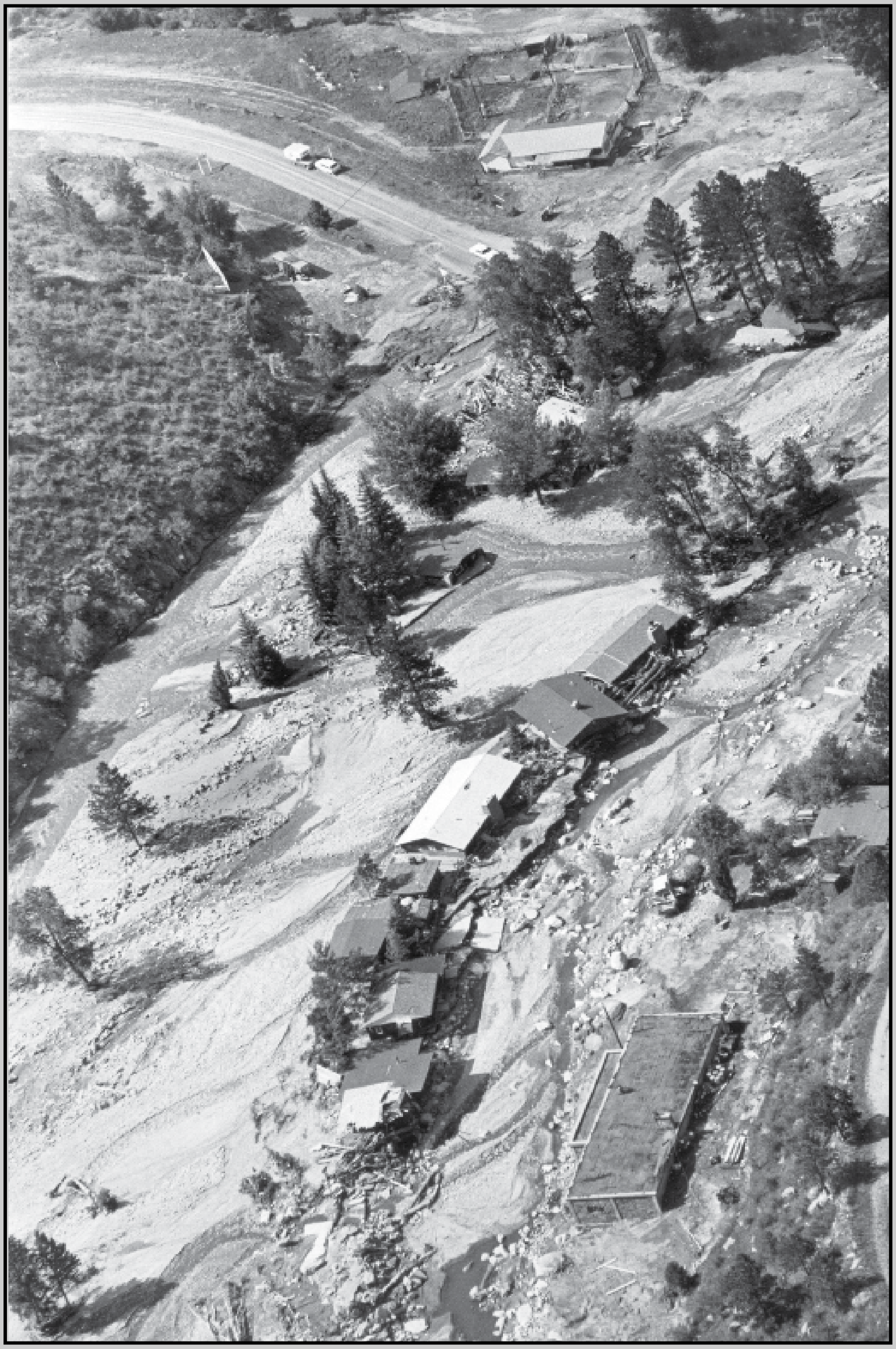
Rocky Mountain

National Park Service
U.S. Department of Interior
Rocky Mountain National Park

Front Range Floods Teacher Guide



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Rocky Mountain National Park

Rocky Mountain National Park (RMNP) is defined by the rugged Rocky Mountains that cut through the heart of the park from north to south. These mountains have shaped the landscape and created the conditions for the ecosystems we find within the park. Three of the park's ecosystems, the montane, subalpine, and alpine tundra, are delineated by elevation, with the montane ecosystem comprising the lowest elevation in the park, from 5,600 to 9,500 ft., the subalpine from 9,500 to ll,000 ft., and the alpine tundra ecosystem comprising the highest elevation in the park, from11,000 to 14,259 ft. This fragile alpine tundra, which comprises 1/3 of the park, is one of the main scenic and scientific features for which the park was established and is one of the largest and best preserved examples of this ecosystem in the lower 48 states.

Environmental Education was formalized at RMNP with the creation of the Heart of the Rockies program in 1992. Our curriculum is built on the principles of RMNP's founding father, Enos Mills. Mills felt children should be given the opportunity to explore and learn in the outdoors, for nature is the world's greatest teacher. This belief is kept alive today through every education program.

