Colorado Water

Colorado State University

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Highlights

In Every Issue

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Front Cover: Westerly Creek at the intersection of Mississippi Avenue and South Kenton Street, Aurora, Colorado. Courtesy of City of Aurora
This Page: A rain garden in Lakewood, Colorado at 21st Avenue and Iris Street services about one acre and is being monitored for pollutant reduction. Photo by Holly Piza

Editorial

by Reagan Waskom, Director, Colorado Water Institute

Stormwater happens. And sometimes it happens in a big way. 2013 was a year of extremes in Colorado. Several intense fires were very costly in property damage and resulted in two lost lives. Widespread drought in southern Colorado damaged agricultural and wild lands, increasing fire severity. In September, historic flooding near Colorado Springs and in the South Platte basin resulted in 10 lives lost, over 16,000 homes damaged, 1,882 homes destroyed, and total losses exceeding $2 billion.

When precipitation intensity or duration overwhelms stormwater infrastructure, resultant flooding may capture our attention for a while—mostly, stormwater is an aspect of water management seldom considered by the public. Yet stormwater is a component of the total water resource, and its management impacts stream functioning, ecosystems, and the quality of the water resource. The recently burned areas in our watersheds are a serious concern as they will generate more runoff and sediment from precipitation events and are a major concern for flooding and water quality.

Simply stated, stormwater is rainwater and melted snow that runs off buildings, streets, lawns, and other urbanized areas in the watershed. As stormwater picks up debris and pollutants and gains velocity, it can erode stream banks; damage bridges, roads, and other infrastructure; and contaminate streams and receiving waters. Stormwater requires continual management as urban development progresses. Stormwater management involves a complex set of approaches that are seldom fully valued by developers or ratepayers. It requires planning, funding, regulatory controls on development and floodplain activities, construction of stormwater treatment systems, acquisition and protection of natural waterways, and enforcement of ordinances. None of these activities are fully appreciated until damaging floods occur. Development near streams and in floodplains often seems harmless and a right of property ownership, as the idea of the 100-year flood seems unlikely to us. This necessitates continuous community education to help us understand the consequences of our land use and development decisions.

Building "soft" or "green" structures such as ponds, swales, wetlands, and other BMP solutions to work alongside existing or "hard" drainage structures, such as pipes and concrete channels, is currently at the forefront of stormwater management. Because it is more efficient and cost-effective to prevent problems than to correct them later, sound land use planning is essential as the first, and perhaps the most important step in managing stormwater. Many municipalities are now requiring all new development and redevelopment plans such as subdivisions, shopping centers, industrial parks, and office centers to include a comprehensive stormwater management system based upon Low Impact Development (LID) principles. This is significant progress, but alone it is not enough. The stormwater management system must also be maintained—failure to provide proper maintenance reduces pollutant removal efficiency and reduces system capacity to move water. The key to effective maintenance is the clear assignment of responsibilities to an agency or organization, and regular inspection by properly trained professionals to determine maintenance needs.

Stormwater and floodplain education is not just for the professional community. There is a need for the public to understand that every piece of land is part of a larger watershed, and that our everyday activities affect the health of the watershed. As a society we tend to lose interest in stormwater and floodplain management during times of normal or dry hydrologic conditions, then we seem surprised when the inevitable flood occurs. To provide public education, CSU and the Colorado Association of Stormwater and Floodplain Managers (CASFM) recently co-hosted a 2013 Colorado Flood Forum on February 27, 2014 to discuss the response and recovery efforts resulting from the September flood (presentations can be accessed at www.casfm.org). We learned of truly heroic actions by public safety and flood response agencies that prevented the loss of more lives. We learned the value of stormwater and floodplain management programs to lessening flood impacts in some areas. But we were also reminded of the limits of our infrastructure and the devastation that flooding can cause. Given the ample 2014 snowpack along the Front Range, areas impacted by the 2013 flood and fires may be vulnerable once again this year, but this time the memory is still painfully fresh on our minds.

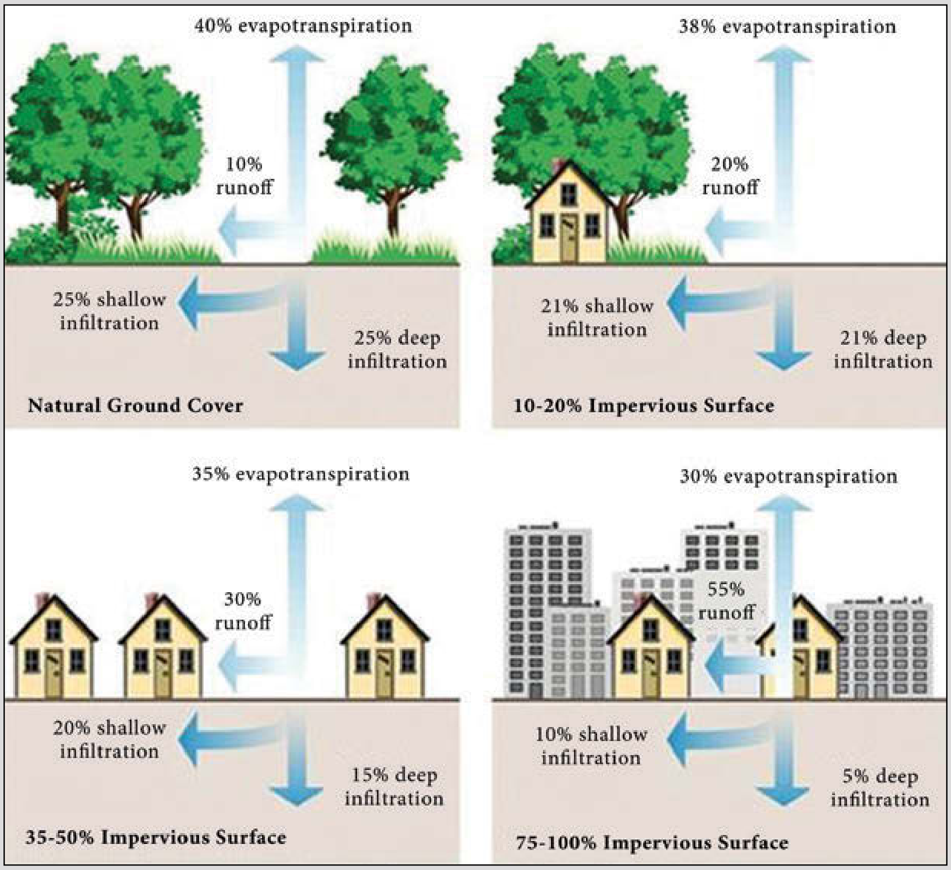
CSU's Urban Stormwater Program

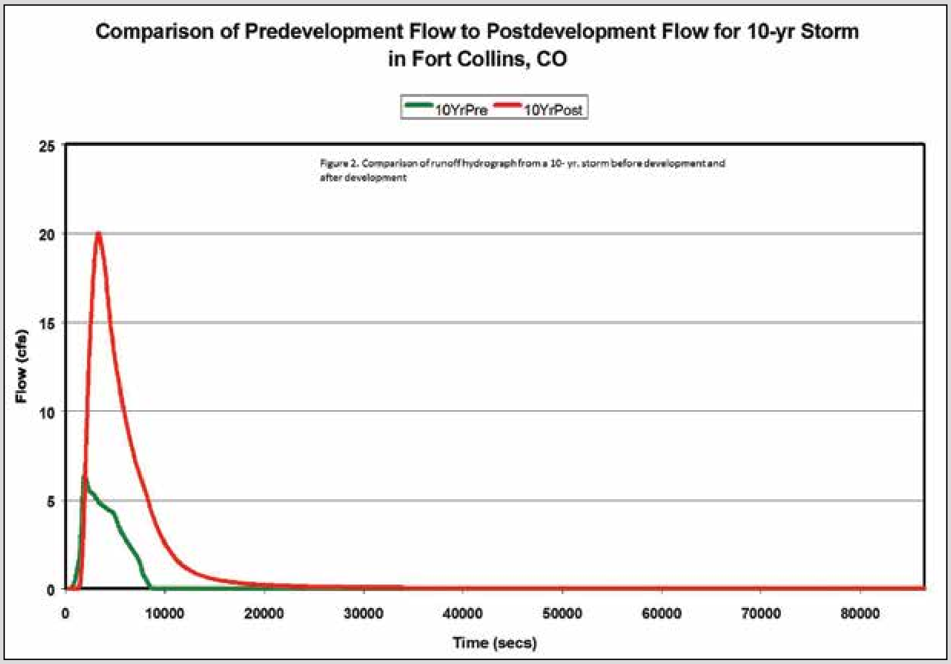
Larry A. Roesner, *Department of Civil and Environmental Engineering, Colorado State University*

Urban stormwater management at CSU has included research by the CSU Urban Water Center, which has studied stormwater runoff before and after urbanization, stream erosion management, and Low Impact Development technologies such as porous concrete and bioretention cells.

Over the last 15 years, Colorado State University (CSU) has developed an international reputation for excellence in urban stormwater management through its teaching, research, and consulting work in Colorado and other states and abroad. Leadership for this program has been provided by Larry A. Roesner, who came to Colorado State University in 1999 to assume the Harold H. Short endowed chair of Urban Water Infrastructure Systems. Roesner's prior 31 years of practice as an environmental consulting engineer with CDMSmith was instrumental in focusing the research program on solutions to real problems that municipalities face in managing urban stormwater, particularly flooding problems, channel erosion, and water quality degradation caused by uncontrolled runoff from urban development.

To provide some background, urbanization changes the hydrology of a watershed by covering the previously pervious ground with roads, sidewalks, driveways, and buildings. The amount of coverage varies from about 35 percent for single family residential areas to nearly 100 percent for commercial areas. Figure 1 shows a typical hydrologic water balance before and after urbanization. Notice that with development, not only does soil infiltration decrease, but surface





Figures on right (top to bottom):
1. *Effects of urban development on hydrology.*
2. *Comparison of runoff hydrograph from a 10-year storm before development and after development.*

runoff increases by a factor of three. And because the impervious area increases the speed of runoff, the resulting runoff hydrographs from developed area have higher peaks as well as increased volume (see for example, Figure 2). The result is significantly increased channel erosion and destruction of aquatic habitat (Figure 3).

The CSU Urban Water Center began studying the hydrologic impacts of urbanization in the year 2000 to gain information that would enable engineers to design runoff controls to mitigate the impacts of urban runoff on receiving streams. These studies were funded from the Harold H. Short Endowed Fund for Urban Water Infrastructure Research. The research involved running mathematical models that simulate runoff from a watershed, taking into account rainfall pattern, pre-development geohydrology, and post-development land use features. This research revealed that the small storms occurring more frequently than once in two years are most affected by urbanization. Figure 4 shows peak flow frequency-exceedance curves for runoff from undeveloped land in Fort Collins and from that same land after development. The differences are striking, and were previously unknown. Storms smaller than the 2-yr storm have post-development peaks that are 10 times larger than the pre-development peaks, while the increase in the peak runoff rate for the 100-year storm increases by a factor of two. This finding enabled CSU researchers to begin looking into better design criteria for controlling urban runoff.

The objective for the runoff control algorithm was to produce a post-development peak flow frequency exceedance curve that matched the pre-development curve. The research team found that using peak flow attenuation facilities (detention storage with outlet flow controls), this objective

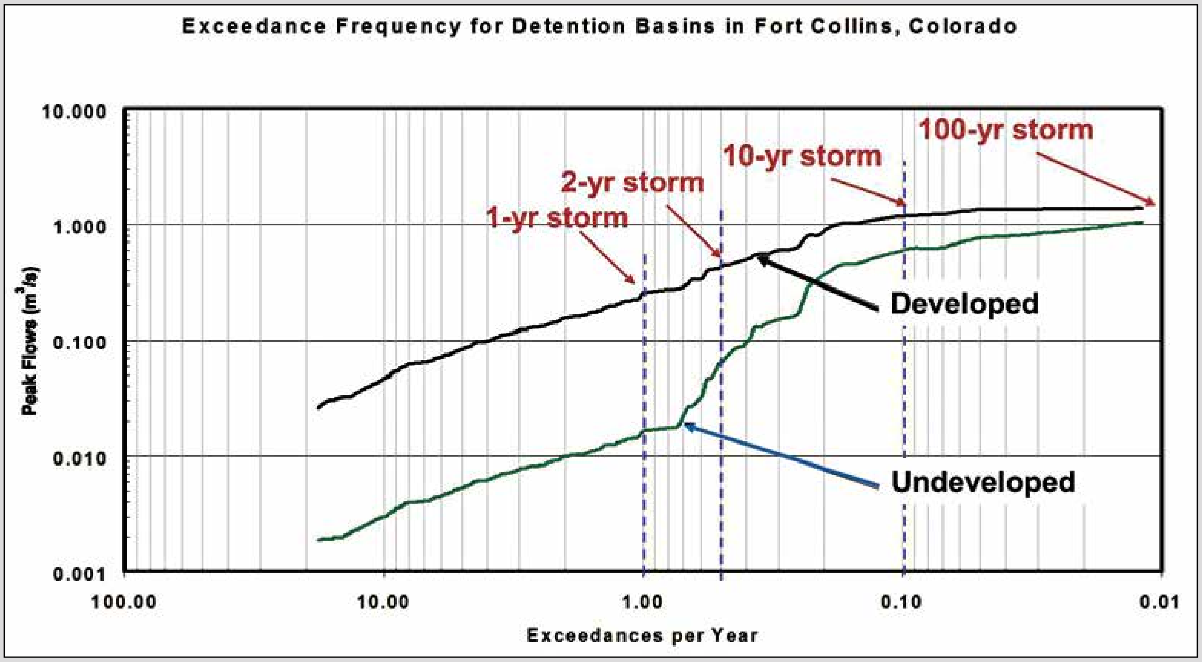


Figure 3 (above): *Typical stream erosion resulting from urban development.* Courtesy of Larry Roesner

Figure 4 (left): *Peak flow frequency-exceedance curves for runoff from undeveloped and developed land in Fort Collins.*

Figure 5. *Typical stormwater detention facility providing peak flow attenuation and pollution removal.*

Figure 6. *Raingarden collects roof and driveway runoff and infiltrates it into ground. Notice the storm inlet at the lower right to drain off runoff from larger storms.*

could be met by designing a four-level outlet structure so that the pre-development peak flow was not exceeded for the 100-, 10-, and 2- (or 1-) year storms, and small storms (generally less than 0.5 inches) were completely captured and released slowly over a 48 hour period. Figure 5 is a picture of a typical facility.

The "BMP" shown in Figure 5 is actually a stormwater treatment facility required by the U.S. Environmental Protection Agency and the Colorado Department of Public Health and Environment.

Table 1. *Cumulative erosive shear stress over 50 years*

Scenario	Shear Stress (lb/ft^2)	Percent Increase
Undeveloped	784	-
Developed Uncontrolled	16,235	1,972%
Recommended Controls	2,518	221%

These facilities are required to capture small storms and provide treatment such as extended detention (24-72 hours drawdown time), wetland treatment, or filtration/infiltration. Typically, these BMPs capture about 75-90 percent of the annual runoff. As it turned out, using any of these devices with a 48-hour drawdown time worked perfectly with the peak flow controls to return the post-development peak-flow frequency curve to its pre-development shape. The findings from this research have been used to guide development of urban runoff control criteria in Colorado, a number of other cities across the United States, and to some extent, internationally.

