State of Colorado
2006 Flood Documentation Reports

Deckers, Colorado flood of July 7th, 2006. Photo Courtesy of Douglas County Office of Emergency Management

Prepared by:
ICON Engineering, Inc
8100 S. Akron St. Suite 300
Centennial, CO 80112
303-221-0802

Prepared for:
Colorado Water Conservation Board
1313 Sherman St. Room 721
Denver, CO 80203
303-866-3441

COLORADO DEPARTMENT OF NATURAL RESOURCES

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COLORADO WATER CONSERVATION BOARD · STATE OF COLORADO · NIL SINE NUMINE · 1876 · 1937

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EXECUTIVE REPORT SUMMARY

During the months of July and August of 2006, various flood events occurred throughout the state of Colorado. Affected counties include: Fremont, Douglas, Mesa, and Pueblo. Douglas County sustained the most damage from a very significant event that closed State Highway 67 for several months.

Each county experienced various degrees of flooding and damage. The event in Mesa County, east of Grand Junction, was the only studied event that had a death attributed to the storm. The varying amounts of precipitation caused different levels of damage to each area. Most counties had: damage to: structures, roads, culverts, bridges, public facilities such as parks, and personal and commercial property damage.

This report summarizes the 2006 flood events that took place in the state of Colorado. In no way is this report intended to review every event that took place during the year, but specific events that the Colorado Water Conservation Board wanted a closer look at. It investigates the key factors of a flood event such as: hydrologic and hydraulic characteristics, storm facts and location, estimated flood damages, mitigation, and a description of any areas that were underwater or impacted by the flood. Additional support information found, such as pictures, maps, etc, was also included in each chapter.

INTRODUCTION

The following chapters discuss the four significant flood events that occurred in 2006 around the state of Colorado. Each chapter follows a specific presentation format of gathered information that was outlined before the project commenced. However, the amount and type of information that could be gathered for each event varies greatly due, in most part, to the quantity of available contacts, and the amount of information gathered by local, state and federal agencies. The general trend seems to imply that the more severe the event, the more contacts and information available. Thus, the levels of detail and discussion depth for each chapter also differ accordingly.

PURPOSE OF STUDY

The intended purpose of this study is to gather information on specific flood events throughout the state and present that information to all interested parties in an organized and presentable fashion. This study is also being done to help inform government officials, and private citizens, on the effects and damage that floods can cause in order to help prepare them for future occurrences. After reading each chapter, one will be able to identify problem spots and areas where flood mitigation projects assisted in minimizing the impacts to the surrounding area.

AUTHORITY AND ACKNOWLEDGEMENTS

Authority

It is the responsibility of the CWCB (Colorado Water Conservation Board) to devise and formulate methods, means, and plans for bringing about the greater utilization of the waters of the state and the prevention of flood damages therefrom. By this authorization, work on this project was sanctioned and funded by the CWCB through a contract dated June 2nd, 2006, with ICON Engineering, Inc. In consultation with the Colorado Water Conservation Board and a variety of federal, state, and local agencies, ICON Engineering, Inc. conducted the study and produced the following document to be used statewide.

Acknowledgements

This report was made possible by funding made available through the CWCB's Flood Response Program, which includes an element for flood documentation services. The following staff played a key role in the completion of this report:

- Tom Browning, CWCB, Flood Protection Program
- Kevin Houck, CWCB, Flood Protection Program
- Penn Gildersleeve, ICON Engineering, Inc.
- Justen Hamann, ICON Engineering, Inc.
- Brian LeDoux, ICON Engineering, Inc.

FLOOD DOCUMENTATION REPORT – CHAPTER 1

Penrose, Colorado Flood of July 5-6th, 2006
Brush Hollow Creek; Eightmile Creek; Beaver Creek
(Fremont County)

Introduction

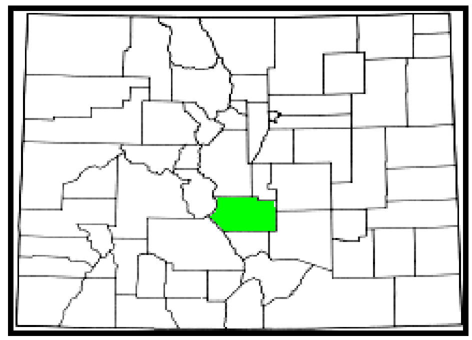


Figure 1.1 – Fremont County Location in the State of Colorado.
Map courtesy of the Colorado Herpetological Society.

On Wednesday night and continuing into Thursday, July 5-6th, 2006, a large storm front extending along the foothills/plains interface of El Paso, Fremont, and Pueblo counties produced a significant amount of rainfall that impacted the un-incorporated town of Penrose and surrounding Fremont County area. There were confirmed reports indicating rainfall amounts in excess of 6 inches in eastern Fremont County, with rainfall of up to 2 inches reported west of Colorado Springs (Manitou Springs and Garden of the Gods area) in El Paso County. Several other rainfall amounts were reported from this storm including 1.79 inches in Florence and 1.65 inches in Canyon City. According to Bill Fortune, meteorologist in charge at the National Weather Service in Pueblo, the rain started around 7 p.m. Wednesday and continued well past midnight with the heaviest and most damaging rainfall occuring between 7 and 10 p.m. This event was preceeded on the previous day by a thunderstorm that reportedly dropped 1.4 inches of rain at the Pueblo Memorial Airport which is approximately 30 miles east of the Penrose area.

Flooding was reported along Eightmile Creek, Brush Hollow Creek, and Beaver Creek, all of which are north-bank tributaries to the Arkansas River. USGS gaging stations on Beaver Creek and the Arkansas River recorded signficant flow increases. Damage occurred to several county roads and culvert/bridge crossings including severe damage to Highway 115 and Highway 50. In particular, the Brush Hollow Creek culvert crossing of Highway 115 approximately 1.5 miles south of Penrose overtopped and failed which resulted in the closure of the highway. Brush Hollow Reservoir, which is located appromately 4 miles north of the Highway 115 crossing, totally contained all flows upstream of the reservoir resulting in a reported water-surface elevation rise of approximately 6.7 feet in one day with a corresponding estimated increase in water storage of 516 acre-feet. A house on Eightmile Creek near County Road 123 was partially inundated as were several structures near the Eightmile crossing at County Road 132. Additionally, flooding from local drainage damaged an apartment complex in Penrose as well as several local roads in the surrounding area.