RMNP was established on January 26, 1915, through the efforts of local residents, especially Enos Mills, Abner Spague, and F.O. Stanley. Today the park covers 415 square miles of spectacular terrain, most of which is designated Wilderness.

Lessons Written and Compiled By
Rocky Mountain National Park Environmental Education Staff

Teacher Guide Created by Jennifer Heindel June 2014

Teacher Guides

Teacher guides have been developed by the education staff at RMNP and each focuses on a topic of significance to the Park. These guides serve as an introductory resource to the topic and the information provided is used by park educators to develop curriculum based education programs. Guides benefit teachers by providing the background information necessary to build a strong foundation for teaching students about specific park related topics; they may also be used as a resource for preparing students for field trips to RMNP. Each guide contains a resources and references section to provide for more in-depth study.

Rocky Mountain National Park Education Program Goals

1. Increase accessibility to Rocky Mountain National Park for students from our gateway communities and under-served students who otherwise would not have the opportunity to visit the park.

2. Develop a variety of internal and external partnerships with other park operations, school districts, universities, professional educational organizations, agencies, friends groups, and various funding organizations.

3. Conduct workshops to train teachers to take a larger role in their students' experiences at Rocky Mountain National Park.

4. Develop distance learning opportunities to serve students from outside our visiting area.

Schedule an Education Program with a Ranger

Field trips to national parks offer unique opportunities for studying and experiencing natural and cultural resources. Field trips are a great way to make abstract concepts from the classroom concrete. RMNP is an ideal outdoor classroom. It has a diversity of natural resources, easy spring and fall access, and is in close proximity to Front Range and Grand County communities.

Rocky Mountain National Park, like many national parks, offers ranger-led education programs. Heart of the Rockies, Rocky's education program, provides free field and classroom based education programs, aligned to Colorado education standards. School groups should make reservations at least 6 months in advance. National Park entrance fee waivers may also be available for school visits. For further information or to schedule a program please contact Mark DeGregorio, Education Program Manager, at (970) 586-3777.

A variety of ranger-led education programs is offered seasonally. Programs in the spring and fall are generally similar, focusing on a variety of park topics; programs in the winter are limited to snowshoeing programs and classroom programs focusing on winter themes. To see a list of the latest available programs please visit http://www.nps.gov/romo/forteachers/planafieldtrip.htm.

Front Range Floods
Background Information

Introduction

In September of 2013, Colorado experienced its most extensive flooding event in the state's history. This storm would cause 8 deaths, the evacuation of 11,000 people, and the destruction of an estimated 1,850 homes. It would leave thousands of homes in need of extensive repairs. The Colorado Department of Transportation reported the damage or destruction of 102 bridges, about 200 lane miles of state highways, and an unknown number of county highways washed out or in need of serious repairs across 17 counties. The media would portray this flood event as "unprecedented," "100 year flood," "never before seen" and "floods never happen in September," when in fact flooding is quite common throughout the history of Colorado's Front Range. There were three factors, however, which set this particular flood apart from the other historical floods:

1) the number of people affected

2) the duration of the storm

3) the estimated 1,000+ debris flows which occurred as a result.

Looking at The Weather and Climate Impact Assessment Science Program website, managed jointly by the University Corporation for Atmospheric Research and the National Center for Atmospheric Research it is clear that periodic flooding along the Front Range happens regularly.

As more and more people and businesses move into and build in flood prone areas along the Front Range, the chance for damage to personal property and infrastructure increases.