While controlling the peak flow frequency-exceedance curve was a major step forward in urban runoff management, these facilities do not reduce the volume of runoff, which we previously noted to be on the order of 100 percent increase from pre-development to post-development. There was concern that even though peak flows were controlled, the duration of those flows would cause continued stream erosion and significant stream habitat destruction. The Water Environment Foundation contracted with the Urban Water Center to examine this question. Again, using continuous simulation of runoff over a 50-year period, CSU researchers

Figure 7. *Modular pavement and infiltration basin.*

were able to compute the cumulative stream bank erosion rate for the pre-development hydrology and compare it to the post-development erosion rate for uncontrolled runoff and with the flow control scenario described above. The results shown in Table 1 reveal that for uncontrolled runoff from urban watersheds, the rate of erosion can be expected to increase by nearly 2,000 percent, whereas the application of urban runoff controls described earlier resulted in only a 200 percent increase in erosion rate. The research did not cover all aspects of stream erosion, but the result indicates that post-development stream erosion and habitat degradation can be reduced significantly by use of the recommended flow controls. In combination with other stream erosion management practices, it should be possible to protect our urban streams even with watershed development.

Since 2008, the City of Fort Collins Stormwater Utility has been funding research and demonstration projects in advanced stormwater technologies through the Urban Water Center. The Urban Water Center has studied the performance of existing stormwater control facilities in terms of runoff volume capture, treatment efficiency performance, and providing recommendations on how to improve performance. But more recently, the Urban Water Center has been partnering with the City of Fort Collins to investigate the efficacy of advanced stormwater treatment technologies that can be integrated into urban infrastructure, rather than require set-aside space as is the case with BMPs of the type shown in Figure 5. Moreover, these technologies can be retrofitted into redevelopment projects in urbanized areas (see for example the rain garden in Figure 6 that infiltrates rooftop runoff). These newer technologies are commonly called LID or the Low Impact Development approach to stormwater control. LID has been popular for many years, but not much is known about hydrologic performance, pollutant removal capability, and long term maintenance. Research at the Urban Water Center is addressing these issues through measuring the performance of several LID facilities constructed by the City of Fort Collins.

Figure 8. *Flow recording equipment and water samples are stored and housed in the decorated cabinet shown.*

Figure 9. *CTL Thompson driveway and parking lot is porous concrete and can infiltrate all the runoff from surrounding roofs and the parking area.*

As part of the Mitchell Block redevelopment in Old Town Fort Collins, the parking areas adjacent to the new building were paved with modular pavement (Figure 7) that is able to infiltrate runoff from the parking area and the adjacent street through the spaces between the paver blocks. Figure 7 also shows an infiltration basin that collects runoff from small storms and infiltrates it into the soil below; larger storms that fill the infiltration basin overflow into the stormwater inlet to the existing drainage system. Figure 8 shows the monitoring system that measures how much runoff is captured by the modular pavement and samples the water to determine how much pollution is removed. Other LID prototype installations that the City has built and CSU is monitoring include a porous concrete parking lot (Figure 9), capable of infiltrating the runoff from a 100-yr storm from the buildings and driveway and parking areas, and a bioretention cell recently constructed at Fort Collins Utilities facilities on Wood Street to capture and treat parking lot runoff.

The Fort Collins program has inspired confidence in LID performance to such a degree that the City now requires that the stormwater from a portion of all new construction or redevelopment sites be treated using LID technologies. Fort Collins is the first city in Colorado to have such a requirement.

CSU's Urban Water Center has gained international recognition through its research publications and invited presentations of its work and findings at international conferences. Researchers Larry Roesner and Chris Olson were recently invited to Korea to provide advice to researchers at Pusan University on their $US 2.5 M dollar LID research program. The visit also included briefing of four Korean infrastructure ministries on approaches to LID application in Korea, plus a two-day training course for employees of K-Water, a Korean government consulting firm for water resource management. See Chris Olson's article in this issue about the Colorado Stormwater Center.

The Colorado Stormwater Center at CSU

Christopher Olson, *Director, Colorado Stormwater Center*

The Colorado Stormwater Center, which operates out of the Department of Civil and Environmental Engineering, has the goal of improving stormwater management practices and providing stormwater management resources for Colorado citizens. The center is working on projects such as stormwater facility inspection and maintenance training and an upcoming "Build Your Own Rain Garden Guide" for homeowners.

Introduction

Most cities, towns, and counties in Colorado must manage urban stormwater according to a municipal separate stormsewer system (MS4) permit issued by the Colorado Department of Public Health and Environment (CDPHE). This collection of permit holders, appropriately referred to as "MS4s," shares a range of common interests and requirements for managing stormwater, including public education, outreach, and training. In the past, these were handled individually by each MS4 in a segregated and non-uniform manner. Realizing the need for, and potential benefits of, a statewide stormwater education, outreach, and training institution, the Colorado Stormwater Center (Center) was established in 2013 with funding provided by the Urban Drainage and Flood Control District, the Colorado Association of Stormwater and Floodplain Managers, the Colorado Stormwater Council, CDPHE, and Colorado State University (CSU) Extension. The Center operates out of the Civil and Environmental Engineering Department at CSU with the primary mission to: *Enhance the quality of the state's streams, rivers, and lakes through education and training of both the public and professionals involved with design, construction, inspection, and maintenance of stormwater management facilities in Colorado.*

Figure 1. *Improperly maintained stormwater management with noticeable pollutant and trash buildup. These materials must be removed regularly.* Photo by Chris Thornton

Figure 2. *Properly maintained outlet with no noticeable pollutant or trash buildup.* Photo by Larry Roesner

After several months of project planning and scoping, organizational development, and other administrative activities, the Center is now up and running. The following sections describe some of the activities the Center is currently working on to achieve its mission.

Stormwater Best Management Practice (BMP) Inspection and Maintenance Training

One of the largest problems facings MS4s in Colorado is keeping stormwater management facilities, also referred to as best management practices (BMPs), properly maintained. BMPs are designed to capture and remove pollutants, trash, and other debris from stormwater before it enters waterways, but these materials must be removed from BMPs periodically to ensure they continue to operate properly (Figures 1 and 2).

There are two primary reasons why BMPs are not maintained properly. One is that the owners of BMPs (e.g., property owner, homeowner's association, schools, churches) are not aware that BMPs require regular inspection and maintenance. The other is that persons who perform the inspection and maintenance activities have not received any formal training for diagnosing and fixing BMP problems properly. An appropriate analogy is to consider how one maintains their own vehicle. If a vehicle owner does not know that the oil must be changed every 3,000 miles and/or if they hire someone who doesn't know how to change the oil, the vehicle is not going to run properly. The Center is addressing these problems in two ways. First, we are preparing a short informational video for BMP owners that will describe the importance of keeping BMPs properly maintained. This video will be distributed to BMP owners all over Colorado by the Center and its MS4 partners. Second, we have developed a two-day training workshop for persons that do (or may) perform BMP inspections and maintenance (e.g., landscape contractors, municipal inspectors, and maintenance crews). This course addresses topics such as BMP operation (how to remove pollutants), frequency of maintenance activities, equipment selection and operation, and diagnosing small problems before they turn into large problems. Those that successfully complete the course and a written exit exam are acknowledged on the Center's website. Completing the loop, BMP owners who recognize the need for properly maintaining BMPs can now go directly to this link: stormwatercenter.colostate.edu/resources/certified-professionals/ to find contractors and other personnel who can provide proper BMP inspection and maintenance services.

Green Infrastructure and Low Impact Development Stormwater Management

An emerging trend in urban stormwater management is the use of green infrastructure (GI) and low impact development (LID) techniques. According to the EPA,

…the term "green infrastructure" generally refers to systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse stormwater or runoff on the site where it is generated. Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID. LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product.

GI/LID techniques include bioretention cells (Figures 3 and 4), permeable pavements, green roofs, rain barrels, and others. Despite showing promise for reducing a number of problems such as stormwater pollution, channel erosion, and urban heat island effects, successful implementation of GI/LID in Colorado is hindered by numerous technical, institutional, and regulatory barriers. One of the most critical barriers is Colorado's prior appropriation water rights laws. Most people assume GI/LID cannot be implemented in accordance with these laws (indeed the use of rain barrels for capturing and reusing stormwater cannot be used in most cases); however most of the other techniques can be implemented as long as they are designed to follow guidelines provided by the State Division of Water Resources. Another barrier is that most GI/LID design and implementation guidelines are from areas of the United States with much greater rainfall than Colorado. GI/LID implementation in Colorado requires different plant selections, considerations for prevalent clay soils, and different sizes of facilities to accommodate the semi-arid climate. The Center is currently developing a series of presentations and workshops on proper GI/LID implementation, with an emphasis on breaking Colorado-specific barriers.

"Build Your Own Rain Garden" Guide for Homeowners

Rain gardens are one type of GI/LID that can easily be implemented by most homeowners in their own backyard. A rain garden is similar to any other household garden, except that it is installed in a "sunken" bed rather than a "raised" bed. The "sunken" bed captures stormwater runoff from rooftops where it slowly infiltrates into the groundwater over a day or two.

While the impact of a single rain garden at one home may not seem significant, the cumulative impacts of hundreds or thousands of rain gardens throughout a city can provide significant stormwater management benefits. Cities such as Seattle, Washington and Kansas City, Missouri have implemented the "10,000 Rain Gardens" project designed to promote the widespread use of rain garden in residential areas. Each project starts with the development of a "Build Your Own Rain Garden" (BYORG) guide specific for the project area.

The Center is developing a BYORG guide for Colorado homeowners that will be released in time for spring planting. Our guide includes Colorado-specific recommendations for sizing (based on Colorado soils and precipitation) and plant selection, with the latter focused on the use plants and grasses that will require little to no supplemental irrigation after the first year of establishment. A demonstration rain garden will be constructed using this guide in spring 2014, and an accompanying video of how to apply the guide will be produced at that time. Check our website in May to find the completed guide and video.

Summary

The Colorado Stormwater Center is here to serve Colorado citizens with all levels of interest and responsibility in stormwater management. Please contact Chris Olson at Chris.Olson@colostate.edu with stormwater related questions, comments, and ideas. More information on the Center's activities, including upcoming education and training opportunities, can be found at stormwatercenter.colostate.edu/.

Figures 3 and 4. *Bioretention cell installed in Fort Collins, CO during dry and wet weather. Bioretention cell treats stormwater runoff from an adjacent parking lot.*
Photos by Chris Thornton

2013 Flood Season Recap

Kevin Stewart, Information Services and Flood Warning Manager, Urban Drainage and Flood Control District

2013 had a record 58 days with flood potential, according to the Urban Drainage and Flood Control District, but with minimal damages until the September 2013 floods. Thanks to years of groundwork in preparing for large-scale flooding after the 1976 Big Thompson Canyon Flood, many early warning systems were in place, and many lives were saved.

September 2013 flood damage along Fourmile Canyon Creek in Boulder County near UDFCD border.
Courtesy of UDFCD

Table 1. *Record 58 days with flood potential in 2013: Red dates are when rainfall measured by automated gages exceeded alarm thresholds. Yellow highlighted dates indicate heavy rainfall only affected areas outside UDFCD's main area of concern such as the Hayman Burn Area in SW Douglas County and watersheds in northern Boulder County. Blue boxes are when a NWS flash flood watch was the highest threat level reached, and red boxes designate a flash flood warning.*

May	8, 15, 29	3
June	15, 18, 23, 28, 30	5
July	10, 11, 12, 13, 14, 15, 18, 19, 20, 24, 25, 27, 28, 29, 30	15
August	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 18, 21, 22, 23, 24, 25, 26, 27, 30	21
Sept	3, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 18, 22, 23	14

Prior to epic floods of September, the Urban Drainage and Flood Control District (UDFCD) Flash Flood Prediction Program was experiencing an unusually wet and long monsoon season, with the stormy weather continuing past Labor Day. By the end of first week in September, local governments served by the program had safely weathered 47 days of heavy rain potential, with 43 of those days producing at least some localized flooding. By the end of September, the program had logged a record number of threat days since its inaugural season in 1979.

The ALERT System generated rainfall rate alarms for 31 threat days in 2013 compared to only 13 days the prior year. Specific alarm dates are noted in Table 1.

Twenty-four hour measured rainfall totals from the Automated Local Evaluation in Real Time (ALERT)/ Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) combined dataset exceeded three inches on six days in 2013 (July 13, August 3, and September 9, 11, 12, and 14). Eight other days (May 8, July 14, August 8 and 22, and September 4, 10, 15, and 22) had 24-hour rain totals between two and three inches. A storm summary table (f2p2.udfcd.org/2013_summary.htm) and corresponding maps are available for every day that heavy rainfall was predicted.

By late April, reports of near normal mountain snowpack conditions were welcomed news for northeastern Colorado communities. The subsequent runoff in May and June was well-behaved. No flood warnings for the snowmelt season were needed this year for the Denver area—a good start!

May rains were uneventful, with the first threat day of the year (May 8) producing quarter-inch per hour amounts in Boulder County's Fourmile Burn Area (FMBA) with no consequence. One week later, Aurora experienced some minor street flooding from a short-duration rainstorm. Looking back now, the most ominous event of the month may have been the rare early morning thunder on May 29 that produced little rain but lasted an unusually long time—possibly a harbinger of what lay ahead.

By mid-June, the region had dried-out, and El Paso County was dealing with the worst wildfire in Colorado history, the Black Forest Fire, destroying over 500 homes and surpassing the prior-year's record held by the Waldo Canyon Fire, also in El Paso County. In 2010, Boulder County's Fourmile Canyon Fire owned this unwanted record. Subsequent of each of these fires, tragic floods occurred. By the end of June, the district had experienced a few bouts of severe weather with a small tornado reported near DIA on June 18, but very little rain fell over the metro area during June with Friday, June 28 producing the most.

This dry trend continued into July until the summer monsoon arrived on July 7, when heavy rainfall occurred over the Hayman burn area and other parts of southern Douglas County. By July 10, the metro area started receiving the rains, and the 2013 fire season appeared to be nearing its end. For six consecutive days (July 10-15), flood threats prevailed, causing the National Weather Service (NWS) to issue flash flood warnings for the July 12 and 13 followed by a flash flood watch on Sunday, July 14. The ALERT system logged 63 rainfall rate alarms over a four-day period beginning Friday, July 12.

The FMBA in Boulder County was the primary target for many of the NWS flash flood warnings and advisories, much like the prior two years. While experts agreed that the watershed had experienced excellent vegetative recovery since the 2010 fire and was less prone to flooding from half-inch rainstorms, the concern remained that larger hillside debris still posed a threat, and that the lack of a healthy forest and deep duff layer would warrant careful watch during rainstorms capable of approaching an inch or more in less than one hour. Flash flood warnings were issued for the FMBA on July 12 and July 18 with little consequence. At this point, it certainly seemed that conditions in the FMBA had improved substantially.

On Saturday, July 13, multiple thunderstorms moved through the district during afternoon hours. This was the first storm of the season with rainfall totals exceeding three inches. Flash flood warnings were issued for central Jefferson County that included Arvada, Wheat Ridge, and Lakewood. The storm caused Lakewood Gulch in Denver to rise over six feet in a short period, setting a new record for the U.S. Geological Survey gage that has operated continuously since 1981. July 13 was also the second anniversary of the FMBA flash flood that destroyed or damaged nearly a dozen homes and threatened many lives. In hindsight, one might see this day as the second harbinger of 2013.

