their own property*, with no knowledge of the effect of their actions on their downstream neighbors. *People made decisions* based on their own assessments of the situation. Those with *strong social networks* had more options for getting help or finding safe places to go. Pre-existing networks – for music, sports, neighborhood development – sprang into action for new purposes when the crisis hit.
3. *Emergent self-organized groups* played a big role in responding, as they often do in disasters. They mobilized hundreds of people in an organized way, greatly *expanded the resources available* to those affected, *responded flexibly and quickly*, and brought new technologies into the disaster response effort. There were *concerns about legal liability* – what if someone got hurt, or someone's house was damaged? – but organizations took action anyway. Established organizations were initially cautious about working with the emergent groups due to a) concern about liability and b) lack of a track record, but were able to rely on them to get things done at times when their own *organizational constraints* made quick or flexible action difficult.



Non-Profit Organizations

1. Existing NGOs — The Boulder area is rich in non-profit organizations, including many that specialize in disaster management. The majority of these organizations are members of Colorado Voluntary Organizations Active in Disaster (COVOAD), which is the Colorado member of the national body. COVOAD has about five dozen members, many of which were active in the Boulder area. In addition to these organizations, many other non-profit organizations in the area that don't normally work on disaster management issues got involved during and following the flood. (Using the term from the previous section, there were many examples of *emergent behavior* here - organizations that adapted their resources to respond to the disaster.)

Larger organizations were part of the County emergency management response, sitting in the Boulder Emergency Operations center with the other 125 people active in the command center throughout the crisis. Many other organizations became more active after the initial rescue phase of operations. These organizations have assembled themselves into the Long Term Flood Recovery Group (LTFRG), composed of non-profits, local government, and local businesses. The LTFRG has divided itself up into work groups to take on the various aspects of flood recovery, especially the social service piece for those people with fewer resources to recover on their own.

Overall the response of non-profit organizations was swift, capable, and well connected. There was deep expertise in disaster management, individual case management, and existing relationships between agencies and with local government human service departments. Non-profits that don't normally work on disaster issues rapidly put their staff at the service of flood affected people. Pulling these groups into a network that could share case management information took longer; most participants note that, based on the flood experience and learning, future coordination and shared case management will likely be significantly faster and more effective in the future.

Disaster response organizations can play a role prior to and during disasters by networking among formal and informal groups, keeping dialogue going and ensuring that relationships are in place already when disaster strikes. American Red



Cross staff cited the value of community and shelter partners in their response, in that they were able to multiply the reach of Red Cross staff and volunteers. Staff say they will expand their use of partners like this in the future.

During the floods, all organizations were overwhelmed by the scale of the disaster. It was beyond anything staff and volunteers had prepared for. The Red Cross, for example was unable to staff the Emergency Operations Center for 24 hours a day as they would have preferred, and they were unable to respond to all requests. The Red Cross was able to bring in staff and volunteers from other regions, which significantly aided their ability to respond. However, this took time; as with all organizations, they were understaffed in the critical first week of the disaster.



National organizations like the Red Cross and United Way sometimes had a hard time fitting their national level policies into local structures and procedures. While these policies have been created over many years from practical experience for excellent reasons, they do not always take into account the local context. During the Boulder floods some of these policies created problems. For example, Red Cross policy is to accommodate any disaster victims that arrive at temporary disaster shelters without discrimination. The City of Boulder's policy is to shelter the homeless at the Boulder homeless shelter, where staff are trained to deal with their special needs. In the few hours it took the City to open the homeless shelter (it normally closes down for the summer and only opens in October), the Red Cross had already admitted homeless to the temporary disaster shelters. Displaced residents, particularly families with young children, were then reluctant to stay in the temporary shelters. The temporary shelters wound up accommodating predominantly homeless people. This continued to be problematic when the temporary shelters were closed down several weeks later. Red Cross policy is to keep temporary shelters open until residents can either return to their prior residences or locate new residences. However, in the case of the homeless population, they didn't have prior residences to return to. Eventually, the Red Cross equipped them with new tents and sleeping bags and sent them back out onto the streets.

A second example of where national organization and local policies failed to mesh effectively is around protecting confidential case management information. Databases constructed by FEMA, The Red Cross, World Renew and several local non-profits contained confidential information that they could not share with local government staff. This is a significant loss, since City and County health, human services, and housing departments have considerable resources they could direct to help flood victims if they had the information they need to work with. An increased culture of partnership on the part of the national organizations would make their huge contributions even more valuable by using and leveraging local organization and government networks, knowledge and resources.

Besides the usual coordination of NGO responses, COVOAD had the additional role in Boulder County of encouraging restraint on the part of some of the spontaneous volunteer groups. In the first few days of the crisis, COVOAD called on volunteers to only operate where authorities had determined it was safe to work. Some of the volunteer groups, particularly those in this outdoor sports-minded region where

skills in climbing and kayaking are well developed, resisted this call for restraint and created tension within the emergency response operation. Again, advanced training and relationship building between the main groups in the area might have eased these tensions during the disaster.

2. Voluntary Organizations and Churches – Existing groups that normally pursue non-emergency functions also made great contributions to the effort. Musician associations helped evacuate friends and equipment, ski clubs and mountain rescue teams used their list serves and social networks to reach out to those needing help, and churches responded in kind and cash.

Existing neighborhood associations provided a ready-made set of relationships for helping each other. For example, the Southeast Boulder Neighborhoods Association had been active for over a decade, largely concerned with a proposed housing development in the area. The activities of the association for other purposes had generated an email list and a set of relationships that allowed the group to spread reliable information quickly in one of the more heavily impacted neighborhoods in the city. It also allowed residents to identify more quickly who was in need of help, especially the elderly. Disaster response agencies could connect with groups like this prior to disasters, either to provide preparedness information or just to network; either would promote faster and more effective disaster response.

One of the more remarkable stories concerns the LifeBridge Church in Longmont, just north of Boulder and east of Lyons. Many of the pre-designated shelters were inaccessible due to washed-out roads. Through a personal connection with the Sheriff's office, members of LifeBridge Church volunteered their church to become a shelter. The shelter got up and running in about an hour. Church members ran the entire shelter operation, including feeding the shelter residents (and shouldering the cost). A few church members had taken shelter training and volunteer management previously, so they had some resources to call on. This is an excellent example of leveraging latent skills and talents in a disaster situation that could easily have been overlooked by an exclusively "official" response. Now in the recovery phase, the faith and non-profit groups are looking at how to work together to set up and conduct a joint assessments inventory to aid in future response efforts.



3. Outside volunteer groups – Local efforts were vastly supplemented by outside volunteer groups that came to help. Dozens of groups of all sizes from as far away as Taiwan and Israel dispatched teams to help, and the [Southern Baptist Disaster Relief](#) sent volunteers and heavy equipment for several weeks. While overall the benefit of these volunteer groups was profound, assessing their capabilities and coordinating their efforts was difficult. In Lyons, for example, there were so many offers of help that early on in the crisis the Town of Lyons asked one of groups – [Team Rubicon](#) – to coordinate all the other volunteers in the town.

Unlike the self-organized groups, outside volunteer groups are established organizations that organize disaster response volunteers as a matter of doing business. Their specializations vary from first-response to post-disaster reconstruction, and they have well-established management and procedures. They mobilize thousands of hours of volunteer labor and bring in necessary equipment for emergency response. Their missions and capabilities vary widely, but residents were universal in expressing appreciation for their efforts. Some organizations are better equipped for the recovery phase, such as Habitat for Humanity, so there is a progression of organizations from first responders to post-disaster rebuilding.

During the disaster and recovery periods, some people were concerned that evangelical groups would use the opportunity to seek religious converts, and more politically liberal groups were wary of Team Rubicon due to its base in military veterans. To date, however, ideological differences have not inhibited the work or coordination.