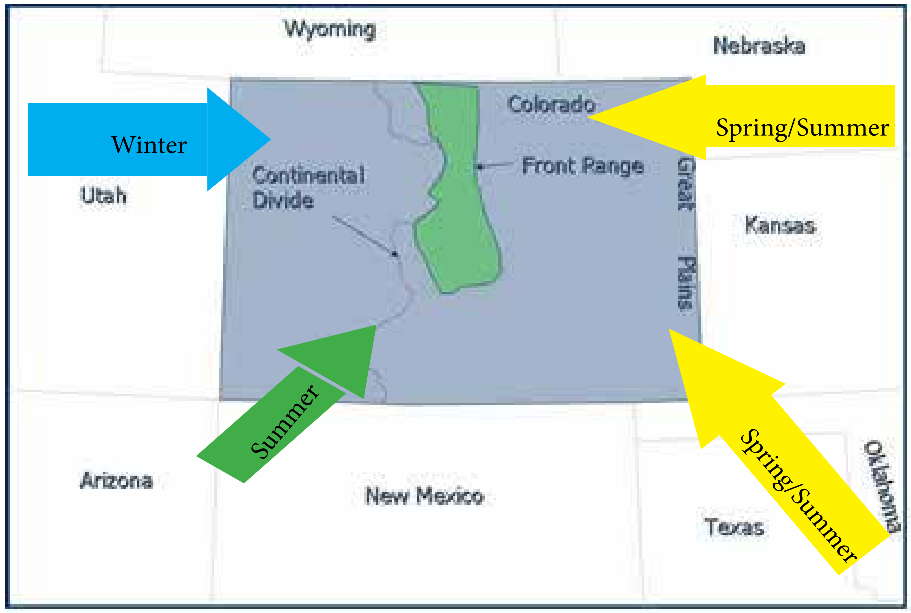
22 Most Damaging Floods in Colorado

Date	Major Stream or Location	Deaths	Damages (In 1999 $)
May 1864	Cherry Creek at Denver	?	$ 6,000,000
July 1896	Bear Creek at Morrison	27	6,000,000
Oct. 1911	San Juan River near Pagosa Springs	2	6,000,000
July 1912	Cherry Creek at Denver	2	120,000,000
June 1921	Arkansas River at Pueblo	78	760,000,000
May 1935	Monument Creek at Colorado Springs	18	52,000,000
May 1935	Kiowa Creek near Kiowa	9	15,000,000
May 1942	South Platte River Basin	?	8,500,000
May 1955	Purgatoire River at Trinidad	2	36,000,000
June 1957	Western Colorado	?	18,000,000
June 1965	South Platte River at Denver	8	2,200,000,000
June 1965	Arkansas River Basin	16	205,480,000
May 1969	South Platte River Basin	0	21,500,000
Sept. 1970	Southwest Colorado	0	13,200,000
May 1973	South Platte River at Denver	10	388,800,000
July 1976	Big Thompson River in Larimer County	144	85,200,000
July 1982	Fall River at Estes Park	3	49,080,000
June 1983	North Central Counties	10	26,250,000
May-June 1984	Western and Northwestern Counties	2	46,500,000
May-June 1993	Western Slope	0	2,140,000
July 1997	Fort Collins and 13 Eastern Counties	6	169,367,000
May-June 1999	Colorado Springs and 12 Eastern Counties	0	100,000,000 (est.)
TOTALS		352	$4,486,577,000

Table info from: Kistner and Associates, 1999. Flood Hazard Mitigation Plan for Colorado. Colorado Water Conservation Board, Denver, CO.

Precipitation Patterns Along the Front Range

The mountainous topography along Colorado's Front Range greatly influences its weather patterns throughout the year.



<u>Winter</u>
Winter moisture is the result of weather patterns which draw moisture from the Pacific Ocean. As the moisture laden air is pushed up the western side of the Continental Divide, snow accumulates in greater depth as the elevation increases. Snowfall totals east of the Continental Divide tend to be much greater because it sits in the rain shadow of the western side of the mountain range.

<u>Spring/Summer</u>
Spring and Summer weather patterns from the east and southeast move moisture from the Gulf of Mexico and the subtropical Atlantic along with moisture evaporated from the Great Plains toward the Front Range foothills. These weather patterns tend to produce locally heavy thunderstorms from May to September and widespread rainfall along the Great Plains and the eastern foothills between April and mid-June.

<u>Summer</u>
During the summer months, subtropical Pacific moisture often produces both localized heavy rainfall and widespread rainfall events along the southwestern mountains.

Terminology in the News

Terminology used by media reporters can often lead to confusion in the general public. When a large scale flooding event occurs, the media use terms such as "100 year flood" and "500 year flood," often giving the general public the mistaken impression that floods of this size come around only once every 100 or 500 years. The 100 or 500 year flood are terms used by scientists and administrators of the National Flood Insurance Program to talk about exceedance probabilities. Every stream or river in the nation has a maximum discharge or stage at which more water added to the river or stream will cause the water to leave the banks and become a threat to lives, property, and commerce. By looking at historical records, scientists can determine how many times a river or stream has exceeded that level and spread a specific distance into the floodplain in a given number of years, or the exceedance probability. Statistically speaking, large floods have a very small chance of occurring each year. With each new flood, scientists recalculate the flood frequency analysis curves factoring in exceedance probabilities.

Exceedance Probability of a N Year Flood	Percentage Chance of Occurrence in Any Given Year
100 Year Flood	1%
50 Year Flood	2%
25 Year Flood	4%
10 Year Flood	10%
5 Year Flood	20%
2 Year Flood	50%

Source: USGS Water Science School

Colorado Flood Events

Historical records show the majority of Front Range flooding has been caused by locally heavy thunderstorms occurring between May and July. This section will highlight not only the September 2013 flood, but also some other historical floods often cited in news reports about the 2013 flood.