For the 21-day period between July 24 and August 13, only three days were forecast as having no flood potential. On Saturday, August 3, slow moving severe thunderstorms during the afternoon and evening flooded portions of Boulder, Adams, and Arapahoe counties. Every UDFCD county experienced moderate to heavy rainfall, with the worst storms concentrating over the southeast and northwest portions of the district. The town of Erie in eastern Boulder County had considerable damage from high winds and flooding, and measured the largest rainfall amount of 3.4 inches. On the following Thursday, August 8, flash flood warnings were issued when a line of strong storms became stationary across the district between 5 and 7 p.m., dropping two to three inches on Aurora. The final flash flood warning for August occurred two weeks later on August 22 when the Ken Caryl Ranch area of Jefferson County and portions of northern Douglas County received two to three inches of rain accompanied by copious amounts of hail. That same day, our friends to the south in El Paso County experienced a three to four inch intense downpour that flooded Woodland Park, narrowly missing the Waldo Canyon burn area. Had that storm occurred

On August 22, the Ken Caryl Ranch area of Jefferson County and portions of northern Douglas County received two to three inches of rain accompanied by copious amounts of hail. Courtesy of Chad Lunde over Waldo instead, the impact to Manitou Springs—an area familiar with deadly post-fire flash floods—would likely have been horrific.

September Flooding

Many Coloradans' lives were changed forever by the rains of September 2013. Over 18,000 homes and businesses were damaged or destroyed by the ensuing floods. Many were uninsured. News reports stated that more than 17 percent of the affected properties in Boulder, Larimer, Logan and Weld counties are not within mapped floodplains. The effect on public transportation was immense, with many roads and railway segments completely destroyed. Mountain landslides and streambank failures were common, while floodwaters carried huge rocks and debris, carving new channels and creating new floodplains. Statewide flood losses are expected to exceed $2 billion.

Sadly, the week of heavy rains caused nine fatalities statewide, according to NWS—two in El Paso County, one in Clear Creek County, two in Larimer County from flooding on the Big Thompson River, and four in Boulder County. Remembering that the 1976 Big Thompson Canyon flash flood claimed over 140 lives, news stories quickly surfaced crediting early flood warning systems with saving hundreds.

The 1976 Big Thompson flood was a catalyst for what followed. Behavioral scientists from the University of Colorado-Boulder were asked to research what people did during the Big Thompson flood, how that flood would have impacted the City of Boulder if it had occurred on Boulder Creek, and what could be done to prevent a similar future catastrophe. Shortly after the findings were revealed, the following actions were taken:

New channel cut by Fourmile Canyon Creek in Boulder County near UDFCD border. Actual creek channel is left of photo. Damaged parking area served the Anne U. White Trailhead prior to the flood.
Courtesy of UDFCD

Stream banks, roadways and buildings collapsed during the 2013 floods, adding to the debris being carried by floodwaters. At points where the movement of debris was either obstructed or slowed, temporary dams formed, and the water backed-up until the failure point was reached. Then a large surge of water would impact a relatively short distance downstream where eventually, the debris load would be deposited. This condition was commonly observed throughout the high country and adjacent plains during the flood.
Courtesy of Army National Guard

- One of the first available color Radar systems was acquired and installed at the NWS Forecast Office in Denver by the UDFCD
- A private meteorological service was employed by UDFCD to monitor a second color Radar receiver and provide local officials in the Denver/Boulder metro area with early notifications concerning potential and imminent flood threats
- An automated early flood detection network of rain and

Utah Park in Aurora, Colorado is a detention basin that worked as designed to minimize damage from floodwater to neighboring property during the September, 2013 flooding. Photo by Jeremy Deischer

stream gauges was deployed for the Boulder Creek watershed in Boulder County and later expanded to include many other locations

- Drainage basin-specific flood warning plans were developed
- Standard operational procedures were revised to better address flood threats
- Annual flood exercises were conducted
- Technological enhancements were constantly introduced
- Public warning systems were improved
- Coordination and cooperation among agencies increased
- Communications remained a priority

Prior to and during the September 2013 floods, the local flood warning system performed very well. The automated gaging network known as the ALERT System generated over 240 rainfall alarms during the week-long storm period, disseminating notifications to a large number of forecasters, emergency managers, public works officials, and others via email and text messages. Stream gages recorded record peaks at 39 locations, logging over 800 alarms. UDFCD, NWS, and local emergency management offices worked closely together delivering critical warning messages to response agencies and the public. UDFCD's private meteorological service produced 162 forecast products and initiated 266 voice contacts with local governments between September 9 and 15. Over 440 NWS communications were relayed by the Denver-regional Emergency Managers Weather Information Network (EMWIN) during that same week. All of this contributed to the situational awareness that local decision makers relied upon to anticipate and react to the circumstances that confronted them.

It is clear that the local flood warning system that evolved over the past 37 years following the Big Thompson Canyon flash flood helped save lives during the September 2013 floods, but the real heroes that deserve the credit are many including:

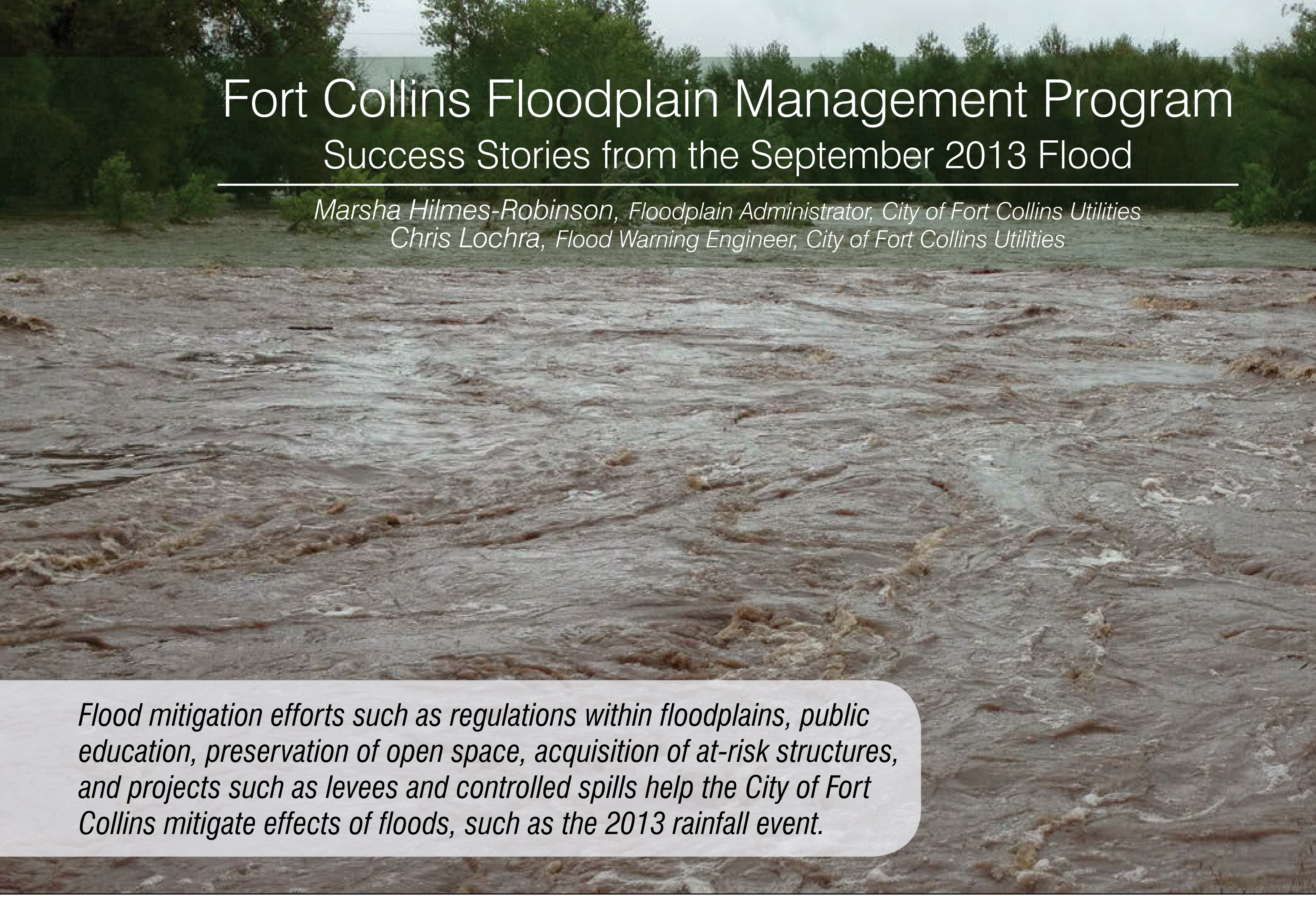
- The CU-Boulder behavioral scientists that taught us how people respond to warnings and what could be done to improve the local warning process
- Community leaders that took this advice seriously by developing better early flood detection capabilities, specialized flood prediction services, siren systems, and other enhanced public warning methods
- Public safety, public works, and other local officials that delivered the message to those at highest risk
- Mountain community alliances that helped citizens know how to survive a wildland fire or flood disaster and established emergency communications for times when normal methods fail
- The countless number of skilled emergency service personnel that risked their lives to save others
- Neighbors helping neighbors
- The people that believed the flood risk message and took appropriate actions when warned

A news release by the National Hydrologic Warning Council observed that Colorado Front Range communities were committed to a "different outcome" than what happened on July 31, 1976 in the Big Thompson Canyon. This statement may best summarize the Colorado recent flood experience. Thirty seven years of preparing for flood disasters using various techniques—not just early warning—undeniably saved lives in September of 2013.

Fort Collins Floodplain Management Program

Success Stories from the September 2013 Flood

Marsha Hilmes-Robinson, Floodplain Administrator, City of Fort Collins Utilities
Chris Lochra, Flood Warning Engineer, City of Fort Collins Utilities



Flood mitigation efforts such as regulations within floodplains, public education, preservation of open space, acquisition of at-risk structures, and projects such as levees and controlled spills help the City of Fort Collins mitigate effects of floods, such as the 2013 rainfall event.

Floodplain management uses various tools to mitigate the impact floods have on our community. These tools include floodplain regulations, open space preservation, acquisition of at-risk structures, capital projects, public education and flood warning.

The City of Fort Collins has a comprehensive program that incorporates all of these strategies. The Fort Collins Floodplain Management Program is ranked as one of the top programs nationwide under the Federal Emergency Management Agency (FEMA) Community Rating System. This ranking results in flood insurance discounts of up to 30 percent for residents and businesses.

The 2013 Cache la Poudre River flood provided an opportunity to evaluate the effectiveness of Fort Collins' mitigation programs. Several successes are highlighted.

Floodplain Regulations – Minimizing Future Damage

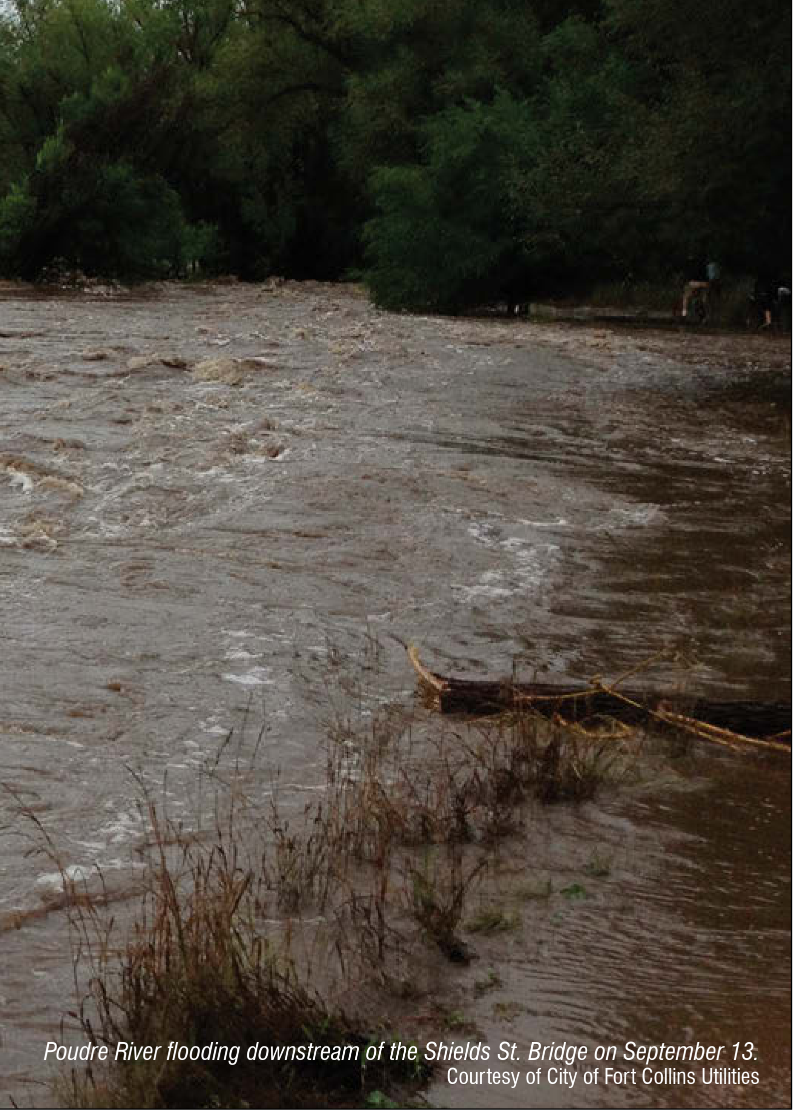
For the 2013 Flood, the minimal damages to structures and the reduced emergency response for life-safety issues resulted partially from strong floodplain regulations in the Poudre River Basin, which protect new structures built in the floodplain from future floods.

Prohibition of Higher-Risk Land Uses

Specific uses are regulated in the Poudre River floodplain. For example, no new residential structures or additions have been allowed in the 100-year floodplain since 2000. Since 1995, At-Risk Population, Essential Service, Government Service and Hazardous Materials critical facilities have been prohibited in the 100-year floodplain. At-Risk and Essential Service critical facilities are also prohibited in the 500-year floodplain. This helps reduce the risk to emergency responders during a flood and allows a community to recover more quickly when a flood does occur.

Elevation Above the 100-year Flood Level

Another regulation that helped minimize damage is the requirement to elevate new structures and additions two feet above the 100-year floodplain. This is a higher standard than the FEMA requirement of only requiring elevation to the 100-year flood level, or the State of



Poudre River flooding downstream of the Shields St. Bridge on September 13.
Courtesy of City of Fort Collins Utilities

Colorado's requirement of elevating one foot above the 100-year flood level. Structures that were elevated and protected from flood damage include the In-Situ building on Lincoln Avenue and the Neenan Building and Orthopedic Center of the Rockies in the Seven Lakes Business Park along Prospect Road (Figures 1 and 2).

Another benefit to elevating structures above the 100-year flood level is reduced flood insurance premiums.