Non-Profit Organizations – *What This Means for Resilience*

1. The presence of a large number of *well resourced non-profit organizations* meant there was a swift and competent response. Good coordination between groups maximized their use of funds and people and minimized the likelihood of people in need being left unassisted. All organizations were overwhelmed by the unprecedented scale of the disaster and took time to adapt.
2. Non-profits, churches, and existing community groups outside the disaster response community adapted their activities and became major players in the response. This emergent behavior – task emergence – utilized the existing infrastructure of these organizations for new purposes, and greatly expanded the response capacity of the community.
3. Outside volunteer groups arrived in the area quickly and coordinated well with existing local groups. They are set up to work quickly, respond flexibly, and adapt to local conditions. While the convergence of so many outside organizations at the same time caused some confusion and difficulty of coordination, all parties – local and external – adapted quickly and added considerable value to the response.



Municipal and County Government

One of the greatest strengths of the Boulder County flood response and recovery is the level of coordination and cooperation within and across government jurisdictions. Many of the western states in the United States, Colorado included, are known for their independent, “we can do it ourselves” spirit. Though a useful quality under some circumstances, in a major disaster it can rapidly become a hindrance. In El Paso County to the south of Boulder, for example, competition between various organizations and agencies has slowed recovery from a major 2013 fire.

The level of cooperation in Boulder County has been notable. Within hours of the flood’s onset city and county governments had passed emergency legislation related to safety and response. City and County Health and Human Services departments were coordinating over the phone to open shelters, trusting that they could figure out later who should pay for what. By the time the rains stopped, the cities, towns, and county were coordinating construction permitting to make it easier and less expensive for people to recover.

The networking, relationship building and lessons learned from past disasters played a large role in this cooperation and coordination. In response to the 2008 economic downturn, city and county governments started working closely with non-profits to identify ways to operate health and human services more effectively, making limited budgets stretch to cover increasing needs. The working relationships and systems put into place as a result of this effort allowed the cities and county to work with those groups during the response and recovery without needing to establish written agreements or work out contract details in advance. They knew the players, the resources they could command, and the capacities they could bring in advance and were able to make the needed links immediately.

Similarly, the Four-Mile Fire in 2010 strengthened relationship between various emergency management organizations. In response to the heightened flood risk the burn area posed, city and county emergency management developed a flood response plan detailing which organizations would do what in case of a flood. The plan is updated annually, and even though it didn’t address the issue of flooding on the scale of 2013, it was still highly effective in coordinating response. Information

Municipal and County Government — *What This Means for Resilience*

1. **Strong pre-existing *relationships* and a *culture of cooperation* within and between departments is an often unrecognized but *critical resource* that can significantly speed response and enable *effective recovery*.**
2. ***Learning* from prior disasters and making changes and improvements based on that learning significantly enhanced response and recovery during and following the floods.**
3. ***Flexibility* of administration allowed local governments to quickly pass emergency ordinances to allow residents to more easily mitigate damage to their property and to speed recovery.**

and citizen outreach around flooding, particularly in the mountain communities, was also highly effective. People heeded messaging such as “don’t drive through water” and “climb to safety”, and as a result people were rescued from many locations in the mountains cold, wet, and hungry but alive.

The personal nature of many of these relationships made it easier to respond during the floods. At the same time, that personal nature makes it harder to sustain this benefit as staff move to different jobs, or as programs end and others begin. Documentation and institutional relationships can only partly fill this gap. Forums, conferences, networks and other forms of social network building can all help to sustain these connections.



State and Federal Government

While many federal agencies were involved in the disaster response and recovery, the principal agency involved was the Federal Emergency Management Agency (FEMA). FEMA's role included:

- **Assistance to individuals** – Between payments to individuals for damage, loans administered by the Small Business Association, and payments from the National Flood Insurance Program, FEMA reported that they paid out \$221 million in Colorado to individuals and businesses. Of this total for the state, Boulder County residents received over \$33 million in Individual Assistance payments, and almost \$45 million in payments from the National Flood Insurance Program. FEMA estimated that almost 9% of households in the County had flood impacts. While most of these payments covered only a fraction of losses, they quickly injected money, targeted at those in need, into the economy.
- **Assistance to Local Government** – FEMA staff advised local government staff in a range of functions, from setting up Disaster Assistance Centers to meet immediate needs to dealing with flood debris to facilitating discussions on recovery planning for small municipalities like Lyons and Jamestown. FEMA staff noted that their role in these efforts was less than they are used to due to the high level of capacity of public officials, organization staff, and residents in Boulder County.
- **Assisting the State** – FEMA staff worked closely with staff from several Colorado State government agencies in both disaster response and recovery. FEMA was the source of hundreds of millions of dollars in reconstruction funding across the state, which was used to hire additional staff, implement cleanup efforts, rebuild roads, and a host of other essential functions. Most FEMA funding was limited to 75% of costs, with state and local governments covering the rest. This funding has been critical to the recovery efforts. However, local officials noted that it was difficult to understand FEMA's rules and conditions for getting access to this money, which greatly increased uncertainty and in some instances delayed recovery projects.

State and Federal Government — *What This Means for Resilience*

1. The *influx of external funding* provided by the federal government was critical to early recovery, but only covered a fraction of individual, community and city costs.
2. *External expertise*, from federal and state government disaster specialists and from states that had recently experienced major disasters, was highly valuable in informing the recovery phase in Boulder County.

Similarly, the State of Colorado mobilized many state agencies. The most notable ones in Boulder County were the State Office of Emergency Management, the State Department of Transportation, and the Department of Local Affairs. These agencies provided funds, staff, technical support, and equipment to speed the recovery. The Office of the Governor played key roles in empowering staff to work with their local and federal counterparts. One action cited by many for its foresight was the Governor's office decision to bring in officials from other states who had experienced similar disasters in the recent past. Advice from them proved useful throughout the entire disaster and recovery experience.



Emergency Responders/Emergency Information

Boulder County and the City of Boulder have a joint Emergency Operations Center which coordinates disaster response. The Emergency Operations Center (EOC) houses dedicated resources for emergency response staging, including desks with computers, phones, up-to-date weather data and other resources. During emergencies, city and county staff, emergency response personnel, aid organization representatives and key non-profit representatives sit next to one another and collaboratively respond to the emergency as it unfolds. Located outside of the floodplain and next to a small, local airport that was used to stage helicopter evacuations, the EOC was operational throughout the 2013 flood event.

The County has a Natural Hazard Mitigation Plan that was in the process of being updated in 2013 with public input. The Plan includes a Multi-Agency Coordination (MAC) group, which meets quarterly, and sub-groups that meet monthly. The MAC group is made up of representatives from numerous City of Boulder and Boulder County departments, non-profit organizations active in disaster, and the private sector. This system was activated the first night of the flood, and brought all relevant agencies together, gathering some 120 local government, public safety, non-profit organization and Federal and State emergency response staff in the Emergency Operations Center.

Most of the Boulder County communities have early warning sirens used to warn of flood, tornado or other disaster. The county and communities also use reverse 911 calls to alert specific locations to specific threats, and the University of Colorado sends emergency text messages to students and staff.

During the floods, the emergency sirens were set off repeatedly in many communities, sometimes in creative ways. In the City of Boulder, the sirens were set off the first night of the flood specifically to alert the homeless population and get them out from under underpasses along the creek. Sirens were used later in the flood to warn of a possible wall of water coming down Boulder Canyon due to debris dam giving way. Though it is hard to quantify the impact of the sirens, it is notable that there were only three lives lost along main creeks and rivers in the county.

Emergency Responders and Emergency Response — *What This Means for Resilience*

1. Disaster planning allowed emergency personnel to act *quickly* and *effectively* when the floods hit.
2. Emergency warning systems provide timely *information* to residents and almost certainly prevented many more deaths.
3. *Learning* from prior disasters allowed emergency warning systems to be tailored to local conditions, improving their effectiveness.
4. Further tailoring of emergency warning systems based on a network of “boots on the ground” volunteer observers would further improve the *responsiveness* of the warning system.