Floods at a Glance

Flood	Geographic Area	Amount of Rain	Lenth of Storm
September 2013	13 Colorado Counties	6-14 inches, Highly variable across the region	6 days
September 1938	Similar north south footprint as the September 2013 storm.	Maximum of 10 inches, 7.5 inches of rain falling between September 203, 1938	5 days
1976 Big Thompson	Western 1/3 of Big Thompson Canyon, roughly a 70 square mile area	12 inches	4.5 hours
1997 Fort Collins Flood	North end of Horsetooth Reservoir to NW Laporte	10-14.5 inches	30 hours
1982 Lawn Lake	Estes Park Valley	223,535,574 gallons of water	3 hours 40 minutes

September 2013 Flood

Weather Pattern
During the September 2013 event a circulating air mass around an upper-level low pressure system, situated over the Great Basin, drew tropical moisture from the Pacific Ocean and the Gulf of Mexico. As the air mass pushed moisture against the foothills, the stalled low pressure system created the lift needed to generate rainfall over a greater area. To put the received rainfall totals in better context it is necessary to compare the six day rainfall totals to the monthly or even yearly rainfall totals.

Location	2013 Storm Total	September Average Rainfall	Total Yearly Precipitation	Comparison
Boulder	14.62 inches	1.63 inches	20.7 inches	9 times the average September rainfall
Aurora (Eastern Denver Suburb)	11.5 inches	1.06 inches	14.92 inches	3/4 the yearly precipitation in just 5 days
Estes Park	9.8 inches	1.17 inches	13.10 inches	8 times the monthly average

Response to the Flood
While the response to the 2013 flooding continues to unfold, there have been a number of changes made. The Colorado Legislature is proposing bills related to flooding and flood response. As of April 8, 2014 a number of bills had passed the Colorado House and Colorado Senate and were waiting to be signed into law.

House Bill 14-1003 allows for a state tax exemption for businesses or individuals engaged in disaster recovery work. The tax exemption would cover income earned on disaster recovery work from the time the Governor declares a disaster until 60 days after the disaster declaration has expired. Prior to this legislation all income earned in the state of Colorado, even on disaster recovery work, was subject to taxation.

House Bill 14-1006 allows for the collection of lodging tax on a monthly basis instead of on a quarterly basis. This would allow the state to disperse funds faster to businesses facing economic hardship resulting from a natural disaster.

Senate Bill 14-138 offers immunity from civil liability damages to volunteers, organizations, or other involved in emergency response so long as they act in good faith. This exemption does not apply to those who knowingly act recklessly.

Along with legislative changes, the Colorado Oil and Gas Conservation Commission also released a report detailing changes and new regulations to make oil and gas extraction sites and storage facilities more secure.

As local governments review their responses to the flood and assess their infrastructures' successes and failures, they are beginning to determine what changes need to be made. For example, in an effort to be able to disseminate emergency information, the town of Estes Park is considering creating a local radio station because cellphone reception was lost during the flood. In addition, the Colorado Department of Transportation is moving a section of US Highway 36 five to twenty feet away from the river to place the road on more stable bedrock instead of roadbed material.

Landslides

Another notable factor from this storm and flood event is the number of debris flows recorded. Scientists define a debris flow as "a moving mass of loose mud, sand, soil, rock, water and air that travels down a slope under the influence of gravity. To be considered a debris flow, the moving material must be loose and capable of "flow," and at least 50% of the material must be sand-size particles or larger." Once scientists were able to get into helicopters and start looking at the Front Range, they recorded over 1,000 debris flows, some small and others huge. One of the larger flows occurred on Mount Meeker, located in Rocky Mountain National Park, with a straight-line length of 2.39 miles. Another large debris flow on West Twin Sister, also located in Rocky Mountain National Park, had an estimated of straight-line length of 1.02 miles. A two meter (six feet) thick debris flow also covered the streets of Jamestown, while the building at 100 Arapaho Ave in Boulder was cut in half by a debris flow. Estimates of the rate some debris flows moved show boulders six feet in diameter moving at speeds of 20-30 miles per hour. Plotting these debris flows on a map shows south facing slopes along the Front Range were more susceptible to debris flows. This is not unusual, considering that south facing slopes tend to be warmer with less vegetation covering them and fewer roots to help stabilize the soil.

Debris Flow on Mount Meeker
Photo By Dr. Jonathan Godt (USGS)

Climate Change and the September 2013 Flood

One of the most difficult questions to answer about the Colorado September 2013 flood in Colorado is whether or not climate change had any effect on the storm which produced the flood. In an effort to try to answer this question, scientists are using attribution science, a process by which they take observed data and compare it to computer models. This process is severely limited because scientists have only fifty years of data from which to draw their conclusions and changes in the hydrological cycle are not well understood. Scientists have noticed an increase in overall water vapor in the atmosphere since the 1970s. This increased water vapor produces heavier rain events than those seen in the past.

Longer dry spells between rains have also been observed. This factor increases the chance of flooding because drought hardened soils take longer to absorb rain, thus producing greater runoff. Current climate models for the Front Range show wintertime precipitation will increase in the future, and summertime precipitation will decrease. Even though climate models show a decrease in summertime precipitation, when flooding along the Front Range is most common, if conditions are right and there is sufficient moisture in the atmosphere extreme weather events will still be possible. Climate scientists studying the data from the September 2013 flood find that heavy rainfall was the result of unusual atmospheric circulation patterns combining with the topography of the Front Range. Other factors, such as wildfire and drought, may have exacerbated the flooding in parts of the flood affected area.