Floatable Materials Regulation

A floodplain regulation that is unique to the Poudre River is the requirement that no floatable materials are allowed in the 100-year floodplain. This regulation is triggered when an addition, substantial improvement, or new structure is built on a non-residential property. Historically, there were several properties along Lincoln Avenue that stored large quantities of floatable materials including metal drums, plastic shipping containers, storage tanks, pallets, construction supplies, and vehicles. Due to implementation over the last 10 years, these properties now comply with the floatable materials requirement and have greatly reduced the amount of materials that could damage properties or public infrastructure downstream. Figures 3 and 4 show Team Petroleum along Lincoln Avenue before the clean-up of floatable materials. During the flood and clean-up operations, field crews reported very little of this type of material carried downstream. To learn more about the floodplain regulations adopted by the City of Fort Collins, visit fcgov.com/floodplainregs.

Open Space Preservation

The City's Natural Areas Program has proactively purchased floodplain property along the Poudre River Corridor, and the Parks Department owns and maintains

Figure 1. *Aerial view of Seven Lakes Business Park looking east in the early afternoon of Sept. 13, 2013 showing floodwater against the Orthopedic Center of the Rockies (lower right) and the Neenan Building (center). These buildings are elevated and did not sustain damage.*
Courtesy of City of Fort Collins Utilities

Figure 2. *Debris line is evident on west side of Orthopedic Center of the Rockies showing the water level against the building. Approximately 6 inches of freeboard remained before water would enter the building, making this a good example of the benefits of elevating structures to protect from flood damage.*
Courtesy of City of Fort Collins Utilities

Table 1. *Open Space Preserved in the Poudre River 100-year Floodplain*

Parks in 100-year Floodplain (acres)	Natural Areas in 100-year Floodplain (acres)	Total Open Space Preserved (acres)	100-year Poudre River Floodplain Inside City Limits (acres)	**66% of the 100-year floodplain is preserved as Open Space.**
55	924	979	1,485	

Figures 3 and 4. *The Team Petroleum site on E. Lincoln Avenue is shown prior to clean-up of floatable materials. As part of the clean-up, all storage tanks were anchored to prevent them from floating away and all pallets, shipping containers and drums were either removed or secured inside a building.*
Courtesy of City of Fort Collins Utilities

Figure 5. *Open Space preserved in McMurry Natural Area and Legacy Park. Floodwaters from the 2013 Poudre River Flood were able to spread out and slow down and not cause any damages.*
Courtesy of City of Fort Collins Utilities

several parks in the floodplain. Table 1 compares the floodplain acreage in the city limits to the amount of open space preserved by the City of Fort Collins. Preserving this land as open space not only minimizes flood damages, but also enhances the natural and beneficial functions of the floodplain, such as providing beneficial habitat and allowing floodwaters to spread out and slow down (Figure 5).

Acquisition of At-Risk Structures

In addition to the City preserving large tracts of open space, the Fort Collins Stormwater Utility collaborated with Natural Areas to purchase several properties on College Avenue and Vine Drive as part of the *Willing Seller–Willing Buyer* program. This program is specifically for existing residential structures in the floodplain or floodway and commercial structures in the floodway that are at high risk of being damaged. Two commercial structures on the west side of College Avenue were removed, and one residential structure just north of College Avenue and Vine Drive was removed. At the time of the flood, a second residential structure at 213 E. Vine Dr. had been purchased, but not yet demolished. That structure had 8-10 inches of water in the basement from the flood and is currently being removed (Figures 6 and 7).

Capital Projects

Two important capital projects were constructed over the past 10 years to help mitigate flood damages along the Poudre River, each for different purposes and utilizing different structural techniques.

Oxbow Levee

The Oxbow Levee was constructed in 2004 between Lincoln and Linden Streets to protect the Buckingham neighborhood and existing commercial structures on the north side of Lincoln Avenue. Levees are not the ideal mitigation strategy because they are subject to failure, but in this case, it was the only cost-effective solution capable of providing 100-year flood protection for this historic neighborhood. The levee was set back from the edge of the river to allow more room for the flood flows to overtop the left bank before coming into contact with the levee. The City performs routine inspections and maintenance and the levee performed as designed in the 2013 Flood and protected the Buckingham neighborhood.

Controlled Spills into Gravel Pits

Just downstream of the Timberline Bridge over the Poudre River is a controlled spill on the left bank into former gravel pits that now comprise Riverbend Ponds Natural Area. This controlled spill and a smaller spill downstream were jointly constructed in 2006 by the City of Fort Collins Stormwater, Natural Areas and Engineering Departments to allow for safe overtopping of the left bank of the river. The controlled spills were part of a larger project to create a second bridge on Prospect Road to handle flood flows that break out of the river and flow through Riverbend Ponds. Without the controlled spills, the entire Poudre River could have potentially been captured into the gravel pits, causing significant erosion of the banks, overtopping of Prospect Road and ultimately leaving no flow in the natural river channel. The main controlled spill just downstream of Timberline Bridge overtopped in the 2013 Flood and performed as designed with no damage to the constructed spill structure (Figure 8).

Public Education

Public education related to floods includes flood risk, flood safety, property protection, flood issuance and flood warning. It is important for citizens to be informed and know where to get additional information. A variety of media are used to reach as many people as possible.

One of the main public outreach efforts the City conducts annually is Flood Awareness Week. Historically, this happens in July, at the beginning of the monsoon season, when the Front Range is prone to large floods such as the Fort Collins flash flood in 1997. However, the past year clearly indicates that we need to be prepared for large floods at any time and that every flood is different. Flood Awareness Week is an opportunity to inform the

Figures 6 and 7. *213 E. Vine Dr. is a structure purchased as part of the City of Fort Collins' Willing Seller-Willing Buyer program. Before the house was demolished, the basement sustained 6-10 inches of water from the flood.* Courtesy of City of Fort Collins Utilities community about flood risk through various activities including display booths, videos on Cable 14, mailers to floodplain residents and owners, and to Realtors, lenders and insurance agents.

Other outreach efforts throughout the year include booths at community events, presentations to community groups, programs throughout the school district, reference materials at the public library and a comprehensive website.

Some public education efforts target specific audiences such as trail users and city drivers. The 1997 Spring Creek Flood is documented by a series of high water mark signs along the Spring Creek Trail. These markers provide a visual reminder to trail users about the magnitude of the 1997 Flood and that floods do happen in Fort Collins. Drivers are targeted by messages on bus benches warning them not to drive through flood waters, to "Turn Around – Don't Drown."

The effectiveness of the City's public education efforts during the 2013 flood has not been quantified, but no rescues were needed in the city limits and damage was minimal. These results are probably due in part to informed citizens who knew their flood risk, where to get information, how to protect their property and how to be "flood safe."

Flood Warning

Flood warning systems often are not considered to be a form of flood mitigation, but in Fort Collins, they are a vital component of a comprehensive floodplain management program.

The City Flood Warning System (FWS) comprises a network of rain, streamflow, and weather gauges that provide data to personnel who implement emergency action plans that are triggered by pre-determined thresholds of rainfall intensity and flow depths. A lack of real-time data was a significant factor during the 1997 Spring Creek Flood, when responders and citizens had

Figure 8. *Downstream of the Timberline Bridge on the Poudre River is a controlled spill into Riverbend Ponds Natural Areas. This photo was taken at 12:20 p.m. on Friday, September 13, 2013 during the flooding of the Poudre River and shows the spill functioning as designed.* Courtesy of City of Fort Collins Utilities

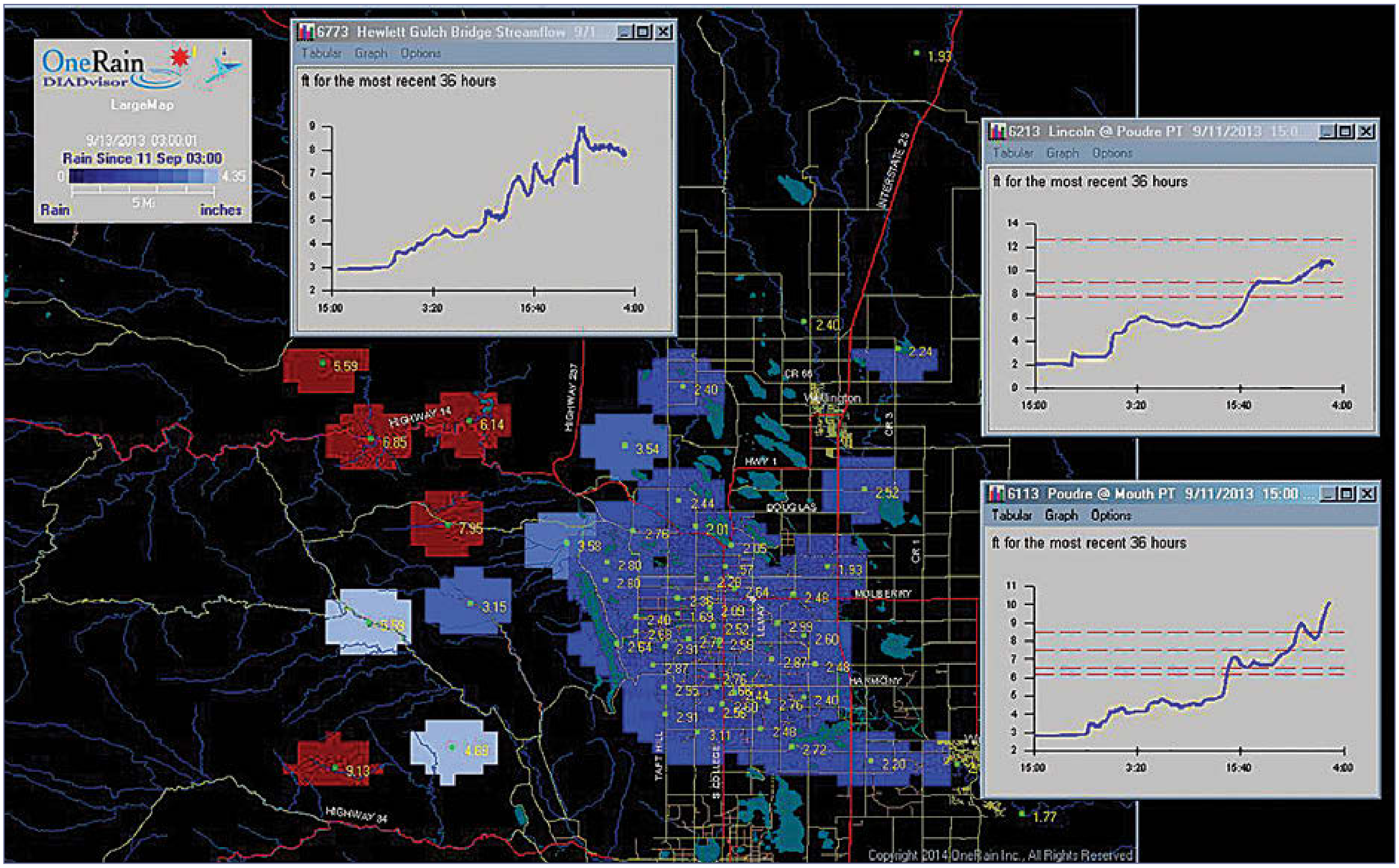


Figure 9. *Screen capture at 3 a.m., September 13, 2013 of FWS data-management software showing 2-day rain gauge totals (in inches) and hydrographs (in feet) from three river gauge locations. Pre-established alarm (emergency response) thresholds shown on hydrographs as red dotted lines.*

Courtesy of City of Fort Collins Utilities

limited information about the magnitude of the local storm and flooding conditions. Since initiation in 1999, the FWS has grown to 75 gauge locations, all monitored by staff on-duty 24/7 between mid-April and late September, our local flood *season*. During the 2013 flood on the Poudre River, the data from this network and other sources such as weather radar were critical to our City's response to the flood threat.

After the High Park Fire, the gauge network was expanded across the burn area and lower foothills west of town. Stormwater staff was alerted to the higher rainfall intensities in these upstream parts of the Poudre watershed. Streamflow gauge data from locations on the Poudre River at the Town of Poudre Park, the mouth of the canyon, and at Lincoln Avenue provided key information about river conditions (Figure 9) to the Emergency Operations Center. The response lead time allowed City crews to close trails and bridges, monitor roads for overtopping or inundation, identify areas requiring emergency notification of imminent flooding via the auto-dialer system (LETA911.org), and to assist in evacuations from three at-risk neighborhoods. The FWS data also were used to provide warnings and updates to the public via the City's website fcgov.com/floodwarningsystem, press releases, videos, and social media. The information was invaluable in protecting people and property during the 2013 flood.

Conclusion

Floods are a part of life in Fort Collins, and having a comprehensive floodplain management program is critical. No single *tool* in the floodplain management toolbox will work in every situation so we need many tools: floodplain regulations, open space preservation, acquisition of at-risk structures, capital projects, public education and flood warning. Each of these mitigation strategies provides benefits to our community as evidenced by the success stories documented during the 2013 flood along the Cache la Poudre River in Fort Collins.

To learn more about Floodplain Management in Fort Collins, visit fcgov.com/stormwater.