However, there were also areas where use of the sirens could be substantially improved. The Boulder County Sherriff operates sirens in Lyons. According to a Lyons resident, sirens should have been set off several hours sooner to give residents more time to evacuate. As it was, the sirens in Lyons were set off at around 3 AM, by which point transport was already dangerous if not impossible. Several people were evacuated in Lyons on Thursday from cars and homes using heavy equipment (e.g. backhoes, graders, etc.). In the northern part of Boulder, sirens were never set off though several small, generally dry drainages had turned into raging torrents, flooding streets and homes. When residents called 911 to ask in which direction to evacuate the 911 operator was unable to provide advice. Clearly, a more distributed network of “boots-on-the-ground” observers to inform use of the sirens is needed if sirens are to be used to their full potential in a disaster of this magnitude. This might be an ideal opportunity to train a geographically distributed



network of specialized volunteers that work closely with emergency management to provide on-the-ground information in real-time.

In many of the mountain communities and some of the plains towns, Everbridge emergency calls⁶ were used to warn people of increasing danger. In response to the Four-Mile Fire and the resulting increased risk of flooding, county emergency management personnel had developed pre-set zones throughout the county to allow Everbridge calls to go out along drainages rather than the most common method in a circular area around a central location. This proved very useful during the flood event as residents could be notified on a creek-by-creek basis of local threats as needed.

The University of Colorado issued a series of very useful messages. Messages were sent out as texts and email to all students and staff, and were posted on the University website. Messages contained up to date information on conditions in the City of Boulder. In many cases, these warnings were more detailed than the information on the Office of Emergency Management website. These warnings went out to everyone who had opted in to the system without differentiating by location, in order to avoid the risk of leaving out people who needed the information. They were primarily focused on areas around the University.



The For-Profit Sector

The response of the for-profit sector falls into four basic categories:

1. Damage mitigation
2. Disaster recovery
3. Finance industry
4. Charitable giving

1. Damage mitigation – One of the main dangers of making the flood worse was the danger of spills from the oil and gas industry. Small wells are scattered through the county and the wider Front Range area. The majority of wells are outside Boulder County, primarily in Weld County, where the damage from spills was more extensive. The oil and gas companies in the area responded quickly to shut down any wells that they identified as being in danger. Nearly 1,900 oil and gas wells in flooded areas of Colorado were shut down, and 600 industry personnel were involved in inspecting and repairing sites. In some cases, wells had to be shut down by hand, and washed out roads made that difficult. For one local company whose Longmont office was surrounded by flood waters, many of the 397 wells it shut down were handled by a single employee with a laptop and an Air card. This technology increased staff flexibility and prevented many potential problems downstream.

Across all affected counties at least 22,000 gallons of oil spilled into waterways, the contents of two storage tanks that were overturned. Given the size of the industry and the numbers of decentralized sites where oil and gas wells and storage are, this volume suggests that planning and regulations likely reduced the potential damage considerably. Regulations include setbacks from waterways, construction codes, and a requirement to report any spills to the State within 24 hours.

Irrigation ditch companies also were profoundly affected by the disaster. Several dozen private ditch companies operate irrigation ditches in the area, and most experienced severe damage. During the floods, nearly all attempted to mitigate damage to their ditches and diversion works. In many cases, the floods overwhelmed any ability to save the ditches.

Following the flood, ditch companies quickly responded to get water flowing before the next growing season. Their ability to do so depended on a number of factors:

- Knowledge of how emergency-response bureaucracies work, and how to apply for assistance;
- The existence of prior relationships among agencies, allowing them to respond readily to farmer requests;
- Presence of staff paid to take on the work, as opposed to volunteers; and
- Financial soundness and the ability to borrow money or prepare FEMA applications.

Not surprisingly, the larger ditch companies were able to mobilize resources to repair structures to get ready for the next planting season; many of the smaller ditch companies are still looking for funding. For both large and small companies, it will take 30 years of increased annual charges to pay off the costs incurred, reducing their ability to withstand future disasters. State emergency loans to the ditch companies have helped them recover more quickly than they could have without this financing.

One of the lost opportunities in the flood was in rebuilding diversion structures in the creeks and rivers. The ditch companies that were able to respond to the flood immediately, reviewing damage, assessing the need for repair and reconstruction, and arranging for work to begin. Unfortunately, most of this was done in the absence of new knowledge, such as how to reconstruct diversion structures to allow for fish passage or recreation, which wasn't an issue a century ago when the structures were originally built. Water Conservation District staff noted regretfully that they missed a window of opportunity because they lacked clear, pre-prepared materials on this topic that they could quickly distribute following the floods.



2. Disaster recovery – Two of the industries most called on for response were hardware and the disaster cleanup and restoration industry.

Local hardware stores were inundated with hundreds of customers from the first day. One local store reported they ran out of their stock of pumps in the first two hours of the first day. Over the next few days, the same thing happened with generators, fans, dehumidifiers, pump-up sprayers and boric acid. Many of their distributors were unable to restock since they could not alter their normal, once a week delivery schedule. In response, store staff made multiple trips every day all over the Denver metropolitan area in personal cars and in the store truck buying up what they could from other stores and vendors. Back office staff were pressed into service on the floor, and in helping the purchasing people find new suppliers. Another hardware store in the area remained open for 72 hours, with some staff sleeping in the back room to remain on site. This operational flexibility and the ability to draw resources from a larger metropolitan area was of substantial benefit to Boulder County flood victims .

Store revenue for September was double its usual monthly amount, and the local store for one national chain was the number one revenue-generating store for that chain in the country for four months following the flood. This increased revenue occurred primarily without great increases in prices.

The disaster cleanup and restoration industry responded as it usually does, descending on the area with staff from all over the country. One national firm manager noted that they had received 2600 calls in the first two days alone. Most residents cleaned up as much as they could on their own, outsourcing only the largest or most technical jobs. Nonetheless, demand for professional support far outstripped supply and professional firms could not keep up. Most hired labor as fast as they could to fulfill contracts. In the lower lying parts of Boulder, much of the damage was from sewage backup, which required specialized equipment and personal protection equipment. The existence of this disaster cleanup industry greatly accelerated the process of cleanup and recovery and allowed many residents to continue to go to work, knowing that their houses were being managed.

The floods generated huge amounts of debris. County entities moved very quickly to contract firms for private property debris removal. For the cities of Lyons and Boulder, for example, staff wrote the Request For Proposals over the weekend,

gave bidders 24 hours to submit bids, reviewed them for two days, and then awarded the contracts and started work the next day. This process normally takes several months. Contracting was made easier by the fact that this office had considerable experience with contracting for debris and waste removal, and had previous relationships with many vendors. FEMA was also helpful with advice for how to do the Request for Proposals.

The City of Boulder coordinated with Eco-Cycle's Center for Hard to Recycle Materials (CHaRM) to waive fees for electronics disposal. The center was so overwhelmed that they worked with the city to set up a second collection and storage location at the city's Municipal Service Center. Much of the construction waste county-wide, however, was unable to be separated out for recycling. In the past the County had talked about constructing a Construction Demolition facility, but had decided it was too expensive. As a result, they were unable to separate out the drywall, lumber and insulation that normally would not have had to go to landfill. In Larimer County, disaster debris cut a significant number of years of life from the landfill. One observer suggested that several counties could work together to purchase mobile Construction Demolition equipment, which would spread the cost over many areas and would reduce the amount of waste that cannot be recycled in disasters.

Organic waste (trees, branches, sand, dirt and rock) was handled differently. Organic waste was used for compost, fill for areas scoured out by rushing water, ground up for landscaping, and was even to help restore a wetland area that has been on City staff agenda for some time, but for which they lacked the funds or materials to get started. In these ways, damage on the one hand can be a solution on the other for unrelated problems.