	Flood 2013	**Flood 1938**
Length of storm	September 9-15, 2013	August 31-September 4, 1938
Amount of rain	7-16 inches, highly variable across the region	Maximum of 10 inches
Weather pattern	Drew moisture from the Gulf of Mexico	Drew moisture from the Gulf of Mexico

1938 Flood August 31 - September 4, 1938

A September 2013 media report stated there had never been floods in September in the state's history. This is not accurate; in 1938 Colorado experienced a storm very similar to the 2013 storm with similar flooding.

Weather Pattern

Researchers have been able to reconstruct the weather pattern which spawned the 1938 Boulder, CO, flooding using data sets from National Oceanic and Atmospheric Administration. A low pressure system to the west drew moisture up from the south and east. This low pressure system was held in place by a series of high pressure systems. The circulating weather pattern allowed vast amounts of subtropical moisture to be drawn toward the Front Range, producing a cloudburst which inundated an area from the Wyoming border to Colorado Springs. Further research by the National Center for Atmospheric Research and the National Oceanic and Atmospheric Administration, when compared to the 2013 flood, found a similar north to south geographic footprint that produced similar peak discharge totals for certain drainages.

Locations along South Boulder Creek

	2013	**1938**
Morrison	6,190 cfs	6,200 cfs
Sheridan		2,810 cfs
Eldorado Springs		7,390 cfs

Response to the 1938 Flood

In 1944, six years after the South Boulder flood in 1938, S.R. De Boer created a plan to control the flood waters in Boulder and to remove buildings from the floodplain. The following year the Army Corps of Engineers report suggested raising bridges to make them less prone to catching debris floating downstream in raging flood waters. The Corps also recommended elevating existing streets to act as a levee system in times of flooding. As was the case with previous reports and flood control plans, dating as far back as Fredrick Law Olmstead's plan in 1910, the City Council disregarded the findings and implemented none of the suggested improvements. It would not be until May of 1969 that the City Council would adopt zoning regulations related to flooding.

1976 Big Thompson Flood

Weather Pattern

Winds from the east and southeast pushed humid air up against the mountains. Calm winds of less than twenty miles an hour helped to hold the storm in place. Over the next four and a half hours twelve inches of rain fell over the western third of Big Thompson Canyon, a seventy square mile area.

Response to the Flood

Once the flood waters had receded and officials were able to take stock of the damage, they implemented a number of changes in Big Thompson Canyon. A section of US Highway 34 called "the Narrows" was raised by 16 feet. Since a number of fatalities resulted from people trying to outrun the flood in their cars, signs were posted at the both east and west canyon entrances urging people to abandon their cars and climb to higher ground in the case of flooding.

Stream Gauge	2013 Flood Value in Cubic Feet Per Second	1976 Flood Flood Value in Cubic Feet Per Second
Fish Creek upstream from Lake Estes	6,900 cfs	182 cfs
North Fork of Big Thompson upstream from Glen Haven	1,700 cfs	888 cfs
North Fork of Big Thompson upstream from Drake	18,400 cfs	8,719 cfs
West Creek upstream from Glen Haven	11,000 cfs	2,320 cfs
Fox Creek upstream from Glen Haven	3,500 cfs	1,300 cfs

Another major change was the installation of automated stream and rain gauge stations. These new gauges uploaded real-time data to a computer network which could be accessed by fire stations and emergency management offices or anyone who had computer access at that time. Along with the rain gauge installation, new protocols were put in place at the Olympus Dam at the western end of Big Thompson Canyon. These protocols set directives on what actions needed to be taken at the dam when the inflow of water reached a certain rate. The county also purchased 153 parcels of land under the Federal buyout program. By removing these parcels from residential zoning the county was able to reduce the number of persons living or working in a future flood's path. Parcels of land purchased under a Federal buyout program have been retained as open spaces and are never allowed to be sold by the city to future developers.

July 28, 1997 Fort Collins Flood

Weather Pattern

During the last week in July of 1997, tropical air from the south moved into the Front Range at the same time that a strong cold front moved in from the north. This cold front triggered a number of small localized storms on July 27 in the foothills west and northwest of Fort Collins. With the cold front firmly in place and moisture continuing to move in from the south, heavy rains fell from the north end of Horsetooth Reservoir to northwest Laporte and areas west and southwest of Fort Collins on the morning of July 28th. While the rain in the area subsided by mid afternoon, it began again around 6:00 in the evening east and southeast of the city. As the wave of thunderstorms to the east and southeast began to abate, the storms on the western side of the city increased in intensity. Between 8:30 and 10:00 p.m., these storms produced the heaviest sustained rains ever recorded for an urban area in Colorado. By the time the rains subsided, the area between the southwest foothills of Fort Collins and northwest Laporte had picked up between 10 and 14.5 inches of rain in a 30 hour period.