Precipitation Frequency

Defining the 100-year Storm

Nolan Doesken & Wendy Ryan, Colorado Climate Center,
Department of Atmospheric Science, Colorado State University

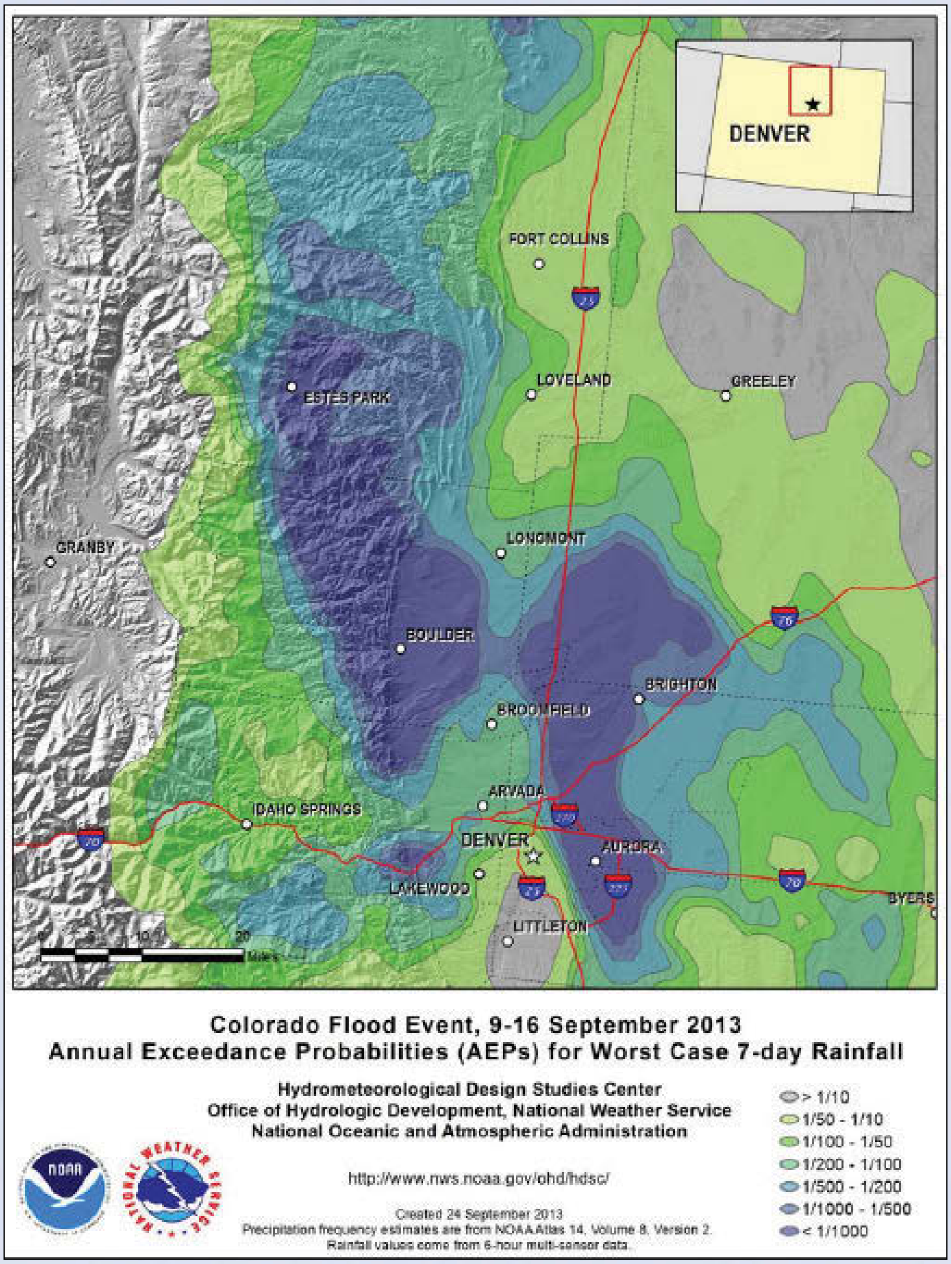


Figure 1. *A map showing annual exceedance probabilities (probability of exceeding a given amount at least once in any given year at a given location) for worst case seven-day rainfall for the September 2013 event.* Courtesy of the Hydrometeorological Design Studies Center

After the floods in Colorado last September (2013), the Colorado Climate Center was bombarded with questions—"Was that a 50-year storm, a 500-year storm, or was it even worse?" The answer was, it depends. Rainfall varied greatly over short distances. Based on preliminary data, the National Weather Service made use of the recently completed NOAA Atlas 14 – Precipitation-Frequency Atlas of the United States (described later in this article) to promptly produce several maps depicting annual exceedance probabilities (Figure 1).

Figure 1 shows the impressive behavior of the storm where areas near and northwest of Boulder may have experienced a rainfall event with less than a 1/1000 probability of occurrence.

Stormwater professionals rely on accurate, objective "design criteria" like this to determine how often a certain amount of rain may fall in a specified period of time and how much runoff that rain could produce. Design criteria are typically based on many years of accurate rainfall data. It is then a matter of policy to determine what level of protection we, the citizens and our communities, want and can afford. Designing drainage, detention, and stormwater conveyance systems to mitigate flood impacts from every single storm—even the largest and most intense—is very expensive and sometimes impossible. But if we only design and

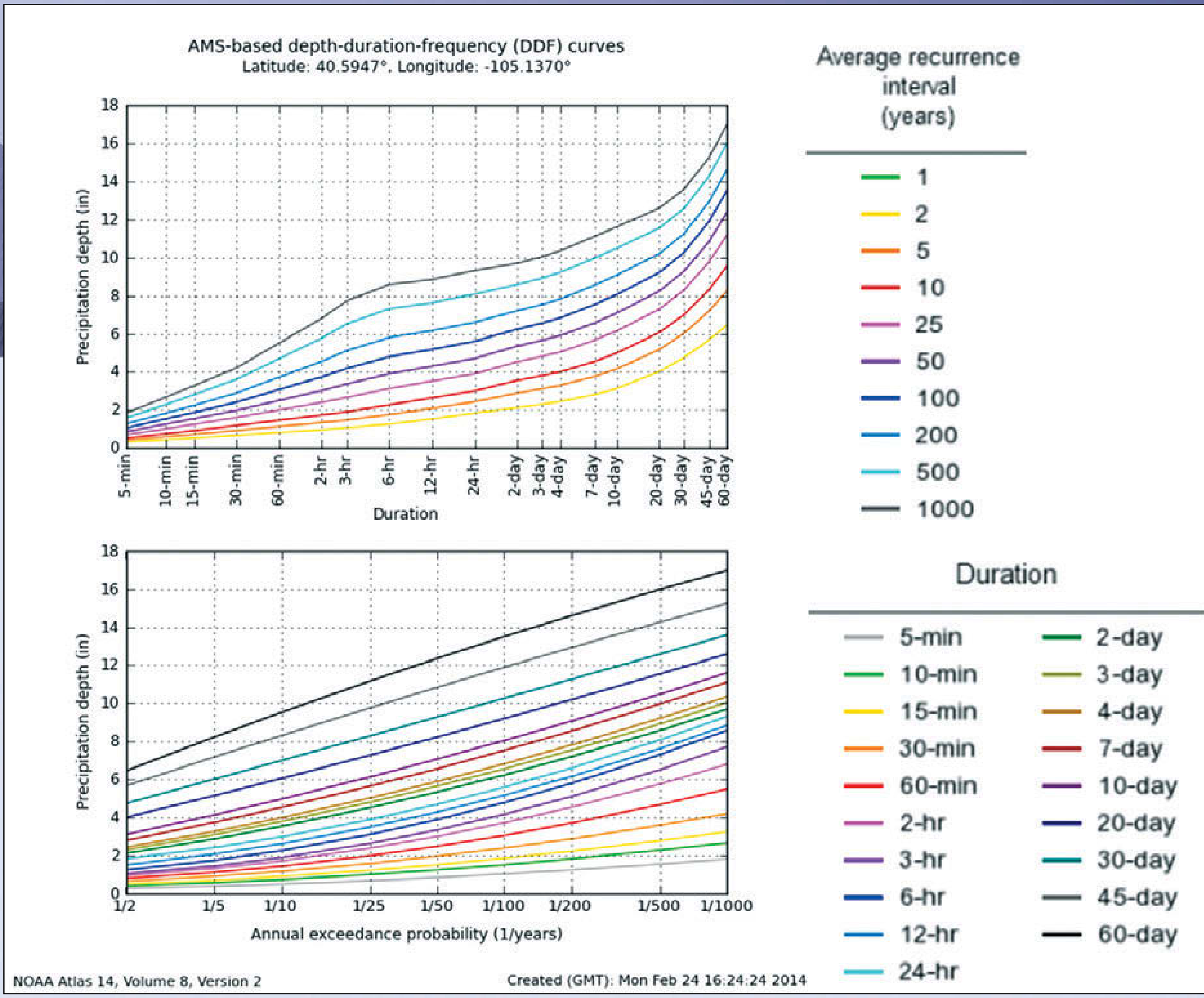


Figure 2. *Annual maximum series for Fort Collins showing exceedance probabilities and duration for varying precipitation amounts.*

plan to mitigate for typical afternoon summer thunderstorms and not the most extreme events, then we'll have to tolerate flood damage fairly often. That may be unacceptable. Most communities design stormwater systems that can handle storms that may only occur a few times per century. Dams and spillways are typically designed to withstand considerably more rainfall than has ever been observed.

How do we Determine "Design Criteria"?

When engineers, hydrologists, and statisticians first developed the concept of "rainfall return periods" starting in the 1930s and advancing in the 1950s and 60s, they may not have imagined how popular this information would become—or how confusing and misleading it could be for the public. The basis is quite simple, provided there are long-term and accurate precipitation data available. For example, Figure 2 shows the largest daily precipitation amount each year at the campus weather station here in Fort Collins. Occasionally there are daily amounts that exceed three or four inches, but most years the wettest day is in the one to two inch range. Occasionally there are years where the wettest day is only around 0.60 inches. If we rank these values from lowest to highest, we can produce an empirical probability distribution. Ranked data can also be fit to a smooth curve using one of a number of statistical distributions. A daily rainfall amount that has only a one percent chance of being exceeded in a given year is the 100-year 24-hour precipitation amount. In this graphical example, that's about 4.50 inches. A daily rainfall amount that has a 50 percent chance of being exceeded each year (the median for this distribution) is about 1.50 inches, and that's called the two-year 24-hour precipitation amount.

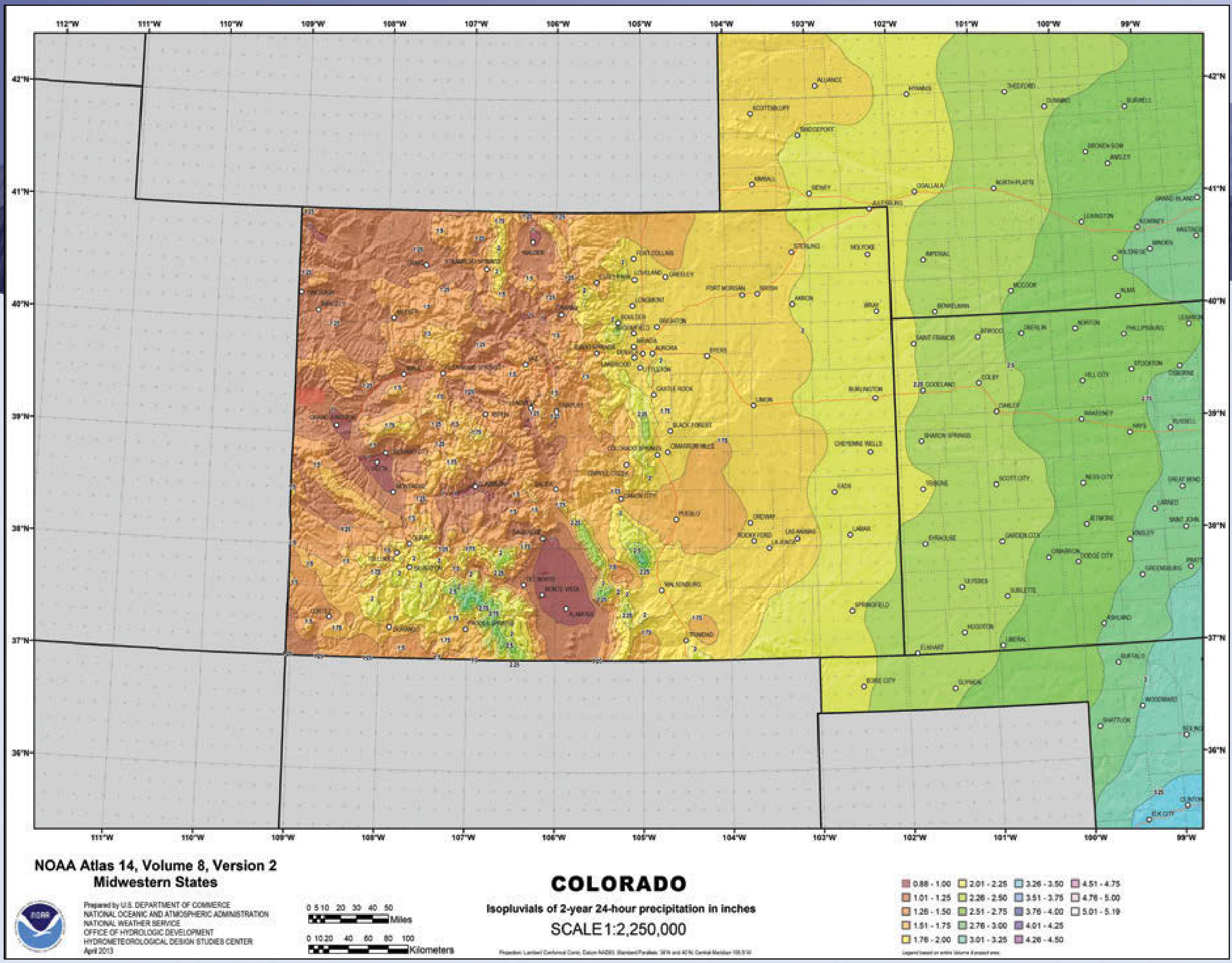


Figure 3. *An example of NOAA Atlas 14 data—the Colorado two-year 24-hour precipitation in inches.*

The same analysis can then be done with other weather stations in Colorado and across the country. Where short interval rainfall measurements are taken, similar analyses can be done for one-hour, three-hour, six-hour, and up to 24-hour periods or anything in between. Historically, many weather stations collected daily totals, but only a fraction of them have short interval data for determining the frequency of short duration, high intensity rains. Likewise, most weather stations do not have the luxury of 125 years of data like we have here in Fort Collins. As a result, statistical techniques have long been used to make use of shorter or incomplete rain gauge records to make reasonable estimates of precipitation frequencies.

Throughout the 1950s, the U.S. Weather Bureau (later renamed the National Weather Service) prepared and published a series of Weather Bureau Technical Papers on rainfall intensities for various durations. This culminated in the 1961 publication by David Hershfield, "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years" (Weather Bureau Technical Paper No. 40).

This document served nationally for several decades as the primary source for rainfall design criteria. Unfortunately, it did not address the complex terrain and climate variability of the Western states. In 1973, NOAA Atlas 2 was published: "Precipitation Frequency Atlas of the Western United States Volume III Colorado." That document addressed the challenges of elevation and complex terrain. The 1973 Atlas was composed of a number of bound, oversized hand-analyzed contour maps for six-hour and 24-hour durations and frequencies of two, five, 10, 25, 50, and 100 years along with various worksheets and nomograms to extract estimates for other durations and frequencies. Based on precipitation data through the late 1960s, it became the de facto standard for civil engineering design and planning for four full decades.

New Atlas

After flash floods hit Fort Collins and Sterling in 1997, questions arose in the engineering and stormwater communities regarding NOAA Atlas 2 and its continued suitability for use in Colorado. Almost 30 years of additional data were then available for updating precipitation frequency estimates. Still, another decade passed before the Colorado Water Conservation Board authorized funding to update NOAA Atlas 2. NOAA's National Weather Service Hydrometeorological Design Studies Center in the Office of Hydrologic Development, with support from 11 Midwestern and Great Plains states, completed this project and in 2013, the NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0 was released to the public: www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume8.pdf

The new atlas is Web-based, GIS compatible, and very user friendly. While not yet widely known, this atlas will soon be the standard for precipitation intensity for any frequency between one and 1,000 years and for any duration from five minutes up to 60 days (hdsc.nws.noaa.gov/hdsc/pfds/).

User Beware

While the new maps and Web interface are marvelous and make access to this new information very easy, users should know that the results are only as good as the data they are based on. While a huge step forward from the 1973 Atlas, available long-term data on precipitation extremes are still very limited, especially in high mountain and steep gradient areas of the state. We are also in an area where the heaviest precipitation may fall as rain or as snow, especially for durations of 12 hours or longer. This obviously affects the relationships between precipitation and runoff. Tabular results in NOAA Atlas 14 do show "confidence intervals" to help users understand the uncertainty we're still dealing with—and there is still plenty of uncertainty.

Why do People Get Confused?