Since so much funding for this work would potentially come from reimbursement by FEMA, understanding FEMA regulations and procedures was very important. There were two County staff members who were familiar with FEMA regulations after the Four-Mile Canyon Fire, so they were very helpful. There were also one or two FEMA staff housed in the office to advise. However, these FEMA staff were unable to keep up with the pace of decisions needed, and instead advised County staff that as it was an emergency, staff should do what was needed regardless of potential for reimbursement. The County accepted that perspective and agreed to deal with the financial implications later on.



3. Finance Industry — Damage mitigation and recovery were significantly sped up by the continued wide use of credit cards and automatic teller machines (ATMs) for essential purchases. In economies elsewhere in the world where credit cards are not widely used, the ability to mobilize finance to repair damage is greatly curtailed. Had the electrical system gone down, access to credit and ATMs would have been lost, compounding the disaster.

Banks displayed some flexibility on loans, which allowed homeowners time to recover. Mortgage lenders primarily offered payment forbearances to homeowners, typically the option to skip three months of payments with the total amount due in the fourth month. Most lenders indicated they would not report these missed payments as late payments on credit reports and would waive late fees, though in practice the results on this were mixed. Homeowners have reported that it was easy to work with the major national lenders (such as Wells Fargo, Chase, Citibank) on accessing forbearances. Smaller lenders like local banks and credit unions (1st Bank, Elevations) were also quick to offer skipped payments and waiver of late fees, and worked closely with homeowners to get needed information to insurance companies. While helpful to many, some homeowners opted against the forbearances because of the large lump payment required at the end.

For homeowners whose homes were substantially damaged, many are seeking determination from FEMA whether their homes will be bought out to remove them from the flood plain. This program is an excellent mitigation program, in that it encourages homeowners to relocate to safer homes. However, it is not designed as a flood recovery program, and determination can take up to two years. As a result, it cannot provide needed funds quickly after a disaster.

Both individual and business low interest loans were available through the federal government from the Small Business Administration (SBA). Applicants needed to qualify as credit worthy; for those who qualified, interest rates were significantly below market rates, and a five-month no-payment period was provided before repayment began.

Other financial resources were available from the Individual Assistance program of the Federal Emergency Management Agency (FEMA). As soon as Boulder County and surrounding counties were declared a Federal Disaster Area, residents qualified for aid. Registration with FEMA was done on-line and was relatively

straightforward. FEMA staff from all over the United States arrived in Boulder County within days of the disaster and began assessing claims, many of them working more than sixteen hour days. FEMA assessors filed their assessments electronically, included bank accounting routing information, and for approved claims money was deposited into disaster victim accounts within days. However, for most people that suffered significant damage, FEMA payments covered only a fraction of their costs. The maximum FEMA payment, for homes that were completely destroyed, was about one-twentieth of the full losses.

FEMA direct financial support was also available for victims that had lost their homes and needed to be temporarily rehoused, or for those who had lost assets they needed to continue work (such as personal cars). Here too, however, financial support was limited and rarely covered the full losses incurred.

Few homeowners in the County had flood insurance, either through private insurers or the government funded National Flood Insurance Program. For those who did, insurance settlements for the most part greatly exceeded the limited FEMA Individual Assistance payments, recognizing the fact that homeowners with flood insurance policies had been paying into the insurance program over time to cover this risk. The existence of insurance, whether public or private, channeled millions of dollars back into the economy and sped recovery. The fact that even these payments covered just a fraction of the damage means that individuals have been either diverting other resources – savings, second mortgages, SBA loans, etc. – or have been forgoing all or some portion of damage repair, with a concomitant decline in property values.

4. Charitable Giving — Individuals and business responded quickly and generously, donating millions of dollars to relief efforts. Many businesses contributed in kind as well, with things like tools, office space, and storage space. Charitable giving was routed through established mechanisms such as community foundations, local non-profits, and directly to affected people themselves. Due to the high capacity of the social service sector, there was no issue with “material or financial convergence.” In many disasters, the outpouring of in-kind and cash donations can overwhelm responders and create new problems in dealing with them. There was little evidence that charitable organizations were overwhelmed in this fashion during or following the Boulder floods. The resources supplied were well directed and transparently distributed.



For-Profit Sector – *What This Means for Resilience*

1. The *existence of key, well-developed industries* – in hardware and construction, disaster clean-up, waste management, oil and gas – meant that much damage was mitigated. In the absence of a *well trained* and *well regulated* oil and gas sector, for example, toxic releases would have been much more severe. Without local hardware stores that were *resourceful* in finding new suppliers, homes would have stayed flooded longer, causing more damage and possibly health problems. The disaster clean-up industry was ready with vehicles, air blowers, pumps, dehumidifiers and trained staff to get residents and business owners back on their feet quickly. The existence of competitive markets in all these industries built *redundancy* into the system, allowing one business to step in when others were overwhelmed.
2. Industry *flexibility* allowed them to solve problems quickly. Technology to shut down wells with a laptop, the ability to multiply disaster cleanup staff numbers a hundred-fold within days, the ability to find new suppliers quickly; all reduced potential damage and sped the recovery.
3. A *well-developed finance system* (credit cards, ATMs, mortgage forbearance, electronic banking) allowed *resources to flow* into the area quickly to mitigate damage and start repairs. More generous relief on loan repayments would have freed up more resources for these purposes.
4. Payments from private insurance companies and FEMA added financial *resources* to the local market and extended private financial *capacity*. More extensive use of private insurance would have provided further resources.
5. *Pre-existing government regulations* created a clear set of rules for everyone to follow. The oil and gas industry had set up their infrastructure to comply with regulations, and responded to avoid government sanctions and fines for violations. Government waste disposal regulations dictated what could be disposed of where, reducing the potential of introducing chemical contamination into the food or water systems. *Uncertainty* over what FEMA would reimburse was an obstacle, and prior training and clearer regulation would have helped.
6. *Lack of prior relationships* among government agencies slowed their response to farmers trying to get assistance in rebuilding their irrigation systems.
7. The case of organic debris shows that waste from one purpose can be a *resource for others*, operating in *cyclic systems* instead of linear ones. This increases the resources available to the system at lower cost, and solves some of the debris problems that would otherwise be just a cost to the system. The absence of technology to handle construction waste represents a missed opportunity, as did the lack of pre-disaster planning for irrigation diversion reconstruction.



II. Analysis: Legal and Cultural Norms

Land use

The City of Boulder and Boulder County have aligned their land-use permitting processes to be fairly consistent. This allows for a fair amount of uniformity in designing buildings and infrastructure. Both sets of laws are fairly strict, often with hazard mitigation in mind.

Following the flood, County land-use staff have been in the impossible position of having to enforce regulations about land-use permits within the mapped 100-year flood plain while knowing that changes in the course of creeks and deposits of sediment have rendered the existing maps inaccurate. Home and business owners are frustrated with delays in rebuilding, and while local government staff are sympathetic, their hands are tied by City, County, State and Federal regulations. Untangling these regulations, re-doing the hydrological studies to update the flood maps, and getting residents back up on their feet is not a quick process since local government staff are forced to individually review each permit application that involves extensive repair or new construction.

Compliance with land-use and other legal building provisions is also an issue for homeowners who have modified their homes or property over the years, sometimes without obtaining permits. Residents have installed basement bathrooms; many of these experienced sewage upwelling during the flood. Sump pumps have often been illegally installed, connecting to the sewage system rather than into the floodwater drainage system. Adaptive modifications such as landscaping sometimes increase personal risk, for example by directing water toward your own foundation, or increase a neighbors risk by directing water toward their foundation. Many of these issues are now being reviewed, as neighbors explore why they had a river running through their yard, as the city utilities department reviews the sewage system performance, and as homeowners apply for renovation permits for damaged basements and have to meet current building codes.

Land Tenure

Expansion of flood mitigation measures such as those noted in the physical systems section – especially storm-water floodways and Open Space – has been stymied in areas where private and public lands exist in a patchwork. Areas around Gregory Creek and Two Mile Creek, for example, have long been identified as high flood-risk areas. Yet the inability to get consensus from private homeowners in these parts of town have prevented the City from implementing these same floodways that were so effective on other drainages. The window of opportunity following the floods may allow for a more flexible dialogue on this issue.