Response to the Flood

The damage to the city of Fort Collins could have been substantially worse if it had not been for the forward thinking of city officials prior to 1997. In the years preceding the flood, 30 mobile homes, 9 residential buildings, and a 15 person retirement home were moved out of the Spring Creek floodplain, an area to be hardest hit in 1997. Elsewhere in the city 45 residential and commercial buildings were removed from the 100 year floodplain. Large parcels of land were purchased to create open space and the city stepped up regulatory enforcement of building codes. These proactive measures earned the City of Fort Collins a class 6 rating in the Community Rating System program instituted by the National Flood Insurance Program. The Community Rating System is discussed in the section on the history of floodplain management later in this document.

After the flood, the city continued to purchase land and buildings in the Spring Creek floodplain. Stabilization of stream banks, creation of new flood water channels, and the purchase of land to increase the size of the Avery Park Detention Pond were initiated. In addition were the installation of larger culverts, the reshaping of road shoulders to channel water more effectively away from structures, and the raising of the Remington St. Bridge to make it less prone to catching floating debris. The city also looked into the creation of an early warning emergency notification system which would incorporate real-time precipitation and stream flow monitoring with a community alert system. During the 1997 storm, city managers were unaware of the severity of flooding in other parts of the city because of a lack of communication. City residents were also unable to keep informed of what was happening because of a loss of cable television, where emergency messages had been scrolling early the flood.

Flooding in Rocky Mountain National Park

Lawn Lake Flood

The flood on July 15, 1982 was the result of the collapse of two dams in the Estes Park valley. The flooding began with the failure of the Lawn Lake dam at 5:30 a.m., releasing 219,623,574 gallons of water. The flood waters from Lawn Lake caused the destruction of the Cascade Lake Dam 6.7 miles below Lawn Lake dam releasing another 3, 912,000 gallons of water into the Estes Park valley. The surge of water then coursed down the Big Thompson River until a debris dam caused the waters to follow the roadbed through downtown Estes Park. Only when the floodwaters had reached the Olympus Dam in Estes Park, three hours and forty minutes after the Lawn Lake Dam failure, were they contained. The flood left three people dead, eighteen bridges damaged, 177 Estes Park businesses inundated with three to four feet of water and one to two feet of mud, and 108 private homes damaged. Damage estimates were $31 million.

Lawn Lake Before Dam Break

Lawn Lake Dam

When the last glaciers receded from Rocky Mountain National Park, water trapped behind the glacial debris created what would be called Lawn Lake. In 1903 an irrigation company enlarged the lake by building a 26 foot high earthen dam at the lake's outlet, accumulating 674 acre feet (219,623,863 million gallons) of water over time. The irrigation company intended to catch spring melt water and slowly release the water during the dryer parts of the summer for crop irrigation in Loveland, CO. Over the years the road leading to the dam crumbled, causing the area to be accessible only by a steep six mile hike. Because of the inaccessible nature of the dam, maintenance and inspections of the dam lapsed. The Lawn Lake dam collapse began with the failure of the lead caulking connecting the outlet pipe to the gate valve. (Lead caulking had never approved for sealing these two pieces together.) As the water leaked from the pipe it eroded the dam fill contacting the pipe. The night before the complete dam failure, campers reported hearing a noise which sounded like strong wind. This report later led the accident investigators to determine that the dam had been discharging water for 3-4 hours before the hole enlarged enough to cause it to collapse in only ten minutes. The breach in the dam measured 28 feet deep, 97 feet wide at the top, and 55 feet wide at the bottom. The water coursed down through Roaring River, gouging out a 50 foot or deeper steep walled canyon, hurling rocks and debris through the air as it moved toward Horseshoe Park, where its velocity would slow due to the meadow's flat topography. The flood waters caused the failure of the Cascade Lake dam over six and a half miles below Lawn Lake.

Cascade Lake Dam

The Cascade Lake dam, constructed in 1908, created a water supply for the hydroelectric plant for the town of Estes Park and the Stanley Hotel. The 143 foot long, 17 foot deep dam had been constructed from concrete settled by gravity and reinforced with a masonry rock buttress on the downstream side. The dam failed because of the pressure created by the additional influx of water coming down from Lawn Lake and the overtopping of the dam by 4.2 feet of water for thirty minutes. The overtopping also caused the reinforcement rock to be pulled off the dam's front side, weakening the structure. When the dam collapsed, it released an additional 12.1 acre feet of water (3,912,000 million gallons).

Response to the Flood

In the wake of the flood, Colorado residents learned that the state had not been inspecting dams in a timely manner. The 1982 inspection of the Bluebird Dam, Pear Lake Dam, and Sand Beach Dam were found by inspectors to be seriously deficient and posing a hazard to residents living below them. While all three dams were located in the high elevations of Rocky Mountain National Park their upkeep was the responsibility of the City of Longmont, the dams' owner. After a review, the City of Longmont determined the dams were no longer necessary for irrigation purposes because of the creation of the Buttonrock Reservoir. It would take until 1987 for Rocky Mountain National Park to purchase the rights to all three dams at the cost of $3,926,794.89 (in 2014 monies). From 1989 to 1990 park staff removed all three dams in compliance with regulations concerning the protection of the threatened greenbacked cutthroat trout and protection of plants and animals in the alpine tundra. Even though the Bluebird Dam was considered to be historically significant, since it was the first high-altitude reinforced concrete dam, the potential for loss of life and property was considered of greater importance. The dam was thoroughly photographed and documented before the removal process began and later an interpretive sign was built to inform visitors of the dam's existence.