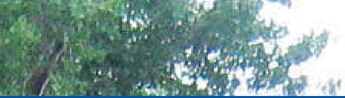
The main issue with the concept of a 100-year storm is that the results are developed for individual points, but people tend to apply them to broader areas. For example, the 100-year 24-hour rainfall for Denver may accurately be close to four inches at any given point. But four inches or more rain may fall at some location in the general Denver Metro area every two or three years on average. That may sound like a total confusing contradiction until you realize that most intense rain storms are small and don't effect the entire area at the same time. Over an area the size of Colorado, we should expect several and perhaps even dozens of 100-year storms to occur most years. Another issue is that fact that rainfall frequencies and flood frequencies often don't line up. For example, the rains in Boulder in September 2013 approached a 1/1,000 frequency while the floods in Boulder Creek in downtown Boulder were only about 1/50. Quite the opposite was true in Lyons. It is totally normal for flood frequencies and rainfall frequencies to differ for a given storm, since many other factors are involved.

The Big Deal about the September 2013 Storms

The areas affected by the heavy rains in September 2013 were much larger than the more typical thunderstorm downpours. Many areas received heavy rains at the same time, especially on September 11 and 12. As a result, runoff volumes in several tributaries to the South Platte River were huge, even though rainfall amounts in places like Fort Collins, Loveland, and Greeley were not exceptional.

Please Explore NOAA Atlas 14

It's free, it's easy, it's interesting. So go exploring. And while you're exploring, please remember it's only as good as the data that goes into it. Please help preserve Colorado's weather stations and long-term climate records.



Water Outreach to the Public as a Demand-Based Endeavor

Perry Cabot, Extension Water Resources Specialist, Colorado State University

Fountain Creek Nature Center in Fountain, Colorado.
Photo by Jessica Lamirand

Introduction

In 2011, Colorado State University (CSU) Extension was in the beginning of a re-structuring process, which was among the major topics at the regional meeting for Southern Colorado. Part of the agenda included the attendees viewing a "TED talk" by Simon Sinek, a trained ethnographer and author of two books: *Start With Why: How Great Leaders Inspire Everyone to Take Action* and his newest book, *Leaders Eat Last: Why Some Teams Pull Together and Others Don't*. The TED talks are freely viewable lectures at the website www.ted.com/, ascribing their name to their focus on technology, entertainment, and design. I later learned that Dr. Lou Swanson had recommended this particular talk, so—upfront, I would like to thank him for the suggestion. It offered a refreshing perspective to my ideas on water outreach, and continues to be a guidepost conducting good public events. Sinek's TED talk was a lecture-style delivery expounding on the subject of his first book, *Start With Why: How Great Leaders Inspire Everyone to Take Action*. Both the talk and the book studied the motivations of leaders who have great influences in the world. His guiding premise, it should be no surprise, is that whatever one does, the question "why?" has the most bearing on the repeated success of a company, movement, or endeavor.

Asking Ourselves Why we do Outreach on Water Topics

So, the question becomes, "Why do we engage in water outreach?" Using Sinek's vernacular, this question yields deeper guidance than, for example, "What should a water outreach program look like?" or "How should water outreach be done?" These questions are ultimately answered as outcroppings of knowing why the endeavor should be taken up in the first place.

Relating to water, Charles Fishman articulates a point in his 2011 book, *The Big Thirst: The Secret Life and Turbulent Future of Water*, providing context to the challenge of outreach activities among the general public. For numerous reasons, much of the public does not identify water resources, water management, or simply "water" as a topic that warrants a deep understanding or appreciation. He writes, "[w]e don't take water for granted, because we don't notice it enough to take it for granted," and goes on to compare water to gravity, known by many as something that is simply "there." Further reading details what Fishman argues is a powerful "invisibility," fostered by such success in the ability of our water providers to deliver clean and relatively cheap water. This success, he flatly states, "has allowed us to become water illiterate."

Granted, the "we" and the "us" to whom Fishman refers are obviously not the faithful readers of the *Colorado Water* newsletter. Rather, his target audience is a member of the so-called "water interested" public, or hopefully someone who is curious enough to be brought into that fold. Unfortunately, a broad swath of "water illiterate" public exists, who—again, for reasons justifiable among busy lives with many competing demands for attention—do not demand information about water topics, as much as they do, say, information on new technology, local issues, or employment prospects. This is to say that "water illiteracy" should not be viewed a derogatory term, but simply a context that should encourage us to examine the nature of public demand for education and outreach on water.

Coming back to Sinek's philosophy to "start with why," one of his primary examples is Apple, Inc. and Steve Jobs. Sinek identifies the consumer's belief in the company itself as a major reason for its success. Regardless of what they design, Apple seems to believe in challenging the status quo and thinking differently, and their success is evident. The point is that Apple has from its beginning stayed true to marketing itself as a kind of "technology rebel," because that is how the company is envisioned. Sinek's central thesis is that, given the success of Apple over the years, the demand for the company's products is evidently based in consumer identification, on some level, with the company's ideals.

Not all programs or products need to be outright rebellious, and certainly not water outreach programs. Nevertheless, the message of "starting with why" is that it doesn't matter so much *what* the endeavor is, or *how* it will be carried out—there is tremendous guidance and structure to be found in asking *why* it is important. In 2012, for example, a great number of entities in the water community cooperated to support the Water 2012 yearlong series of events to engage the public with water topics. It was a large campaign, not without difficulties, but underpinning the message was a clear rationale. In other words, why spend the time and energy reaching farther than we ever have to educate the public about water in Colorado? In my opinion, the answer is that water is anything but a "dry topic"—the personalities, conflicts, and goals are exciting and important. Another good example is the massive, open, online course (MOOC) on Water, Civilization, and Nature: Addressing Water Challenges of the 21st Century, currently offered through CSU. Underpinning these programs is a belief that Colorado citizenry is made stronger by more visible demonstrations of water's dominant role in society.

Earth Day cleanup event sponsored by the Fountain Creek Watershed, Flood Control and Greenway District. The event brought people together from El Paso and Pueblo Counties to focus on restoration and community building in a watershed that crosses county boundaries and plays an important role in the overall health of the Arkansas River Basin. Courtesy of Perry Cabot

Concluding Thoughts

The simply titled poem Water by Philip Larkin begins with the stanza, "*If I were called in to construct a religion, I should make use of water.*" These are wonderful words because they elevate water to the level of an inspiration. Water should be inspirational. Consider for a moment the fact that the average human can survive less than a week without water. An awe-inspiring reality, for example, is that life and civilization itself exists in a seven-day window held together by water. Even in the most remote areas, people are naturally drawn to water for its safety in the case of public health, opportunity in the case of commerce and agriculture, and enjoyment in the numerous way that we use our water resources to recreate. The simple idea of "starting with why" encourages us to look for the big themes that can promote a water literate public.

Water Tables 2014

Patricia J. Rettig, Head Archivist, Water Resources Archive, Colorado State University Libraries

The Colorado water community showed its support for the Water Resources Archive at Colorado State University by making Water Tables 2014 another successful fundraiser. Approximately $30,000 was raised to benefit the Water Resources Archive.

Held in Denver instead of Fort Collins for the first time, Water Tables 2014 included a reception with archival displays, a formal dinner, a keynote speaker, and discussion over dessert. The Archive partnered with the Colorado Water Congress to hold a joint reception on January 30 during the Thursday evening of their annual conference. The Water Tables keynote speaker, Dr. David Schorr from Tel Aviv University in Israel, also spoke Wednesday at the conference.

At Water Tables, Schorr spoke on the topic of "Colorado's Appropriation Doctrine: Forged as a Tool to Spread Water Rights Among the Citizens?" He delved into the origins of Colorado's prior appropriation law, which derived from mining law as a deliberate departure from riparian law. Schorr also discussed the "tricks" water developers attempted using to skirt the law and how litigation and legislation have deterred that.

Dr. Schorr's interest in Colorado water law arose upon learning about the famous *Coffin* v. *Left Hand Ditch Company* (1882) case during law school at Yale. To retrace the origins of Colorado water law beyond his textbooks, Schorr used documents from the Water Resources Archive and many other repositories in writing his dissertation, published in 2012 as a book entitled *The Colorado Doctrine: Water Rights, Corporations, and Distributive Justice on the American Frontier*. Schorr's book demonstrates the value of preserving, protecting, and promoting original documents associated with Colorado's water history. His Water Tables presentation further conveyed his research and insights, enabling the Colorado water community to reflect on the facts and reasons behind the state's water law.

Though nearly 180 guests were expected to attend the event, an evening snowstorm kept some from attending. Nonetheless, the event's sponsors enabled 20 students from Colorado State University, the University of Colorado-Boulder, and the University of Wyoming to attend. The Colorado Water Conservation Board generously stepped forward as the premier sponsor among the event's 19 total sponsors.

An additional opportunity for supporting the Archive arose from the dinner table centerpieces. Handcrafted by a local artist, lifelike sculptures of rainbow trout were available for purchase. As of February 2014, we have a few of these unique artworks still available, so contact us if you would like to purchase one.

As Colorado's only archive dedicated to water issues, the Water Resources Archive preserves materials critical for documenting the state's water history. The ever-growing contents of the Archive serve as a living repository for the history of public policy, engineering, law, ecology, economics, and the cultural aspects of water use. Funds raised from Water Tables support the Archive's efforts to preserve and make available more than 80 collections important to the water heritage of Colorado and the

Sales of handcrafted sculptures, functioning as table centerpieces, provided an additional opportunity to support the Archive. Courtesy of the CSU Water Resources Archive

Justice Hobbs provided an introduction to keynote speaker David Schorr. Courtesy of the CSU Water Resources Archive

David Schorr presented images of archival documents he used for his research on the origins of Colorado water law. Courtesy of the CSU Water Resources Archive

West, including outreach activities, digitization projects, and the work of several student assistants.

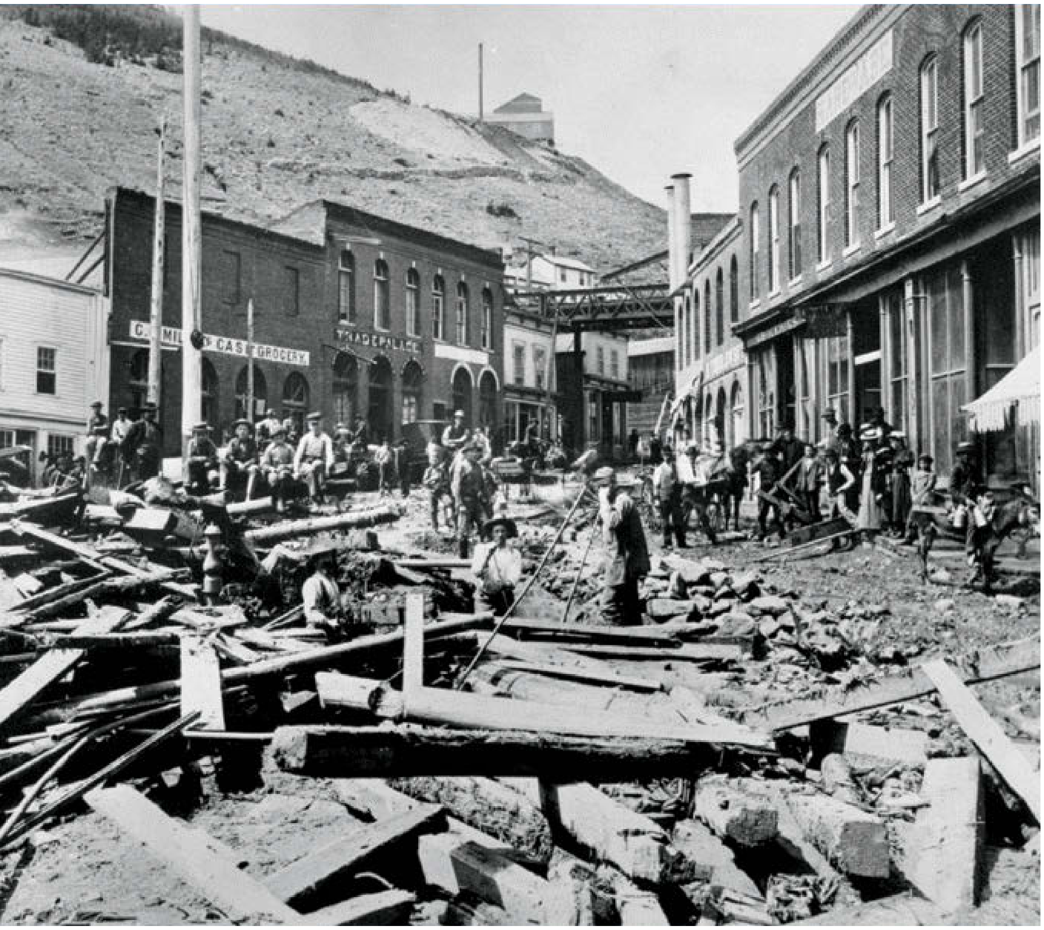
The Water Tables steering committee will conduct a survey and assess the results to determine whether to continue the event at the Colorado Water Congress convention in Denver, whether to return to Fort Collins in future years, or whether to do something completely different. Stay tuned for that information and plan to join us for Water Tables 2015!

To share an opinion about Water Tables, contact me (970-491-1939; Patricia.Rettig@ColoState.edu) at any time. For more information about the Water Resources Archive, see our website (lib.colostate.edu/water/).

The Colorado Water Conservation Board was the premier sponsor of Water Tables 2014, buying a table for ten of their staff and guests.

History of Colorado Flooding

Kenneth R. Wright, Chief Financial Officer and Principal Engineer, Wright Water Engineers



The Front Range flooding of September 2013 reminded us how devastating floods can be and also how far we have come. Records of great floods in Colorado are numerous; they have provided us with lots of warnings, as well as knowledge about floods and their characteristics. Historic images of some of Colorado's floods tell a profound story of the hardships wrought by floods (Figures 1-5).

Information about past floods is available in many forms. Paleoflood analyses, for example, are performed by U.S. Geological Survey (USGS) hydrologists who examine canyon walls and ledges (for ancient gravel deposits), stands of mature trees (for certain types of bark damage) and floodplains (for sediment deposits). The study of long-ago flooding can tell us much about how to better manage floodplains.

Research work at Mesa Verde National Park by the author involved exploration of pre-historic Anasazi reservoirs to study water use and water handling by ancient people. The research included the excavation of a 16-foot-deep trench at Morefield Canyon that revealed dozens of sediment layers laid down over 350 years from A.D. 750 to 1100 (Figures 6 and 7). The layers contained evidence of berm failures, pieces of pottery, and thin carbon layers indicating the occurrence of 14 different major forest fires.