Expectations of Government

For many stakeholders, there is an unspoken assumption that government can solve all disaster related problems and can respond adequately to any emergency. The disaster-response was largely effective, but emergency response staff note the disaster was far out of proportion to anything they had planned for, and it overwhelmed existing resources. City and county staff were overwhelmed simply maintaining city infrastructure and assuring emergency safety provisions and had little time to spare for non-life-threatening resident issues. Residents reported getting incorrect or inadequate information from emergency phone operators. Planned infrastructure largely held up, but many residents who might have expected more city government support were left on their own to deal with sewage backups, cut off roads, and flooded homes through several days of the emergency.

City of Boulder residents have a reputation for seeing government intervention in largely positive terms. This cultural belief may contribute to a reliance on government systems to respond to any disaster. The experience of the September floods suggests that government agencies are able to do many things well, but no government can do everything well when disaster strikes. The disaster has spurred



wide discussion of how to build resilience from the individual to neighborhood to municipal and county level. It is also worth noting that in other parts of the County, the dominant culture is the reverse — people rely on themselves and their neighbors and prefer little contact with government beyond the essentials. This culture paid off well in the mountain towns, many of which were cut off during the floods, leaving residents to improvise on their own until outside help could arrive.

Potential for Lawsuits

In those areas where public infrastructure failed, there is a high potential that home and business owners may sue the City or County for redress. This potential greatly constrains the ability of actors on all sides to engage in open dialogue. The ability to share observations and ideas on this topic is important for a learning process that will increase resilience in the future. The potential for litigation reduces the trust required for the community discussions necessary for making tough choices about how to build resilience.

Undocumented immigrants

Legal constraints on assisting undocumented immigrants have limited the ability of local government to assist residents who lack proper immigration documents. FEMA is able to provide basic emergency services to anyone, but undocumented immigrants and those in the United States with temporary tourist visas, student visas, work visas and temporary resident cards are not eligible for cash assistance. Many undocumented immigrants feel the risk of deportation is too great to risk seeking assistance, even for those benefits that are technically available to them.

To manage this issue, the Long Term Flood Recovery Group has created a system where all case management work is conducted by non-profit organizations that do not share their information with government departments. Non-profit organizations that worked with undocumented groups prior to the flood continue to work with them post-flood. However, non-profits have been constrained by rules that require people to show evidence of pre-disaster income to qualify for assistance. For those in the informal economy — laborers, housecleaners, those with small, home based businesses, etc. — who have few bank records or income tax returns, assistance is hard to come by.

Legal and Cultural Norms – What This Means for Resilience

The legal and administrative rules that govern an area, and the assumptions residents make about what is and is not expected or acceptable, both *enable and constrain* the options for dealing with disasters.

1. Land use permits allowed the City and County to *implement flood mitigation measures* that protected many people. Yet when the stream flow and flooding patterns changed as a result of the flood, the same permitting regulations *tied the hands of local government staff* in following a flood map that is no longer accurate.
2. A *patchwork of private and public property* along several drainages *slowed the expansion of flood mitigation measures*, and thus increased the damage from the flood in those drainages.
3. Many citizens have a *reliance on government response* that is out of proportion to what is possible in a large disaster. During the flood, city and county staff were fully occupied maintaining city and county infrastructure and addressing life-threatening issues; residents were left to deal with major but non-life-threatening flooding, transportation and sewage issues on their own. Building greater neighborhood connection and collaboration would greatly improve community resilience when faced with these realities.
4. The potential for *lawsuits*, especially against local government agencies, has put a *dampener on learning processes*, significantly inhibiting the opportunity to use the floods to increase resilience in the future. Ongoing recovery and future preparation and mitigation are proceeding fastest where *communication and learning* are greatest. Where fear of litigation is constraining communication and learning it appears vulnerabilities will likely remain unchanged.
5. *Laws constraining government staff* from assisting undocumented immigrants required the creation of parallel social service structures to meet their needs.

3. Key Learning

1. Victimhood, Voluntarism, and Agency
2. Planning and Investment Pays
3. A Strong Social Service Sector Increases Responsiveness
4. Learning is Critical to Building Resilience
5. Relationships and Connectivity
6. Organizations and Safety Nets have Limits
7. Limits of Our Imagination

1. Victimhood, Voluntarism, and Agency

Even in the face of disaster, people found ways to help themselves and their neighbors. This was true both of those directly affected, and those who were only indirectly affected. This is common in disasters, and suggests a couple of conclusions.

- a) **Taking action for self and others reduced the opportunity to feel like a “victim.”** Creating opportunities for people to take positive action reduces the sense of helplessness, and increases the individual ability of people to bounce back. People in Lyons and Jamestown, for example, were stranded for days, surrounded by rushing water. Yet they pulled together, searched for other trapped people, cooked up large barbecues with food before it spoiled, created their own volunteer roles in town. In the recovery period hundreds of people have participated in committees and working groups to create recovery plans, taking control of the future of their towns.

- b) **Emergent organizations allowed thousands of people to help in the clean-up and recovery right from the beginning.** Volunteer management organizations like the Mudslingers and Boulder Flood Relief mobilized hundreds of volunteers with virtually no outside resources. In addition to physical labor, volunteers used their own professional skills as accountants, lawyers, academics, web developers and database managers to build a critical response mechanism. The legal risks for established disaster response organizations – public and private – made it difficult for them to work together in the beginning. This reduced the capacity of communities to make best use of this invaluable resource. Since emergent organizations are a normal phenomenon in disasters, established organizations would do well to train for ways to deal with them when they arise, and develop materials or referrals that willing but untrained volunteer organizations can use to figure out how best to contribute (and how to minimize risk). Advice about volunteer management software, sample risk waiver forms for volunteers, web sites with links to personal protective equipment, and referrals to existing disaster response organizations that manage volunteers would all increase local capacity to respond. In some cases established organizations can benefit from the specialized skills and networks that some of these emergent organizations bring, such as their social media savvy and connections.



2. Planning and Investment Pays

Mitigation Measures Worked

The system of storm-water mitigation measures worked as designed. The main elements of it were:

- Bike paths and underpasses along the creeks to allow additional space for floodwaters;
- Tear-away bridges designed to swing open like gates to allow water to pass without accumulating debris;
- Rip-rap, pools, drops, other in-channel features constructed to slow floodwater and divert it back into the creek;
- Prevention of further construction of critical infrastructure in the floodplain, and removal of high-hazard buildings in the floodplain prior to the flood;
- Design of roads to carry flood waters into the storm-water drainage system; and
- Open space which allowed creeks to overflow their banks with minimal damage to private property.

All of these measures were in place for years before the flood, many serving other purposes such as recreation and transportation.

Mitigation is hard, and more is needed

While the mitigation measures worked as designed, many parts of Boulder County did not have adequate mitigation measures, and so the destruction in those areas was severe. Of the fourteen drainages in the City of Boulder, only a few had adequate measures in place, and consequently streams flowed through houses and businesses, and sewage welled up into many homes from overtaxed sewage pipes. In Lyons, the older part of town lies along the St. Vrain Creek and thus bore the brunt of the damages. In mountain towns such as Jamestown and Salina, the narrow canyons make it difficult to propose effective mitigation methods that would not profoundly alter the historical character of the communities.

A number of issues make mitigation difficult.

- River corridors are patchwork of public and private lands. Any mitigation plan requires agreement from a large number of individual property owners. Agreement is especially difficult in a community where disasters have not occurred in a while and the risk seems low.
- When mitigation measures have multiple uses, such as in the Open Space program which is designed to balance recreation with flood control with biodiversity conservation, social values can conflict. Competing groups often emphasize one of these purposes over others, such as closing trails to rehabilitate damaged land vs. maintaining recreation opportunities.