Flooded Area Description

As mentioned in the Introduction section of this report, flooding was reported in and around the town of Penrose as well as several other areas within Fremont County. Most of the damage occurred at bridge/culvert crossings along county roads and state highways. Figure 1.2 shows the Penrose and Fremont County area in relation to the areas where damage was reported.

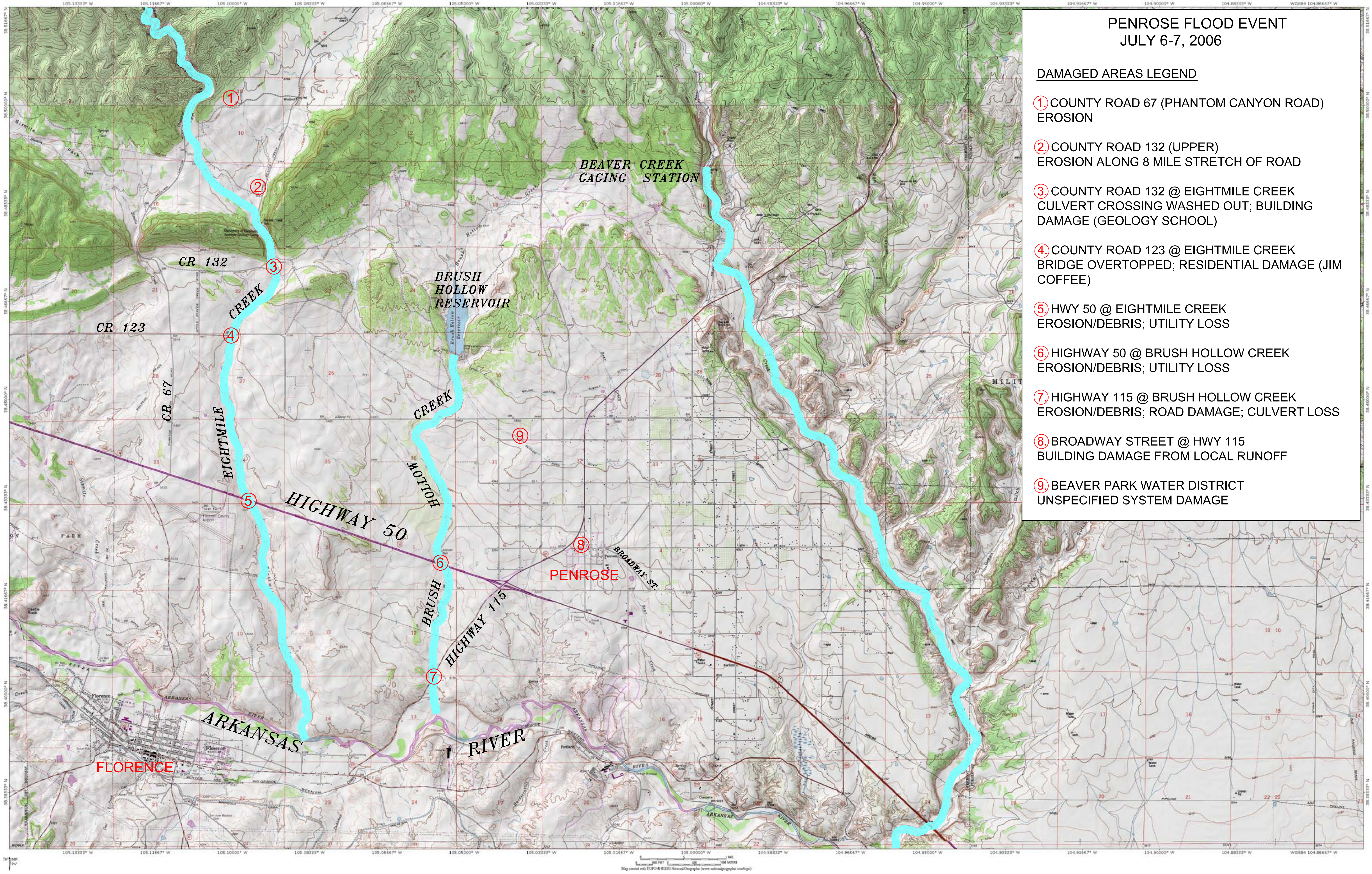
Location and Watershed Description

Eightmile Creek, Brush Hollow Creek, and Beaver Creek are all north-bank tributaries of the Arkansas River. The points of confluence for these creeks with the Arkansas River all occur within an 8-mile reach of the river just downstream of the Town of Florence.

Eightmile Creek is a large north-south tributary to the Arkansas River which runs through mostly unincorporated areas of Fremont and Teller counties. Its drainage area at the Arkansas River is estimated at 63.4 square miles and has several road crossings near its downstream end including various county roads as well as a large bridge crossing at Highway 50. Approximately 70% of its drainage area lies within the mountainous sparsely populated region to the north of the Arkansas River.

Roughly $1/3^{rd}$ of the Brush Hollow Creek Basin is controlled by the Brush Hollow Creek Reservoir which was constructed in the 1920's as an irrigation supply reservoir. While it is on the main stem of Brush Hollow Creek, it is largely fed by a canal system that transfers water from the Beaver Creek Basin to the reservoir. Approximately 8.2 square miles of the Brush Hollow Creek basin drains to the reservoir. At the time of the July 2006 flood event, the water-surface elevation within the reservoir was fairly low allowing for enough storage capacity such that no flows were released from the outlet works or from the spillway during the flood event. An additional drainage area of approximately 12.3 square miles spans the area between the Highway 115 road crossing along Brush Hollow Creek (Damage Area 7 on Figure 1.2) and just downstream of the reservoir. This location is approximately ½ mile above the creek's confluence with the Arkansas River.

Although only minor damage was reported along Beaver Creek, it is included in this report primarily due to the presence of a USGS Gage Station located along the drainageway. Station 07099060 is situated on the left bank of Beaver Creek 300 feet downstream from the Beaver Park Irrigation Company diversion dam, and 1.8 miles upstream of State Highway 115 (See Figure 1.2). Tributary drainage area to this gage station is approximately 138 square miles.