The sediment layers in the trench alternated between clay and sand. The

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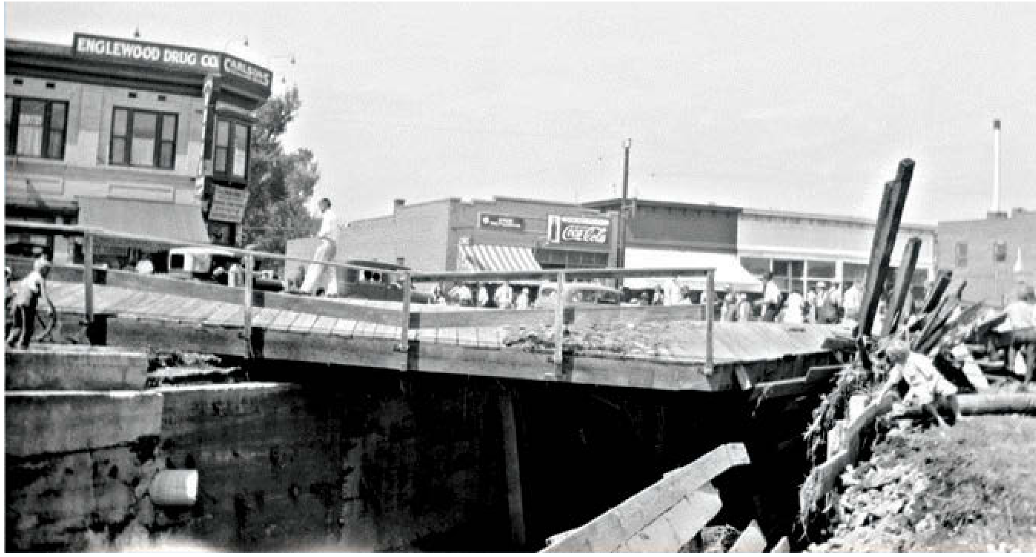
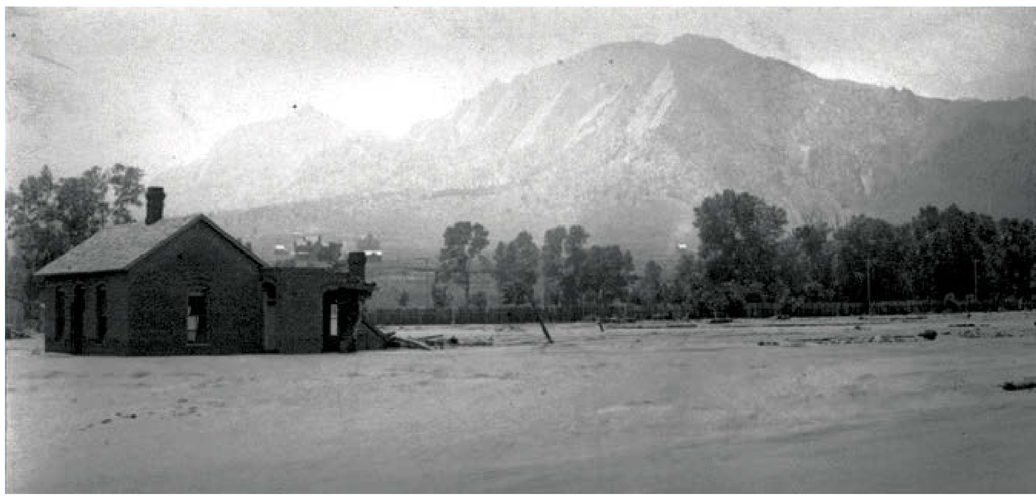
Photos on left (top to bottom):
Figure 1. *View west on Gregory Street in Black Hawk, Colorado, after the flood of 1895; shows flood debris such as planks, posts, rocks, dirt and silt.*
Figure 2. *View of flooded Cherry Creek and inundated buildings in Denver, Colorado, in 1864.* Courtesy of Denver Public Library, Western History Collection

350-year sediment record in Morefield Reservoir showed 21 periods of canyon flooding, coupled with distinct evidence of dredging operations to maintain reservoir storage capacity. In effect, the sediment depositions provided a continuous record of water use and water handling by the Anasazi, including the floods they experienced.

Written documentation of floods in Colorado began in the early 1800s. In 1826, an employee of the Hudson Bay Company reported an Arkansas River flood at the old site of Fort Lyons. At the same time, the Republican River was also flooding, according to USGS. Later, in about 1857, the Arkansas River below the mouth of the Purgatoire River was in flood stage, according to reports by Santa Fe Trail travelers.

One of the earliest Front Range floods written about in detail was the May 1864 Cherry Creek flood in Denver. Cherry Creek was a mostly dry creek bed at the time, which lulled many Denverites into a false sense of security. When the creek became a raging torrent after days of heavy rain, the flows swept away homes, churches, and other infrastructure that had been constructed along the creek bed. The 1864 Cherry Creek flood caused about $1 million in damage (equivalent to about $15 million in 2013 dollars) and took between 15 and 30 lives. The lesson of this disaster was long remembered, so that a similar flood in Cherry Creek in 1878 washed away bridges, but not buildings. The citizens





Photos on right (top to bottom):
Figure 3. *The flood waters of Little Dry Creek in Englewood, Colorado, probably the floods of 1927 or 1933, have severely damaged a bridge over the stream.*
Figure 4. *Flood water fills the scene in Boulder, Colorado. The flat-roofed extension of a brick house is partly caved in, and trees and fence edge the floodplain in 1894.*
Figure 5. View of mangled steel from the Curtis Street bridge, after Castlewood Dam collapsed (1933) during a severe rainstorm that innundated Cherry Creek, Denver.
Courtesy of Denver Public Library, Western History Collection

had learned not to construct buildings in the creek bed.

Another flood-prone area along the Colorado Front Range is land along the South Platte River, which sustained severe flooding in May 1942, June 1965, May 1969, and May 1973. Eight people lost their lives due to flooding of the South Platte in Denver, with a total estimated value of property loss over $2.6 billion for the four incidents.

The 1965 South Platte River flood alone destroyed 25 bridges and caused over $2.2 billion in damage stretching from Littleton to Julesburg (Figure 8). This was followed by the then-wettest year in Denver history in 1967. The record of 1967 was surpassed by 1969, which became the new record-breaking year for precipitation in Denver. Flooded underpasses and water-damaged neighborhoods near the city center were all-too-common during these years.

The Urban Storm Drainage Criteria Manual

Like many metropolitan areas in the 1960s, the Denver area experienced unplanned and disorganized growth. Suburbs developed around the core city and then incorporated, creating a hodge-podge of agencies, policies, and administrations for the Metro area, often competing for resources, and focused on water and sewer infrastructure rather than drainage. It is easy to disregard where your city's runoff is going, particularly if it seems like the entity upstream is sending more water your way than it should.

Ironically, Denver's arid climate also contributed to drainage problems. A dry gulch or channel is easier for developers to fill in than a channel with perennial flow, but both are essential for drainage when it rains. Other factors contributing to runoff problems were the increase in unmanaged and impervious areas due to development, downstream drainage bottlenecks, poor maintenance, and stormwater conveyance systems such as concrete channels and buried storm drains.

Figure 6. *Trench excavated in Morefield Canyon at Mesa Verde National Park, Colorado.* Courtesy of Wright Paleohydrological Institute

Citizens asked for solutions. In the late 1960s, city, county, state, and federal engineers, lawyers, and politicians joined together to address the flood control and urban drainage infrastructure and policy dilemma facing the Denver Metro area. The solution centered on a unified strategy and criteria that could readily by adopted by the 32 local governments within the five-county area.

The Urban Storm Drainage Criteria Manual was prepared in 1969 to reform the archaic drainage policies and practices of the Metro area. Then the State of Colorado created a five-county Denver Urban Drainage and Flood Control District that would have authority to oversee regional drainage and flood control policy and practices. While a criteria manual and a drainage district on their own would not solve the drainage problems facing the rapidly developing metropolitan area, these two tools provided the needed impetus for the many local governments to join together in a major common effort to resolve issues that were too insurmountable for any one agency to solve alone.

The last 45 years have seen the Denver Metro area grow, prosper, and become a national and international drainage and flood control leader. The policies, practices, and design criteria of the Urban Storm Drainage Criteria Manual have been adopted

Figure 7. *Layers in Morefield Canyon trench provide evidence of flooding history.* Courtesy of Wright Paleohydrological Institute

widely throughout the United States and foreign countries ranging from Australia to Venezuela.

Denver Urban Drainage Four Decades Later

The Front Range flooding of September 2013 was the result of days of record-breaking rainfall that demonstrated the value of urban drainage planning. While the event was severe in many locations, those areas that used Manual design criteria fared better than those that did not. Record-breaking precipitation will happen again, but the successes and failures of the September 2013 flood can help us prepare for it.

The Urban Storm Drainage Criteria Manual, still in use, has been revised several times over the years and is accessible at www.udfcd.org/downloads/down_critmanual.htm. The Manual provides the governing design criteria for 40 cities and counties in the Denver metropolitan area, covering a full range of conditions from rural to highly urban. It has been distributed to cities and counties throughout the U.S., as well as many other countries.

Figure 8. *"South Platte Torrent Deals Denver Worst Disaster" Denver Post June 1965; view of the flood along the South Platte River, Denver, Colorado; general view from a helicopter shows the railroad yards south of the 14th Street Viaduct.* Courtesy of Denver Public Library, Western History Collection

References available upon request.

Poudre Runs Through It Launches the First Annual Poudre River Forum

MaryLou Smith, Policy and Collaboration Specialist, Colorado Water Institute
Zoe Whyman, Community Relations Manager, City of Fort Collins Natural Areas Department

What motivates 275 people to spend a Saturday talking about water? The Poudre River Forum; which posed the challenge: "Let's make the Cache la Poudre River the world's best example of a hard working river that's also healthy. Agricultural and urban water rights owners joined in with environmentalists and recreation promoters to learn about and celebrate their common ground. The event was held February 8 in Larimer County.

Mayors from Greeley, Windsor, Timnath, and Fort Collins—the four communities through which the Poudre River flows—greeted water enthusiasts from one end of the river to the other, reading from historical passages tying their particular community to the river.

The fast moving day also featured "spring run-offs"—ten-minute brief but critical insights into the Poudre River. The "working river" run-offs covered uses of the river for agriculture, cities and towns, industry, and tourism/recreation, as well as an overview of where water in the Poudre comes from, how it's diverted for various uses, and who administers it, by water commissioner Mark Simpson. "Healthy river" run-offs shared insights about fish, riparian habitat, flows, water quality, and how it all ties together. Floods and Fires: Extraordinary Challenges for the Poudre and an inspiring keynote speech by Supreme Court Justice Greg Hobbs rounded out the presentations, the latter being the highlight of the day for many. Hobbs' colorful stories about the history of humans in the region intrigued the audience. He told the story of how prior appropriation got its start with conflict on the Poudre and pointed out that we are in an era of cooperation—that we have to be, because the resource we all depend on is severely limited.

A lively audience dialogue showed interest in a variety of topics, including the potential for creative

City of Greeley showed off a giant water faucet at their display promoting urban water conservation.
Photo by Stephen Smith

Healthy River presenters Sara Rathburn, Dave Merritt, Boyd Wright, Joe Konovik, and Jen Shanahan relax before their ten minute "Spring Runoff" presentations. *Photo by Stephen Smith* "nutrient trading" between agricultural non-point sources of nitrogen and phosphorous and cities, like Greeley, who must reduce point source nutrient loads through expensive waste water treatment upgrades.

Why stage a Poudre River Forum? The Poudre Runs Through It Study/Action Work Group has spent 18 months learning about the Poudre from a variety of viewpoints and then deciding on a trio of collaborative actions—actions that appeal to farmers just as much as environmentalists: Forum, Flows, and Funding. The Flows Initiative seeks to increase water flows in the Poudre in order to improve the health of the river while maintaining private property rights. The third initiative is generating funding for the improvements.

John Stulp, Governor Hickenlooper's special advisor on Water, tells the crowd about the Colorado Water Plan. Photo by Stephen Smith

Paul Ackerman, Barb Perusek, and Dale Trowbridge gave away ice cream bars at the New Cache la Poudre Irrigating Company display. *Photo by Stephen Smith*

The Work Group has 30 members and a steering committee that includes a water lawyer, a city natural resources manager, a ditch company manager and agriculture producer, a conservation group administrator, and a retired ecologist—very much representative of the diverse group.

The Colorado Water Institute at Colorado State University is the facilitator of the Poudre Runs Through It Study/Action Work Group. Director Reagan Waskom says that the group was formed as a means to bring together those who in the past have often talked past one another. This forum exemplified the same spirit of learning from one another and contemplating actions that the group itself has fostered. One participant said the best part of the forum was "the coming together of issues and cross community collaboration." Though the first Poudre River Forum laid a foundation of understanding many aspects about the Poudre, future forums will likely dig into issues more deeply. Whatever topics and issues are addressed, the Poudre Runs Through It Study/Action Work Group are devoted to making sure that those who are concerned about the ecology of the river and those who are intent on protecting water rights for agricultural and urban diversions have a forum for finding common ground. As Justice Hobbs said, "We must manage our waters through smart cross-connections of all our values." For more information about the Poudre Runs Through It Study/Action Work Group, visit www.cwi.colostate.edu/thepoudrerunsthroughit.

Recent Publications

Use of multi-node wells in the Groundwater-Management Process of MODFLOW-2005 (GWM-2005); Ahlfeld, David P.; Barlow, Paul M.

Chemistry and age of groundwater in bedrock aquifers of the Piceance and Yellow Creek watersheds, Rio Blanco County, Colorado, 2010-12; McMahon, P.B.; Thomas, J.C.; Hunt, A.G.

Chemistry and age of groundwater in the Piceance structural basin, Rio Blanco county, Colorado, 2010-12; McMahon, Peter B.; Thomas, Judith C.; Hunt, Andrew G.

Ranking contributing areas of salt and selenium in the Lower Gunnison River Basin, Colorado, using multiple linear regression models; Linard, Joshua I.

Potential depletion of surface water in the Colorado River and agricultural drains by groundwater pumping in the Parker-Palo Verde-Cibola area, Arizona and California; Leake, Stanley A.; Owen-Joyce, Sandra J.; Heilman, Julian A.

Geodatabase compilation of hydrogeologic, remote sensing, and water-budget-component data for the High Plains aquifer, 2011; Houston, Natalie A.; Gonzales-Bradford, Sophia L.; Flynn, Amanda T.; Qi, Sharon L.; Peterson, Steven M.; Stanton, Jennifer S.; Ryter, Derek W.; Sohl, Terry L.; Senay, Gabriel B.

Groundwater contributions of flow, nitrate, and dissolved organic carbon to the lower San Joaquin River, California, 2006-08, USGS Scientific Investigations Report: 2013-5151; Zamora, Celia; Dahlgren, Randy A.; Kratzer, Charles R.; Downing, Bryan D.; Russell, Ann D.; Dileanis, Peter D.; Bergamaschi, Brian A.; Phillips, Steven P.

Postwildfire debris-flow hazard assessment of the area burned by the 2013 West Fork Fire Complex, southwestern Colorado USGS Open-File Report: 2013-1259; Verdin, Kristine L.; Dupree, Jean A.; Stevens, Michael R.

Evaluation of Pleistocene groundwater flow through fractured tuffs using a U-series disequilibrium approach, Pahute Mesa, Nevada, USA, Chemical Geology, 358: 101 – 118; Paces, James B.; Nichols, Paul J.; Neymark, Leonid A.; Rajaram, Harihar

Comparison of a karst groundwater model with and without discrete conduit flow, Hydrogeology Journal, 21: 1555 – 1566; Saller, Stephen P.; Ronayne, Michael J.; Long, Andrew J.

Developing and implementing the use of predictive models for estimating water quality at Great Lakes beaches, USGS Scientific Investigations Report: 2013-5166; Francy, Donna S.; Brady, Amie M. G.; Carvin, Rebecca B.; Corsi, Steven R.; Fuller, Lori M.; Harrison, John H.; Hayhurst, Brett A.; Lant, Jeremiah; Nevers, Meredith B.; Terrio, Paul J.; Zimmerman, Tammy M.