Redundancy, Modularity and Flexibility help

The existence of two separate water treatment facilities in the City of Boulder allowed safe water to continue to flow even when one plant was knocked out. The existence of a single sewage treatment plant that nearly failed exposed the city's vulnerability. Creative thinking about smaller, modular sewage treatment plants, or even in-home composting toilets that could generate an entire local industry represent potential ways to make the system less dependent on a single facility.

The existence of an extensive road network in the plains allowed transportation to flow even when floods closed a large number of roads. In the mountains the physical terrain made this redundancy more difficult, and thus several towns were cut off, or alternate routes added hours to any trip. One solution for the mountains would be to choose one or two important routes and construct them to a far higher standard than the others, which would increase the chances that at least one route would remain open in a disaster situation. Ideally, these two roadways would have different vulnerabilities, so they would not be likely to both fail in the same type of disaster.

3. A Strong Social Service Sector Increases Responsiveness

All observers noted that Boulder County is rich in civil society capacity, both formally organized non-profit organizations and non-formal citizen groups. There are a large number of groups, they are diverse in structure and function, and they are good at what they do. This is especially true of the direct service organizations that help individuals and families. Public and private agencies across the county came together to get people the help they needed, though it was impossible to determine how many people moved out of the area or were reluctant to come forward for assistance.

Two concerns about this capacity were:

- a) the amount of time it took to set up a coordinated system, and
- b) the relative inflexibility of some of the traditional service providers.

On the first point, there were Disaster Assistance Centers set up around the county within days of the start of the storm, yet the follow up case management system for long term recovery did not go into full operation for almost five months. On the second point, some responders found that some traditional service providers were constrained by cumbersome rules and procedures, and creative people found ways to use more informal systems to get done what was needed.

Outside organizations increased the local response capacity. National organizations brought in their volunteers, systems, and sometimes equipment to multiply the capacity of local organizations. While there is always a problem of handling the convergence of a large number of organizations in a disaster area, local agencies handled the influx well and made good use of the resources offered. A greater culture of partnership and greater flexibility in policies and procedures would make collaboration with local agencies more effective and efficient.

4. Learning is Critical to Building Resilience

The Boulder County area experienced several important shocks and stresses in the years leading up to the flood; learning from those experiences helped when the flood came. The 1976 flood in the Big Thompson Canyon to the north, which killed 139 people, proved to be a strong motivator to plan for floods. The 2008 economic downturn brought non-profits and municipal governments together to find ways to handle the increased need for assistance, coupled with declining revenue. This developed a whole set of relationships that made responding during the flood emergency much faster and more effective. The 2010 fire in Four-Mile Canyon highlighted areas where better communications, early warning techniques, resident capacity for preparedness and response, and response and recovery coordination were needed. When the floods hit, the experience from the fire of coordinating agencies, setting up Disaster Assistance Centers, creating forums to listen to communities for what they need, working with emerging community groups, and communicating messages all improved the response.

The long time since previous catastrophic floods had hit the area, though, meant that some learning was forgotten. Homeowners that disconnected their sump pumps, neighborhoods that resisted construction of Greenways, agencies that had difficulty adapting their standard operating procedures to the needs of other organizations and communities, and the high cost of creating a more adaptive sewage system all led to the reappearance of previous difficulties in this disaster. Legal liability can also act as a damper on learning as government agencies, and potentially other organizations, seek to insulate themselves from lawsuits by not sharing openly what happened during the disaster.

5. Relationships and Connectivity

Running through the observations of nearly every person interviewed for this study was the fact that pre-established relationships greatly sped response and improved results. Social service agencies with prior experience working together were able to put together emergency responses quickly, even when that was not the focus of their work. Existing relationships with local governments allowed service providers and government officials to adapt quickly without lengthy meetings or contract negotiations. Good working relationships between municipal and County staff promoted smooth coordination of all staff, from public safety to public utilities.

Emergency response personnel had already established relationships across agencies and jurisdictions through regular training events, whether in the field or in table-top scenario exercises. Broadening these out to include non-traditional partners would help in spreading and maintaining relationships. Inclusion of disaster preparedness and climate information games such as that developed by the Red Cross Climate Center⁷ can further enhance trainings and further develop networks.

Personal relationships among individuals provided rapid assistance for neighbors, especially the most vulnerable. Several observers pointed to the strong relationships among women in the Latin American immigrant community as a key to helping them cope despite a lack of resources. Where relationships did not exist, people built them quickly, building on the basic level of trust that already existed in most communities.

The implication for Disaster Risk Reduction is that social service agencies like the Red Cross and United Way can take on an explicit role of advocating for vulnerable groups in good times and bad. Also, any activity that builds social networks – music groups, sports leagues, parent-teacher associations, etc. – can build the ability of people to get help and information when disaster strikes. Social media can help to maintain these networks even in the absence of a high level of activity.

6. Organizations and Safety Nets have Limits

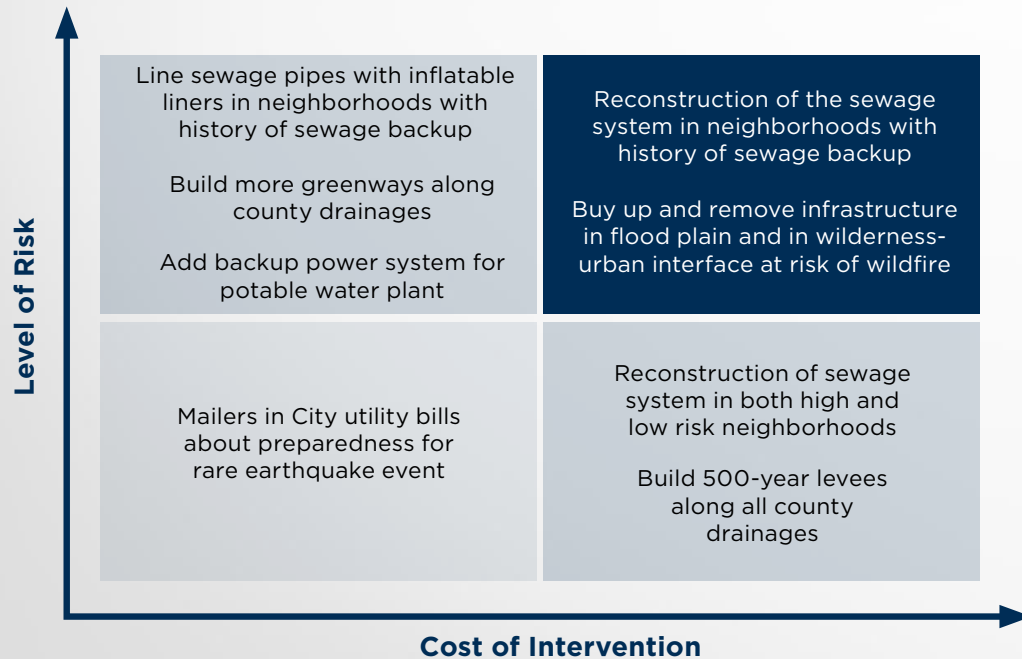
This report documents the successes and failures of the disaster response system. It also points to the limits of these systems. In fact, any system, no matter how well designed, can never anticipate every scenario and respond flawlessly in all situations. More fundamentally, individuals will always respond to a situation as they perceive it. So every set of rules, every disaster as it shapes up, will generate a response on the part of individuals that cannot be predicted or easily controlled. Zoning rules try to shape flood and fire mitigation behaviors, but individual property owners assess their interests and risks against those rules. So some people build berms and swales that look like garden structures but also divert water away from their homes, some buy insurance, some install sump pumps, some choose not to act at all.

In addition, even the best-designed system has limits. Insurance is limited, FEMA cannot cover all costs, and municipal systems cannot handle every act of nature or people that arises. The increasing uncertainty from climate change only adds to the risk. As a result, emergency preparedness needs to continue to develop mechanisms for enabling resident response and responsibility. For example, Boulder County has programs to advise landowners on how to reduce their fire risk, including payments to reduce fire mitigation costs, and programs on how to reduce household and garden water use to conserve water resources. For individuals, improved “disaster literacy” will increase the chances of surviving a disaster and speed recovery.