PENROSE FLOOD EVENT
JULY 6-7, 2006
DAMAGED AREAS LEGEND
1 COUNTY ROAD 67 (PHANTOM CANYON ROAD) EROSION
2 COUNTY ROAD 132 (UPPER) EROSION ALONG 8 MILE STRETCH OF ROAD
3 COUNTY ROAD 132 @ EIGHTMILE CREEK CULVERT CROSSING WASHED OUT; BUILDING DAMAGE (GEOLOGY SCHOOL)
4 COUNTY ROAD 123 @ EIGHTMILE CREEK BRIDGE OVERTOPPED; RESIDENTIAL DAMAGE (JIM COFFEE)
5 HWY 50 @ EIGHTMILE CREEK EROSION/DEBRIS; UTILITY LOSS
6 HIGHWAY 50 @ BRUSH HOLLOW CREEK EROSION/DEBRIS; UTILITY LOSS
7 HIGHWAY 115 @ BRUSH HOLLOW CREEK EROSION/DEBRIS; ROAD DAMAGE; CULVERT LOSS
8 BROADWAY STREET @ HWY 115 BUILDING DAMAGE FROM LOCAL RUNOFF
9 BEAVER PARK WATER DISTRICT UNSPECIFIED SYSTEM DAMAGE
BEAVER CREEK GAGING STATION
BRUSH HOLLOW RESERVOIR
CR 132
CR 123
CR 67
EIGHTMILE CREEK
BRUSH HOLLOW CREEK
HIGHWAY 50
HIGHWAY 115
BROADWAY ST.
PENROSE
FLORENCE
ARKANSAS RIVER

Storm Characteristics and Rainfall Information