Quantifying groundwater's role in delaying improvements to Chesapeake Bay water quality, Environmental Science & Technology, 47: 13330 – 13338; Sanford, Ward E.; Pope, Jason P.

The effects of artificial recharge on groundwater levels and water quality in the west hydrogeologic unit of the Warren subbasin, San Bernardino County, California, USGS Scientific Investigations Report: 2013-5088; Stamos, Christina L.; Martin, Peter; Everett, Rhett R.; Izbicki, John A.

Coastal processes influencing water quality at Great Lakes beaches, USGS Fact Sheet: 2013-3070;U.S. Geological Survey

Research on pathogens at Great Lakes beaches: sampling, influential factors, and potential sources, USGS Fact Sheet: 2013-3071; U.S. Geological Survey

Real-time assessments of water quality: expanding nowcasting throughout the Great Lakes, USGS Fact Sheet: 2013-3069; U.S. Geological Survey

Michael N. Gooseff

Lindsey Middleton, Editor, Colorado Water Institute

Faculty Profile

Michael Gooseff joined Colorado State University (CSU) faculty in July of 2013 as an Associate Professor of Civil and Environmental Engineering. Before the move, Gooseff was an Associate Professor at Pennsylvania State University's Civil and Environmental Engineering Department.

Gooseff had previously worked for three years at the Colorado School of Mines Geology and Geological Engineering Department and for two years at the Aquatic, Watershed, and Earth Resources Department at Utah State University. He has a Ph.D. in Civil Engineering from the University of Colorado-Boulder.

Gooseff's research interests include how ecosystems are impacted by hydrologic processes, particularly as related to stream-groundwater interactions. Within that field, his lab, called the Hydroecology Research and Engineering Lab, employs modeling and quantitative analysis techniques. The lab is currently working on projects in Alaska, Antarctica, and the Continental U.S. "We use the lab to do prep work before going out to research sites—we have a lot of field gear," says Gooseff.

Gooseff says most of his research since staring at CSU has been out-of-doors—in Alaska, he is working on a project monitoring meteorological and ground temperature data related to permafrost thawing, which can impact soils and related ecosystems. In the McMurdo Dry Valleys of Antarctica, he is part of the McMurdo Long Term Ecological Research project to determine how the area's ecosystems function and how they respond to changes. Recent flood years and high melt rates affect closed basin lakes, which have inflow from melting but no outflow.

Gooseff says that while at CSU, he hopes to contribute in a meaningful way to water programs, with the goal of addressing research, education, and outreach. He is currently mentoring five students, two of whom transferred to CSU from Penn State to continue working on graduate research projects with Gooseff.

In the fall of 2013, Gooseff taught Introduction to Civil Engineering and Water Quality Modeling, and in upcoming semesters, he will likely teach groundwater and ecological engineering classes.

"I hope to invigorate students with a passion for understanding how we can engineer natural systems," Gooseff says of his goals at the university. He also hopes to lead a research program that remains focused on natural systems, geared toward understanding how certain environmental processes responed to changes.

Compared to Pennsylvania, Gooseff says that there are greater opportunities for breadth of water research in Colorado and the West. In eastern U.S. states, he says, research focuses more often on water quality, whereas in Colorado, quantity is also an important topic. Though a challenge to society, he says, water scarcity provides a great opportunity for research with the potential to positively impact society.

Gooseff notes nonstationarity among future challenges in his field. Models come into play in planning for unexpected future events, and the challenge lies in accurately predicting event outcomes without extrapolating to an extent that would lead to inaccuracies. Such planning will have to include how natural processes are changing and provide strategies to maintain clean and adequate water resources for municipal and agricultural use.

Gooseff was recently funded by the CSU Water Center to work with Thomas Borch and Jens Blotevogel on an investigation of the effects of fracking spills. The study, he says, will look into the fate and transport of chemicals spilled before or after use for fracking, with the goal to stimulate research, discussion, and education of issues related to water and energy production. The project was funded under the title, "Exploring the Water-Energy Nexus at CSU: Hydrologic Fate and Transport of Chemicals Used in Oil & Gas Development," with expected deliverables in early summer of 2014.

Michael N. Gooseff, PhD
Associate Professor

Colorado State University

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Water Research Awards

Colorado State University

(November 16, 2013 to March 15, 2013)

Photo by Bryce Bradford

Alexander, Ruth M, History, Colorado Water Conservation Board, Colorado Flood 2013 Oral History Project, $25,000

Arabi, Mazdak, Civil & Environmental Engineering, Environmental Protection Agency, Nutrient Reductions in Agricultural Watersheds: Intentional Planning, Implementation & Maintenance, $214,626

Arabi, Mazdak, Civil & Environmental Engineering, Environmental Protection Agency, Urban Stormwater Management: Evaluation of Simple Retrofits/Design Enhancements & Development of Simple Assessment Tools, $288,846

Arabi, Mazdak, Civil & Environmental Engineering, EPA-Environmental Protection Agency, Assessing Nutrient Management Tradeoff & Targets Under Uncertainty, $383,858

Barbarick, Kenneth A, Soil & Crop Sciences, Metro Wastewater Reclamation District, Testing the Implications of Phosphorus Processing on Land Application of Biosolids, $209,117

Bauder, Troy A, Soil & Crop Sciences, Colorado Department of Agriculture, CSA (5359190-5389820) Training and Education for Agricultural Chemicals and Groundwater Protection, $8,346

Berg, Wesley K, Atmospheric Science, NASA - National Aeronautics & Space Administration, Intercalibration and Rainfall Intensity Characterization for a Diverse GPM Radiometer Constellation, $116,742

Bledsoe, Brian, Civil & Environmental Engineering, Southern California Coastal Water Research, Technical Support for Development of Numeric Flow Criteria to Support Freshwater Bio-objectives, Hydromodification Management, and Nutrient Numeric Endpoints – SCCWRP, $460,732

Bledsoe, Brian, Civil & Environmental Engineering, University of Arizona, An Ecohydrological Approach to Managing Intermittent and Ephemeral Streams on Department of Defense Lands, $55,079

Bledsoe, Brian, Civil & Environmental Engineering, Environmental Protection Agency, Fluvial Instability & Riparian Degradation: Evaluating & Reducing Nutrient Loading from Channel-Riparian Interface, $235,725

Byrne, Patrick F, Soil & Crop Sciences, USDA-National Institute of Food and Agriculture, Plant Breeding for Improved Water Productivity, $200,000

Doesken, Nolan J, CIRA, DOC-NOAA-Natl Oceanic & Atmospheric Admn, Effective Collaborative NIDIS Drought Monitoring and Early Warning in the Upper Colorado Basin, $188,765

Doesken, Nolan J, CIRA, DOC-National Oceanic & Atmospheric Administration, Variability in Snow Sublimation Across Basin Scale Systems, $37,547

Gates, Timothy K, Civil & Environmental Engineering, Colorado Department Public Health & Environment, Enhancement for Identifying Arkansas River Selenium and Nitrogen Best Management, $256,620

Hall, Edward H, Natural Resource Ecology Laboratory, AMUPROLAGO-Asociación de Municipios del Lago de Yojoa, Carrying Capacity of Lake Yojoa, $58,125

Johnson, Jerry J, Soil & Crop Sciences, Syngenta, Influence of Agrisure Artesian water-optimization alleles on hybrid performance and response to plant density, $35,865

Laituri, Melinda J, Ecosystem Science & Sustainability, DOI-National Park Service, Water Rights Activity Assessment, $14,882

Lemly, Joanna, Colorado Natural Heritage Program, Colorado Division of Parks and Wildlife, Arkansas River Basin Wetland Profile and Reference Network, $124,894

Omur-Ozbek, Pinar, Civil & Environmental Engineering, City of Loveland, Colorado, BIOWIN Modeling/Simulation for Biological Nutrient Removal Expansion Improvements to the Loveland WWTP, $30,000

Rathburn, Sara L, Geosciences, National Science Foundation, Collaborative Research: RAPID Assessment of 2013 Flood Sedimentation, Button Rock Reservoir, North St. Vrain Watershed, CO, $11,475

Rathburn, Sara L, Geosciences, USDA-USFS-Rocky Mountain Research Station - CO, Mechanisms & Controls on Post-Fire Sediment Delivery: The High Park Burn in South Fork Cache la Poudre Basin, $5,000

Sale, Thomas C, Civil & Environmental Engineering, Chevron Corporation, Technology Development Initiative 2014: Sheens, Natural Losses of LNAPL, & Enhanced Natural Attenuation, $300,000

Calendar

Sanders, Thomas G, Civil & Environmental Engineering, DOI-National Park Service, Preservation, Protection, & Management of Water Aquatic Resources of Units of the National Park System, $52,864

Sharvelle, Sybil E, Civil & Environmental Engineering, Environmental Protection Agency, Achieving Nutrient Reductions Through Innovative Approaches for Wastewater Management & Water Demand Reduction, $327,477

Thornton, Christopher I, Civil & Environmental Engineering, Colorado Department of Transportation, Developing Bridge Scour Equations for Colorado Mountain Streams, $79,999

Wardle, Erik M, Soil & Crop Sciences, Western Sugar Cooperative, Demonstration and Validation of an Online Irrigation Scheduling Tool for Use in Sugar Beet Production in Northern Colorado, $14,750

Waskom, Reagan M, Colorado Water Institute, DOI-USGS-Geological Survey, ICIWaRM Research Workshops and Advisory Committee, $76,247

Waskom, Reagan M, Colorado Water Institute, DOI-USGS-Geological Survey, Modeling of Watershed Systems NIWR-USGS Student Internship Program, $78,509

Wohl, Ellen E, Geosciences, National Geographic Society, Floodplain-Instream Wood Interactions in the Central Yukon River Basin, $15,810

Recurring

2/11-5/22

Fracking Sense 2.0; Boulder, CO
Beginning on February 11, on most Tuesday nights through May, a speaker with expertise on natural gas development will provide a measured, honest exploration of this controversial topic.
centerwest.org/events/frackingsense-2-0

May

4-7 **2014 NGWA Groundwater Summit; Denver, CO**
Model, explore, characterize, bank, inject, extract, treat, and predict all your subsurface needs with everything groundwater.
ngwa.confex.com/ngwa/2014gws/cfp.cgi

8 **NGWA Conference on Characterization of Deep Groundwater; Denver, CO**
Gain insight on what is currently known, share ideas, and discuss what can possibly be done going forward to better understand and characterize deep groundwater.
www.ngwa.org/Events-Education/conferences/Pages/5042may14.aspx

June

5-6 **Clyde Martz Summer Water Conference; Boulder, CO**
Reviewing the ongoing efforts of governments and industry to develop the regulatory and management practices necessary to protect water and air resources.
www.colorado.edu/law/research/getches-wilkinson-center/gwc-events/clyde-martz-summer-water-conference

18-20 **39th Annual Colorado Water Workshop: The People's Water; Gunnison, CO**
Presentations and conversation on water issues in Colorado and the West, including the Colorado State Water Plan, regulating the Colorado River and responses to drought in the southwestern states.
www.western.edu/academics/undergraduate-programs/environment-and-sustainability/conferences/

August

20-22 **Colorado Water Congress Summer Conference; Snowmass, CO**
The high-energy summer conference is packed with great topical content. It's a don't-miss event for those who wish to stay informed about water issues in Colorado while engaging in numerous professional development activities.
www.cowatercongress.org/cwc_events/index.aspx

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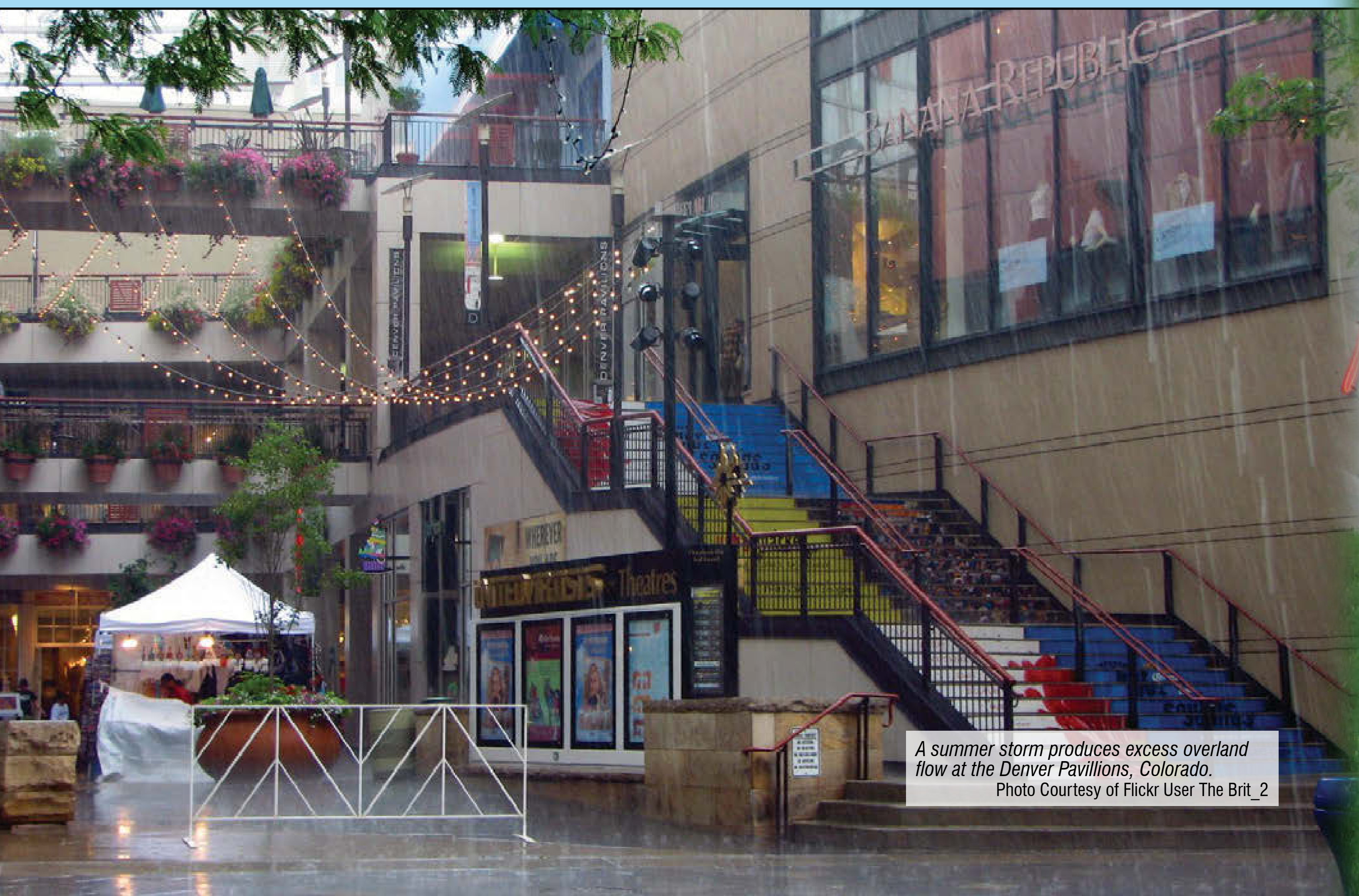

A summer storm produces excess overland flow at the Denver Pavillions, Colorado.
Photo Courtesy of Flickr User The Brit_2