17 foot tall 425 ton boulder deposited during the Lawn Lake Flood.

17 foot tall 425 ton boulder after the September 2013 Flood.

Alluvial Fan (Pre 2013 flood)

One of the most enduring reminders of the Lawn Lake flood is the presence of the Alluvial Fan. As over 219 million gallons of water coursed its way down Roaring River, the river channel widened by 10 feet and was scoured by another 5-50 feet deep, depending on where in the channel one stood. All this scoured debris was deposited near the base of the mountain creating an alluvial fan, a triangle-shaped deposit of gravel, sand, and even smaller pieces of sediment, such as silt. The Alluvial Fan covered 42.3 acres and contained 364,600 cubic yards of debris, enough debris to cover a football field to a depth of 205 feet. The debris weighed approximately 829,000 tons, 1.5 times more sediment load than is deposited by the Mississippi River in one day. In some places the debris measured 44 feet thick, although on average the depth was 5.3 feet. The force of Roaring River even moved a boulder 14 by 17.5 by 21 feet, estimated to weigh 452 tons. As the rushing waters exited the mountains and began to slow down, suspended debris began to settle out. Scientist looking at the debris noticed that over a 1,900 foot distance the particle size ranged from boulders 7.5 feet in diameter at the beginning to sand and silt at the bottom closer to Horseshoe Park. The deposited rubble dammed up a portion of Fall River creating a 17 acre lake near the Alluvial Fan.

History of Floodplain Management in the United States

In the United States approximately 178 million acres lie within floodplains. These floodplains also contain 15% of our urban areas, estimated to be $17-18,000 flood prone communities nationwide. Ten million households and $800-900 billion dollars in property are subject to flooding risk. Since 1935, the United States has spent $25 billion dollars on projects to control flooding. The United States would not make a concerted effort at a national floodplain management plan until after the beginning of the 20th Century. There were four main reasons for Congressional resistance to a national floodplain management plan:

1) The government lacked the financial resources to fund major flood construction projects.
2) Engineering obstacles
3) The populations of cities along the nation's waterways remained relatively small until the beginning of the 20th century; therefore, when floods did occur the damage was relatively low.
4) Political leaders believed federal aid for flood control was unconstitutional.

A number of flood control decisions regarding legislation were done under the premise of improving certain rivers for navigation and commerce.

Some examples of legal issues and legislation:

1) <u>1824 Gibbons vs. Odgen</u>
   The Supreme Court extended the commerce clause allowing the federal government to finance and construct a number of river improvements. These improvements caused widespread arguments among communities who felt it was unfair to protect those communities along the major river ways and not those along some of the small tributaries which fed off those larger rivers.

2) <u>Swamp Lands Act of 1849 & 1850</u>
   The federal government turned over the swamp land and floodplain land to the control of states along the lower Mississippi River. Through the states' selling of this land to people wishing to turn it into farmland, the states would be able to finance the construction of levees and drainage channels to protect areas from flooding. The reauthorization of the Act in 1850 also allocated $50,000 to the Army Corps of Engineers to conduct hydrological and topographical study of the Mississippi Delta in the hopes of determining the best way to control it from flooding.

3) <u>1879 Mississippi River Commission</u>
   The commission's charge was to investigate and then to devise a plan to control flooding and improve navigation along the Mississippi River. The plan would also be designed to protect people and property along the river. During the period 1882 to 1916 the federal government would spend only $30 million on levee construction leaving most of the financial burden to the states, which collectively spent $90 million dollars.

The tipping point in favor of a national flood plain management plan came after a series of devastating floods.

Flood	Cost in Property Losses in 2013 Monies	Number of People Dead or Displaced
1907 Pittsburg Flood	123 million in property damage	6-12 people dead
1912 &1913 Mississippi River Flood	1,450 million in property damage	270,000 people driven from their homes
1913 Ohio River Flood	2,322 million in property damage	467 people dead, 65,000 people displaced
1927 Mississippi River Flood	4,644 million in propery damage	250 people dead, 700,000 people driven from their homes and 330,000 people rescued from rooftops after newly constructed levees failed

With states unable to tax their citizens further to finance levee construction, it became clear that the federal government would need to step forward to finance a greater portion of the levee systems, or thousands of acres of farmland would revert back to swamp and millions of dollars already spent on levee construction would have been wasted. Congress responded with the Flood Control Act of 1917.

This legislation set four precedents which would help to lay the foundation of the Flood Control Act of 1936.

Precedent #1- Congress appropriates funds primarily for the purpose of flood control without having to hide it under the guise of improving commerce or navigation.