Information on storm characteristics, such as the recorded rainfall amount, was readily available for this event. Two separate field visits were conducted for this event which included talking directly to citizens and public officials regarding the characteristics of this storm. The personnel and dates of the site visits are listed below in Table 1.1.

Table 1.1 – Field visit dates and personnel.

Date of Site Visit	Entity Represented	Personnel
July 10, 2006	CWCB	Tom Browning Joe Busto
July 13, 2006	ICON Engineering	Penn Gildersleeve Justen Hamann

Limited field surveying was also performed in order to obtain high-water marks and drainageway cross-sections along Brush Hollow Creek at Highway 115, and at Eightmile Creek at the County Road 123 crossing.

Total precipitation amounts for this storm event were obtained from several different sources including both amateur weather data monitoring volunteers and national weather bureaus. Figures 1.3 through 1.5 show several of the various rainfall sources and their respective rainfall amounts.

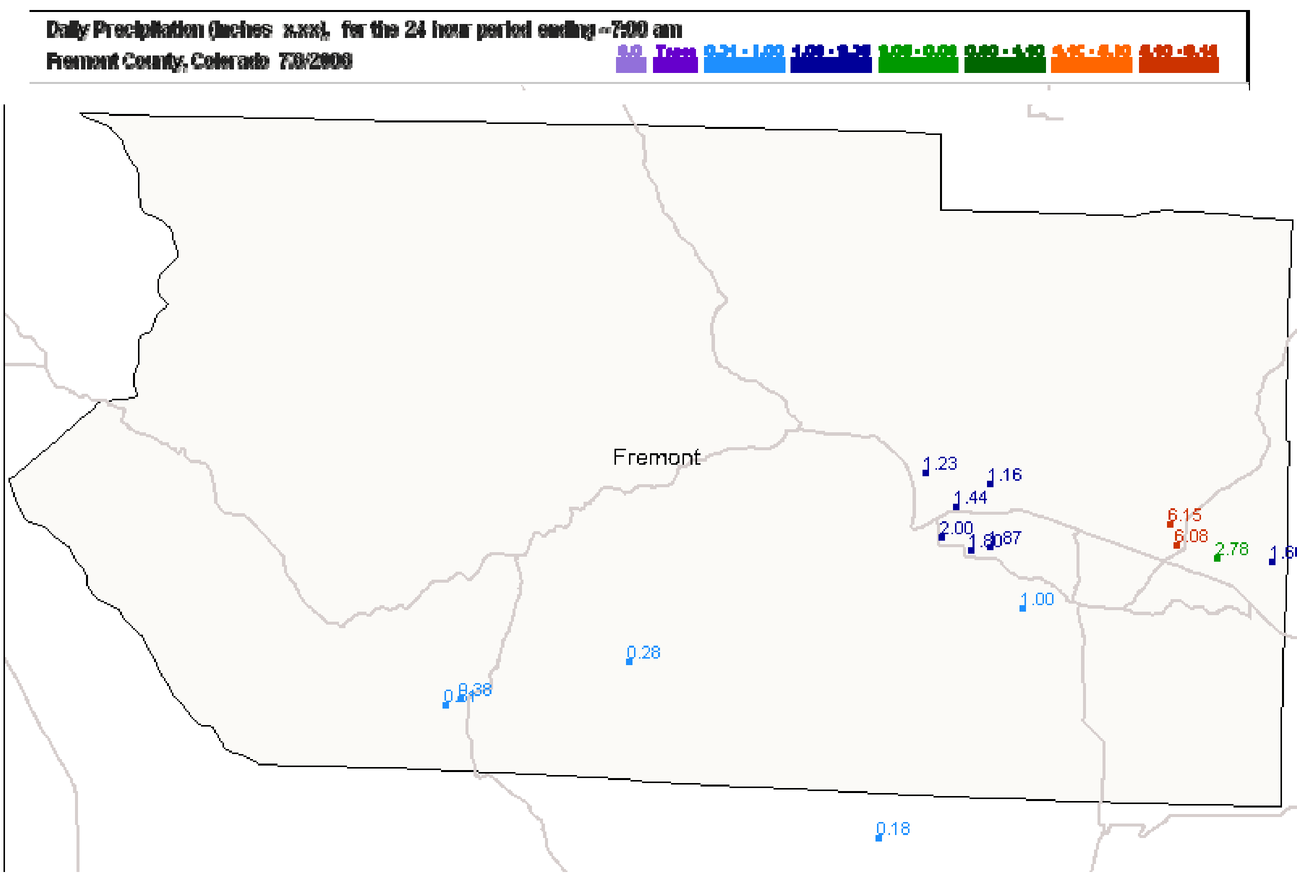
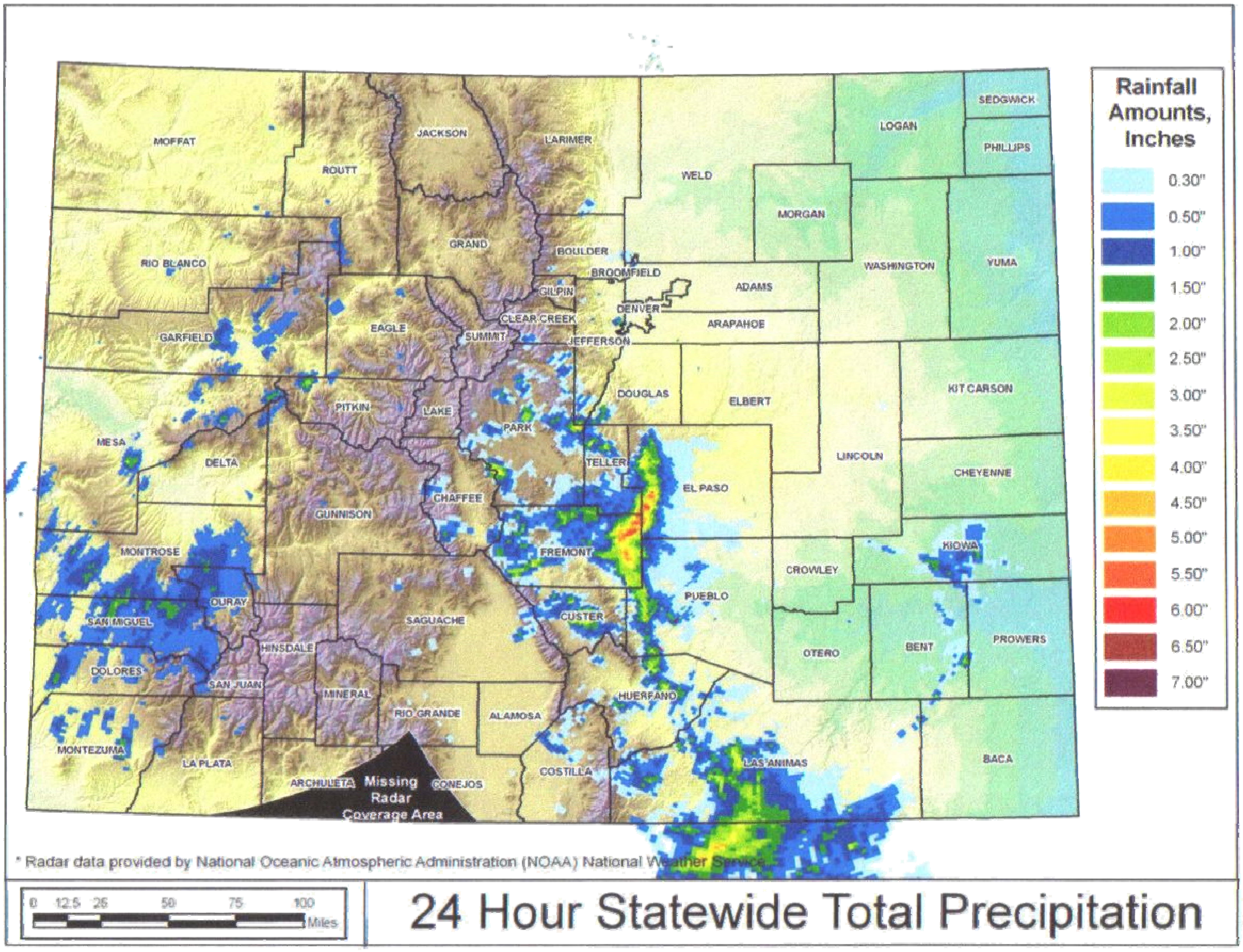