7. Limits of Our Imagination

Planning for disaster often means implementing measures that would have helped in the last disaster. While learning from experience is critical, looking backward can often limit our imaginations as to what future disasters might bring. This is the strength of using a resilience lens – by looking at the resources, capacity and connections of our residents, agencies and organizations, the diversity, modularity and redundancy of our infrastructure, and the rules we live by we can pose questions that will help respond to disasters we cannot yet imagine. In Boulder, emergency responders had trained well to respond to floods on one to two drainages, but never all fourteen at the same time. Public utilities and emergency responders are trained to respond to local power outages, but what about a power outage across the state? Terrorist attack? Wildfire in the city? Other unforeseen disasters? What other unforeseen disasters might we experience in the near future?

We can look at a matrix of cost and risk tradeoffs in this thought experiment.



It is simple to imagine high-risk, high-cost interventions, and those can often get the most attention. But consider the diagram below—how can we move those interventions to another quadrant? Failure of the city-wide Boulder sewage system would be very expensive to mitigate or deal with, and in light of the experience in the flood, the risk of it is fairly high. Replacing the entire 400 miles of piping across the city would cost half a billion dollars. However, we can focus on the few neighborhoods where it the sewage system failed and think about interventions that could apply to those locations alone. This begins to identify other options that are available at much lower costs. These could include creating incentives for homeowners and landlords to install backflow devices on basement and garden-level apartments to prevent backflow into homes, or strengthening the sewage drainage system just in high-risk neighborhoods. The goal in this type of exercise is to shift problems from the high risk, high cost quadrant to the high risk, low cost quadrant by finding smaller, more modular, more distributed and more collaborative solutions. In many cases, multiple small solutions will be far more effective than one large solution.

4. The Next Disaster

What and where will be the next disaster our community faces? And how resilient will we be in the face of that disaster?

Modern society is increasingly dependent on complex, rapidly evolving, widespread and interlinked systems for survival.

- Our food and water comes from distant sources that are beyond our control, and in many cases beyond our national government's control as well. This means local disasters may have little impact on the local food supply, but distant disasters can cause spikes in food prices.
- Food, water, shelter and livelihoods are often highly dependent on interlinked power and transportation systems that cover large areas. This provides for a higher standard of living, but can lead to cascading failure of systems.
- Our daily interactions both for work and personal connection are heavily dependent on a web of distant, powered communication. This allows us to tap into a much broader world of information and community of capacity, but can leave us highly vulnerable if communications are lost.
- In-person interactions increasingly involve transportation over miles, sometimes thousands of miles, in timeframes of hours. This allows us to access much greater knowledge, capacity and learning, but also allows for the rapid spread of viruses and infections.

These dependencies, with their pluses and minuses, exist at all levels, from the individual to the neighborhood to the city, the nation, and internationally. In light of these dependencies, the possibilities for the "next disaster" become quite broad, although the area from which resilient responses can come is broad as well.

Clearly an intense, local climate event can create a local disaster. Boulder County continues to be at risk of flooding, fire and drought. However, Boulder County may also be at risk of crop failure in Mexico, of a flu outbreak in Europe, of global bank failure. At the same time, the nature of potential disasters is changing. Climate change is likely to intensify rainfall, fire and drought in Boulder County. Overuse of antibiotics is creating new antibiotic-resistant diseases. Factory farming is creating new pesticide resistant bugs and super-weeds. Population growth, land-use changes and urbanization are, in many places, putting greater numbers of people in the way of hazards.

This widespread risk and high interdependence makes the resilience of core systems, of people and organizations, and of legal and cultural norms ever more important. Given the growing challenges faced by humanity, we need to take the opportunities we have now to leverage incredible resources of wealth, knowledge and power, and we need to act.

Endnotes

- 1 Videos of the floods in these towns are available for Lyons (<https://www.youtube.com/watch?v=QPrA6S4prjI>) and Jamestown (<https://www.youtube.com/watch?v=y3jy1IECjIo>).
- 2 In the United States, cities and counties use historical flood maps and computer modeling to estimate the areas that will be flooded in a 1-in-100 year flood event. These areas are designated the “floodplain”, and in many areas there are restrictions on the types of new construction allowed in these areas
- 3 A video describing how these Greenways functioned during the flood is available at: <http://nextcity.org/forefront/view/you-cant-stop-urban-flooding>
- 4 It is noteworthy that many of the shelters called for in the Boulder Natural Hazard Mitigation Plan were inaccessible due to the extent of flooding. For more on this issue, see the section on emergency responders.
- 5 Four-mile Canyon lies due west of downtown Boulder, CO. In September 2010 a major wildfire broke out in Four-mile Canyon just a few miles west of Boulder. The fire burned more than 6000 acres and destroyed 169 homes. Until it was surpassed by two fires in 2012, it was the most devastating and expensive wildfire in Colorado history.
- 6 “Everbridge” is a commercial company that provides emergency mass notification services for government and industry. Everbridge calls in Boulder County are calls pushed to resident home and cell phones to notify them of emergency conditions.
- 7 Games are a fun, effective way to explore complexity, volatility and uncertainty. Since 2011, the Red Cross Red Crescent Climate Centre and its partners have designed at least 45 new games about a wide range of key humanitarian issues. Each involves decisions with consequences, enabling players to “inhabit” the reality of climate-risk management and test plausible futures. These games speed up learning, dialogue and action. <http://www.climatecentre.org/site/games>

Photo Credits

We would like to thank the following individuals and organizations for generously providing photography for use in this report.

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Appendix A

Interviews, meetings and forums providing information for this study.

Interviewees

Andy Rumbach, *Assistant Professor, College of Architecture and Planning, University of Colorado Denver*

Bernadette Tillis, *Store Manager, McGuckins Hardware*

Brett KenCairn, *Senior Environmental Planner, City of Boulder*

Bridgette Cram, *Graduate Student, University of Florida (funded for small grant study of the Boulder Flood by the University of Colorado Natural Hazards Center)*

Bruce Vaughn, *Four-mile Fire Department volunteer*

Christine Manson de Rabe, *Senior Disaster Program Manager at American Red Cross, Denver, CO*

Chris Meschuk, *Planning Department, City of Boulder*

Crystal Launder, *Housing Planner, City of Boulder*

Dan Barber, *Deputy Director, Boulder Office of Emergency Management*

David Driskell, *Executive Director of Community Planning and Sustainability, City of Boulder*

Edwina Salazar, *Executive Director, OUR Center*

Eric Lombardi, *Executive Director, Eco-Cycle*

Garry Sanfacon, *Boulder County Flood Recovery Manager*

George Gerstle, *Boulder County Transportation Director*

Iain Hyde, *Colorado State Disaster Recovery Manager*

Jeff Arthur, *Director of Public Works for Utilities, City of Boulder*

Jeff Callahan, *Resource Conservation Division Manager, Boulder County*

Jeff McWhirter, *neighborhood coordinator, Keewaydin Meadows*

Jim Pullen, *KGNU (local Boulder County non-profit radio station)*

Jonathan Wachtel, *Sustainability Planner, City of Lakewood, Colorado*

Karen Rahn, *Director of Human Services, City of Boulder*

Lloyd Banta, *Engineer and Lyons resident*

Marcelo Ferreira, *Emergency Management Coordinator, Boulder Office of Emergency Management*

Mark Gershman, *City of Boulder Open Space*

Mark Leese, *Leese and Associates LLC, FEMA Community Facilitator*

Mary Steffen, *American Red Cross*

Matthew King, *Living GREEN Network*

Meghan Dunn, *University of Colorado Graduate Student, Occupy Sandy and Boulder Flood Relief*

Ricky Munoz, *University of Colorado Graduate Student, Occupy Portland, and Boulder Flood Relief*

Sandy Banta, *Town of Lyons Trustee*

Sean Cronin, *Executive Director, St. Vrain and Left Hand Water Conservancy District*

Sue Anderson, *Boulder County Long-Term Flood Recovery Group Manager*

Thomas Rounds, *Region VIII, Federal Emergency Management Agency (FEMA)*

Thomas Wells, *Boulder Flood Relief (Executive Director during floods)*

Tiernan Doyle, *Executive Director, Boulder Flood Relief*

Tim Gelston, *Region VIII, Federal Emergency Management Agency (FEMA)*

Tim Oakes, *Lyons resident and University of Colorado Geography Professor*

Will Toor, *Former Boulder City Council member and Boulder County Commissioner, Director of the Transportation program at the Southwest Energy Efficiency Project (SWEEP)*

Meetings and Forums Attended

Boulder Outreach for Homeless Overflow

Meeting two months post flood; discussed disaster response, post-disaster increase in homeless population, needs of community, how to coordinate with other systems

2013 Colorado Flood Forum

Sponsored by the Colorado Association of Stormwater and Floodplain Managers and Colorado State University, meeting held 5 months post-flood.