Precedent #2 - Congress sets a commitment to fund long range flood control measures on both the Mississippi River and Sacramento River. These flood control measures were mainly dams, reservoirs, dikes, levees, riprap, floodwalls, channel alterations, and diversion spillways.

Precedent #3- The act stipulated that for every $2.00 the federal government spent, state and local communities would need to contribute $1.00 towards flood control projects.

Precedent #4- All flood control plans would be evaluated by the Army Corps of Engineers to see if they should be federally funded and could be completed in conjunction with other approved plans for projects such as hydroelectric power, increased navigation, or irrigation projects.

Even with the passage of this new legislation, the nation's understanding was lacking in the areas of flood hydrology and the local flood control practices already being utilized, as well as their success. To this end, Congress passed the Rivers and Harbors act of 1927, which authorized the Army Corps of Engineers to evaluate 180 named rivers and countless unnamed tributaries. The reports generated by the Corps greatly increased knowledge of flood hydrology and became the most detailed account of multipurpose river development plans and data at that time. All of this information was used to create the Flood Control Act of 1936, established the National Flood Program and gave the federal government responsibility in assisting with flood control on the Mississippi River and all other waterways.

In 1968, Congress passed the National Flood Insurance Act, which aimed to integrate social awareness, zoning regulations, and land use practices with floodplain management, shifting these factors away from reliance on structural mechanisms to control flooding. The National Flood Program went on to administer the National Flood Insurance Program, a partnership among local, state, and federal governments. Through this partnership, the federal government agreed to make insurance available to citizens as long as local authorities agreed to enforce floodplain management zoning ordinances and building codes for new construction in high hazard zones of the floodplain.

In 1990 the National Flood Insurance Program created a voluntary Community Rating System to encourage and reward communities which go above and beyond the National Flood Insurance Program's minimum standards for floodplain management. Communities are rated on a scale from 1 to 9, with 9 being the highest. A community can increase its rating by continuously improving its ability to warn citizens during potential flooding, by educating citizens about what steps to take to protect themselves and their properties, and by continuing to reduce the number of structures which potentially may be impacted during a flood. Communities participating in the rating system receive a discount on their flood insurance premiums. With each change made to a community's floodplain management the insurance premiums go down.

Front Range Floods
Resources

Glossary

Alluvial Fan: An alluvial fan is a triangle-shaped deposit of gravel, sand, and even smaller pieces of sediment, such as silt. This sediment is called alluvium. Alluvial fans are usually created as flowing water interacts with mountains, hills, or the steep walls of canyons.

Attribution Science: Demonstration that a detected change is consistent with computer modeled climate response under a combination of human induced changes and natural changes.

Debris Flow: A moving mass of loose mud, sand, soil, rock, water and air that travels down a slope under the influence of gravity. To be considered a debris flow the moving material must be loose and capable of "flow," and at least 50% of the material must be sand-size particles or larger.

Ephemeral Steams: An intermittent stream that has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow.

Erosion: The process whereby materials of the earth's crust are loosened, dissolved, or worn away and simultaneously moved from one place to another.

Exceedance Probabilities: The probability that a flood will generate a level of inundation that exceeds a specified reference level during a given exposure time.

Flood: An overflow of water onto normally dry land. The inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch. Ponding of water at or near the point where the rain fell. Flooding is a longer term event than flash flooding that may last days or weeks.

Flood Stage: An established gage height for a given location above which a rise in water surface level begins to create a hazard to lives, property, or commerce. The issuance of flood advisories or warnings is linked to flood stage.

Flash flood: A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. Flash floods are usually characterized by raging torrents after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours of excessive rainfall. They can also occur even if no rain has fallen, for instance after a levee or dam has failed, or after a sudden release of water by a debris or ice jam.

Front Range: Specifically the Front Range in Colorado is the eastern most mountain range of the Rocky Mountains stretching from Pikes Peak to the Colorado/Wyoming state line. However, the term “Front Range” is used to loosely describe any area from the urban corridor west to the Continental Divide.

Rain Shadow: An area having relatively little precipitation due to the effect of a barrier, such as a mountain range, that causes the prevailing winds to lose their moisture before reaching it.

Roadbed Material: The base course, or subbase if specified, is a layer of material (e.g., bituminous mix, aggregate) that is placed, graded, and compacted on top of the subgrade. The base course provides the pavement structure with a free-draining, nonfrost-susceptible material layer that distributes the traffic load from the surface course to the underlying subgrade.

Succession: The process by which the structure of a biological community evolves over time. Creating a continually changing mix of species within communities as disturbances of different intensities, sizes, and frequencies alter the landscape.

Soil: Top layer of the earth's surface where plants can grow.

Straight-line Length: an estimate of the distance covered by a debris flow as measured by having a straight line connecting the beginning and the end points.

Topography: The science of describing an area of land, or making maps of it. The shape of an area of land, including its hills, valleys etc.

Weathering: The breaking down or dissolving of the Earth's surface rocks and minerals.

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