Figure 1.3– Community Collaborative Rain and Hail Study (CoCoRaHS) Reported Results



PRECIPITATION TOTALS FOR 24-HOURS ENDING: 7:00 am – Thursday July 6, 2006

Figure 1.4 – National Oceanic Atmospheric Administration (NOAA) National Weather Service 24 Hour Statewide Total Precipitation. **Note the rainfall depth along eastern Fremont County and western El Paso County have 24-hour depths ranging from 1.00-inch up to in excess of 6.00-inches.**

According to data produced by the Community Collaborative Rain and Hail Study, (CoCoRaHS) which is a science education project managed by the Colorado Climate Center at Colorado State University and driven by volunteer participants, total rainfall amounts in the Fremont County area ranged from a trace up to 6.15 inches for July 5th through the 6th. These reported rainfall amounts, as well as their respective locations in relation to the County, are shown in Figure 1.3.

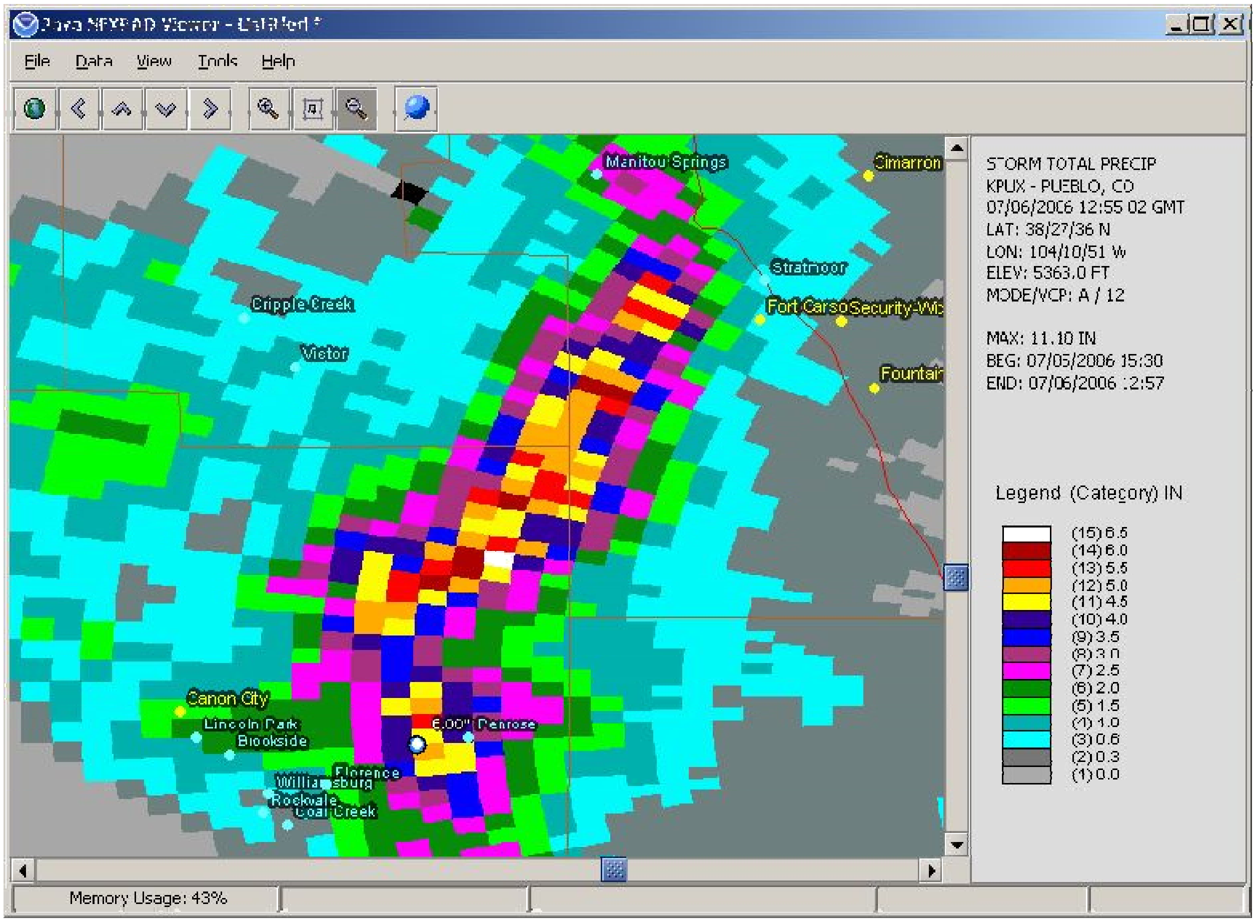


Figure 1.5 – Regional NEXRAD Rainfall Data.
Obtained from the National Weather Service Forecast Office in Pueblo, CO.

According to the National Climatic Data Center's NEXRAD radar images, a large front of severe storm activity formed in the mountains and intensified as it moved east. The storm front hit the Front Range area at approximately 10:00PM on July 5th and ended near 1:00AM the following day. The radar images are shown on the following pages, in Figures 1.7 through 1.16. The legend adjacent to Figure 1.9 indicates that the higher color numbers relate to higher precipitation intensities from the storm. In order to locate Penrose on the NEXRAD radar images, Figure 1.6 contains a map of the state of Colorado with the Penrose area marked with a black star.

Figure 1.6 – Map of the Penrose Area in Relation to the State of Colorado.
Map courtesy of the Mapquest website.

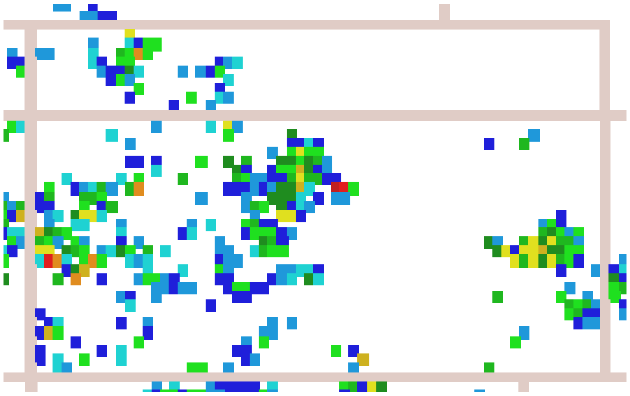


Figure 1.7 – State of Colorado NEXRAD Radar Image July 5, 2006 at 3:00PM MDT

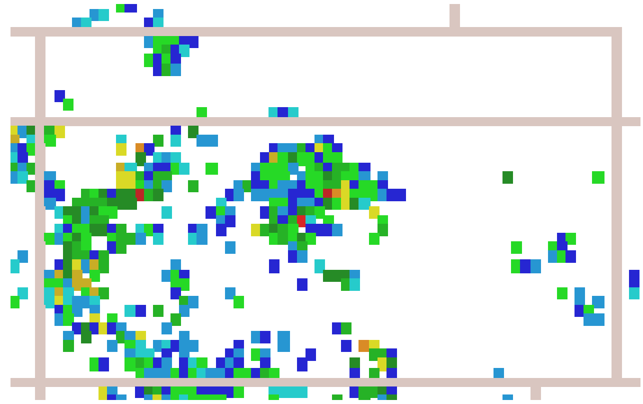
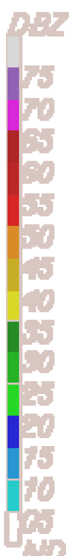