Community Resilience and Engagement Committee of the Long-Term Flood Recovery Group of Boulder County

Multiple meetings from February to April 2014

City of Boulder Flood Open Houses

November 2013 and April 2014

What's Natural About Natural Disasters

Multi-Disciplinary Presentations by Faculty of the University of Colorado November 2013

City of Boulder and Flood Researchers Meeting

November 2013 and February 2014

Town of Lyons Flood Recovery Public Meeting

February 2013

Boulder County Flood Stakeholder Consultation

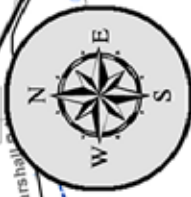
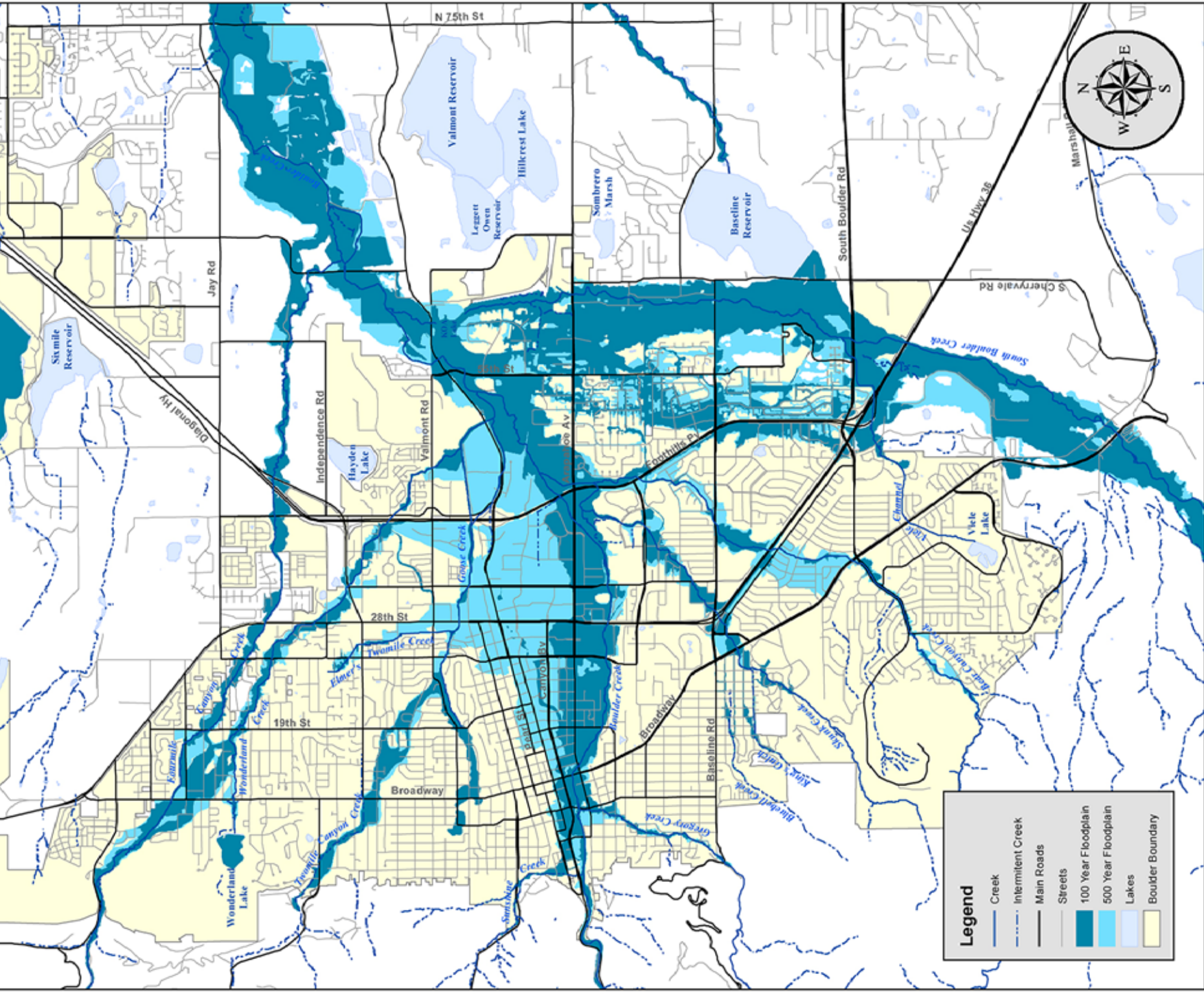
March 2013

Acknowledgements

The authors would like to thank everyone who took the time to meet with us and provide their insight, knowledge, and in many cases, personal stories for this study. Though everyone we spoke to was responding to the floods in some capacity — professionals still in response mode, as volunteers in addition to outside work, or as victims attempting to rebuild on top of all their other demands — everyone took time out of their already overfull lives to sit down with us, often for several hours. Without their generous contributions, this report would have been impossible.

We would also like to thank our donors, the Global Disaster Preparedness Center and the Rockefeller Foundation Asian Cities Climate Change Resilience Network. Their willingness to provide rapid funding enabled us to undertake this study while it was still fresh in everyone's mind.

We have done our best to reflect the input and interests of both our sources and donors. However, the opinions and perspectives expressed in this report remain ours alone.



Legend

	Creek
	Intermittent Creek
	Main Roads
	Streets
	100 Year Floodplain
	500 Year Floodplain
	Lakes
	Boulder Boundary



City Of Boulder

100 & 500 Year Floodplains

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This product was funded by, and in partnership with:



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Boulder, Colorado, is prone to fires, floods and droughts. All are likely to intensify with climate change. This study looks at flooding in Boulder in September 2013. Though the scale of flooding was unprecedented, only 10 lives were lost, most infrastructure was maintained, and the recovery has been strong. This case study explores this resilience — what made it possible, and where there is opportunity for learning— by breaking it down into three categories:

Built Infrastructure:

- Community paths and open space along rivers allowed rivers to overflow their banks with minimal damage.
- Six of the seven roads into the mountains failed because they were all next to rivers; systems are not redundant if they have the same point of failure.

Human Systems:

- Learning from previous disasters directly improved the flood response.
- Self-organized groups mobilized thousands of people, expanded resources, and brought new technologies into the response. This could have been even more effective if existing aid organizations had connected with them early.

Legal and cultural norms:

- The culture of individuality gave staff the freedom to take independent action and innovate. This allowed systems to be operated effectively under a wider range of conditions than they were initially designed for.
- In some sectors the potential for lawsuits has put a damper on learning processes and reduced resilience in the recovery.

Perhaps most important for climate change adaptation and resilience is promoting imagination. We need to get good at imagining the unimaginable, and thinking about how existing systems, people, and policies can be easily, cheaply adapted to meet those challenges.

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For more information on ISET-International's Boulder Floods Study, please visit www.i-s-e-t.org/work/boulder-flood