Figure 1.8 – State of Colorado NEXRAD Radar Image July 5, 2006 at 4:00PM MDT



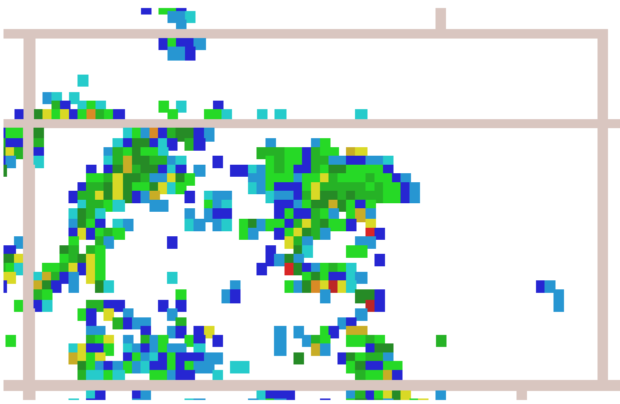


Figure 1.9 – State of Colorado NEXRAD Radar Image July 5, 2006 at 5:00PM MDT

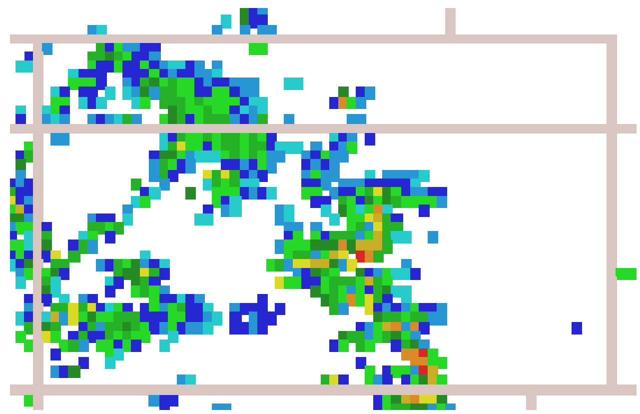


Figure 1.10 – State of Colorado NEXRAD Radar Image July 5, 2006 at 7:00PM MDT

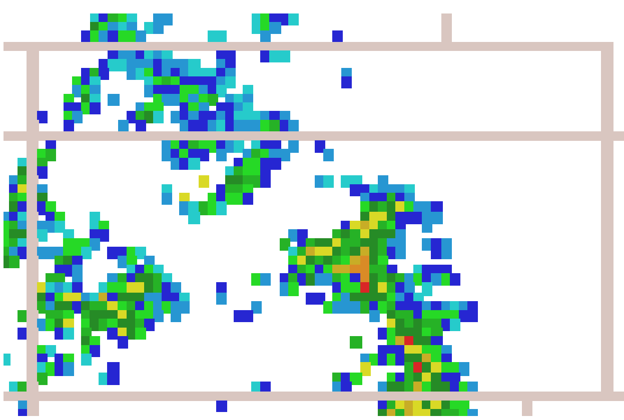


Figure 1.11 – State of Colorado NEXRAD Radar Image July 5, 2006 at 8:00PM MDT

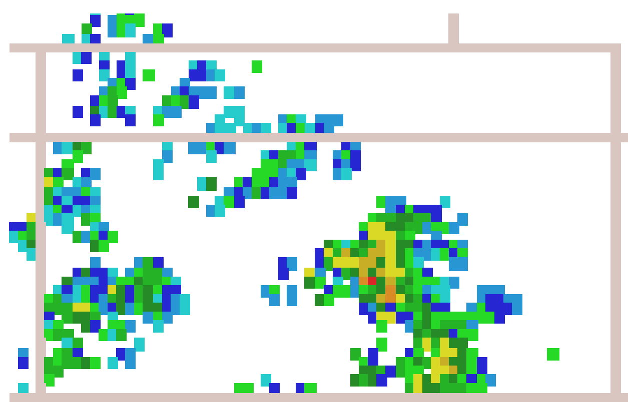


Figure 1.12 – State of Colorado NEXRAD Radar Image July 5, 2006 at 9:00PM MDT

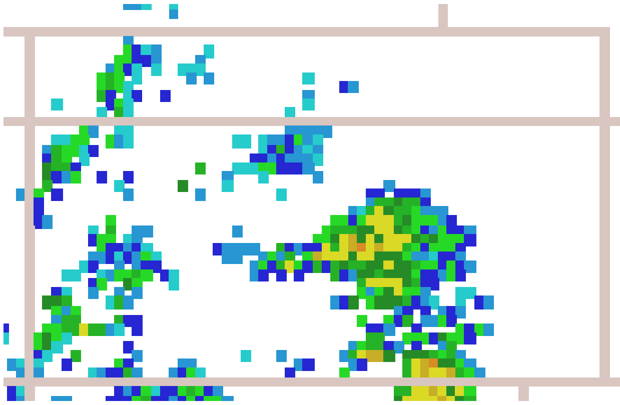


Figure 1.13 – State of Colorado NEXRAD Radar Image July 5, 2006 at 10:00PM MDT

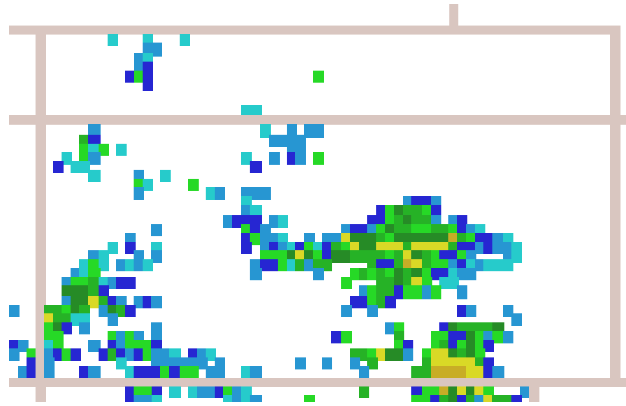


Figure 1.14 – State of Colorado NEXRAD Radar Image July 5, 2006 at 11:00PM MDT

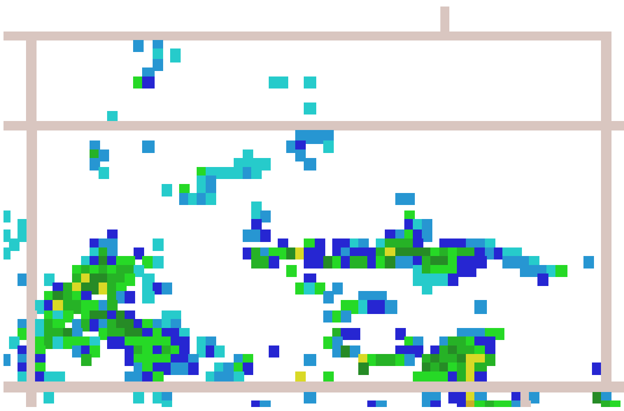


Figure 1.15 – State of Colorado NEXRAD Radar Image July 6, 2006 at 12:00AM MDT

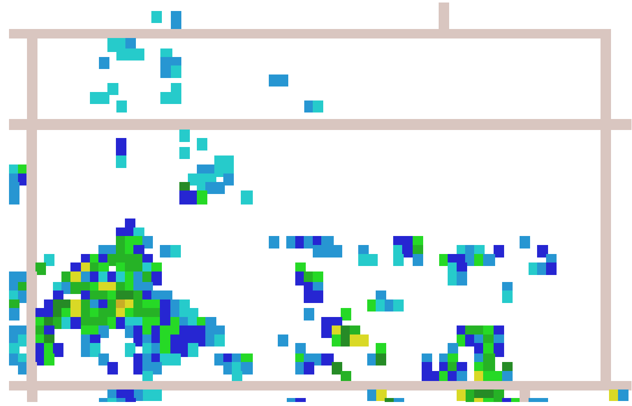


Figure 1.16 – State of Colorado NEXRAD Radar Image July 6, 2006 at 1:00AM MDT

Hydrologic and Hydraulic Investigations

A USGS gage station is located on only one of the three flooding sources studies by this report. This station is located on Beaver Creek above Highway 115 (See Figure 1.2). Provisional data, which is subject to revision, was initially reported for this station and indicated a very significant flood event had occurred during late July 5th and into July 6th. The provisional data was initially posted on the USGS website however; after a short time it was removed. This likely indicates that the provisional information was suspected of somehow being inaccurate and was therefore removed from the site. As shown in Figures 1.17 and 1.18, the provisional data indicated that the normally dry creek experienced a very rapid spike in flows peaking at approximately 1,600-cfs with a corresponding flood depth of over 14-feet. The rating curve data for this station indicates a gage maximum of 1,580-cfs with a corresponding depth of 8.53 feet for this storm. Therefore, while the initially reported data is suspect, it does indicate that a very significant event occurred.

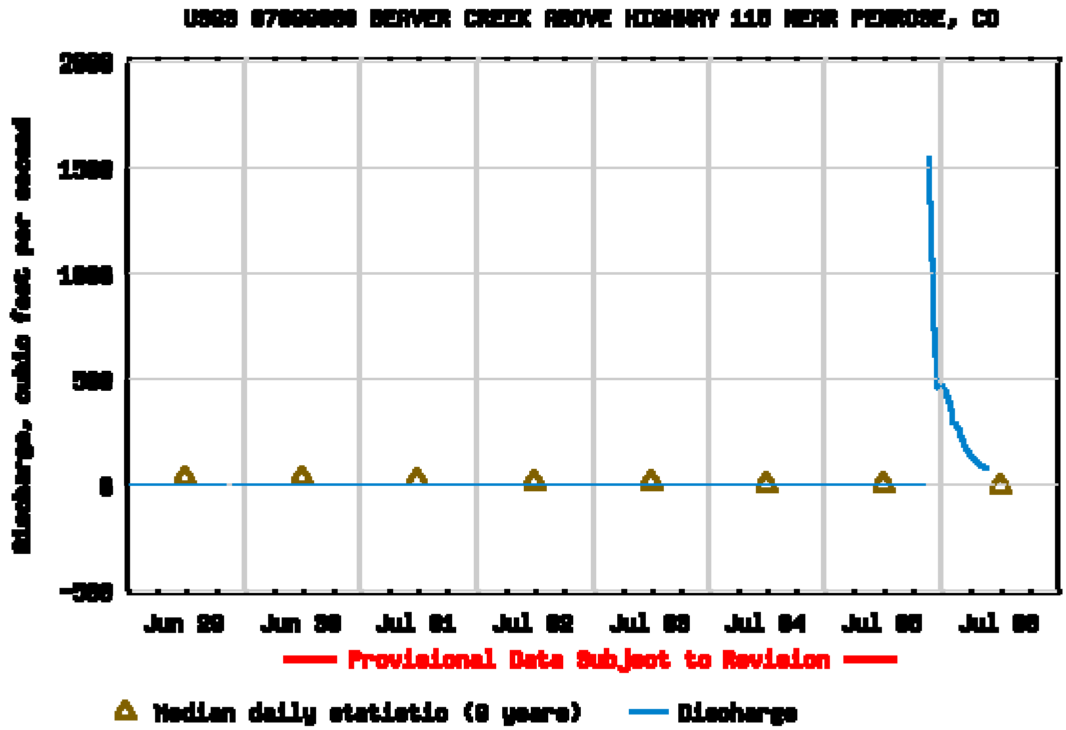


Figure 1.17 – Graph of Daily Discharge for USGS Flow Gage along Beaver Creek

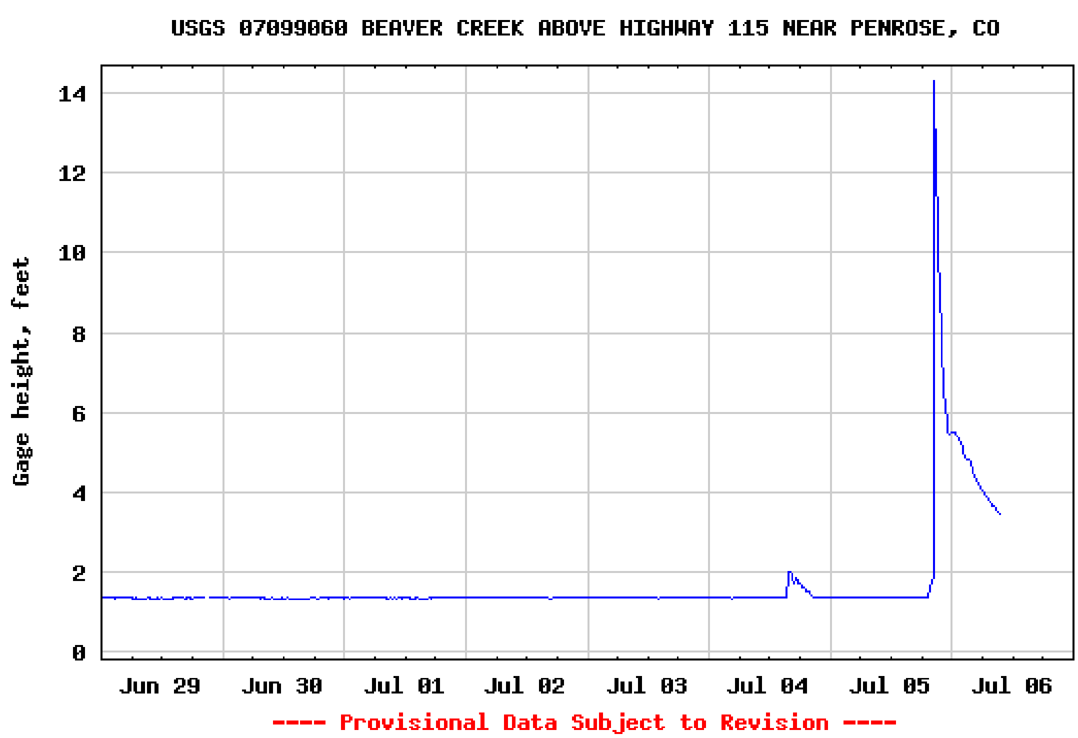


Figure 1.18 – Graph of Gage Height for USGS Flow Gage along Beaver Creek

Figure 1.19 shows a daily discharge graph for a Colorado Division of Water Resources gage station on the Arkansas River at Portland. While there was no reported flooding attributed to the Arkansas River, the graph does show a moderate spike (approximately 5,000-cfs) in flows likely attributed to the inflows from Brush Hollow Creek, Eightmile Creek, and Beaver Creek.

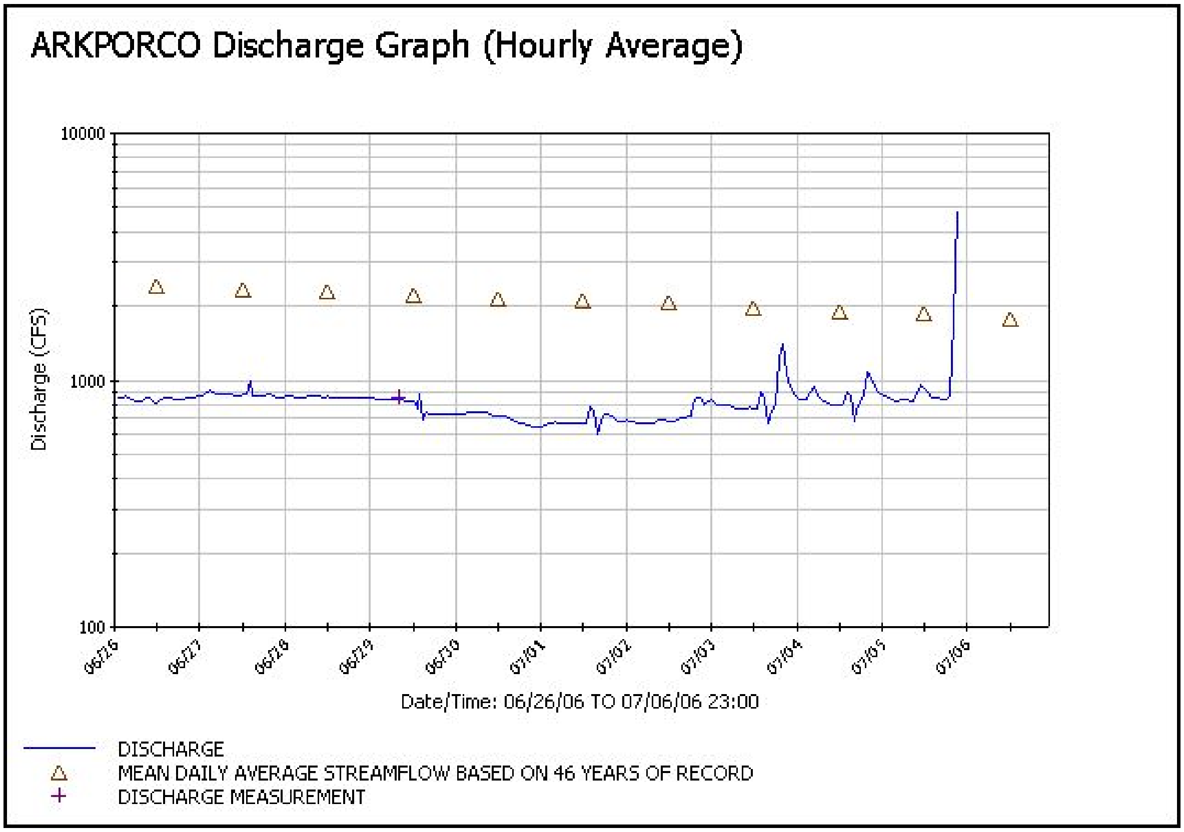


Figure 1.19 – Graph of Daily Discharge for Flow Gage along the Arkansas River

<u>Brush Hollow Creek Hydraulic Analysis</u>

Based on survey data from high-water marks along Highway 115, the existing box culvert was found to have a slope of 1%, indicating that inlet control may govern flows. The measured depth from the invert to the surveyed high-water marks was approximately 18.9 feet. Using the Federal Highway Authority's Inlet Control Nomograph for concrete box culverts, a culvert flow of approximately 1,200-cfs is estimated based on the high-water marks. Using the surveyed high-water marks and comparing those to the elevation of the low point in the roadway, the flow overtopping the highway was estimated to be 3.2 feet deep during the maximum flow. Using a field-measured weir length of roughly 510-feet and averaging the depth of flow over the entire weir, the calculated flow over the roadway is approximately 3,100-cfs. This indicates a total peak flow (culvert and weir) of about 4,300-cfs.

Using the same methodology, the total flow upstream at the Highway 50 Bridge was approximately 5,200-cfs.

Regression equations, which relate the frequency of flood events to a flooding source's drainage area, are reported in the water resources investigation report entitled, "Analysis of the Magnitude and Frequency of Floods in Colorado," dated 2000 as prepared by the USGS in cooperation with the Colorado Department of Transportation and the Bureau of Land Management. According to this report, the Penrose area is located in the Plains region and therefore, the applicable regression equation for the 100-year recurrence interval is:

$$Q = 1640\ (A)^{0.388}$$

Where A, the drainage area, is expressed in terms of square miles.

At the Highway 115 bridge, the above regression equation indicates that the anticipated 100-year flow would be about 4,342-cfs. This compares favorably to the calculated flow based on high-water marks of about 4,300-cfs, indicating that the July flood event at the Highway 115 Bridge was equivalent to the 100-year flood. Although rainfall depths were reported in excess of the 100-year event, it is believed that these were likely localized rainfall amounts which were not necessarily indicative of the average rainfall that occurred over the entire drainage basin.

Estimated Flood Damages & Any Special Factors Affecting the Flood

Flood damage from this event occurred to a number of areas including:

- Erosion and loss of shoulders along County Road 67, also known as Phantom Canyon Road.
- Erosion and loss of shoulders along an 8-mile stretch of upper County Road 132.
- County Road 132 Culvert crossing washed out at Eightmile Creek crossing. Damage was also reported to buildings upstream of this crossing.
- County Road 123 Bridge over Eightmile Creek overtopped damaging the abutments. A residence upstream of this bridge also sustained damage.
- Highway 50 Bridge crossing at Eightmile Creek had erosion and debris damage with minor shallow utility damage.
- Highway 115 Bridge crossing at Brush Hollow Creek had major roadway damage causing the closure of the highway. Erosion and debris damage with minor shallow utility damage also occurred here.
- Damage to local commercial buildings, primarily an apartment complex near Broadway Street and Highway 115.

- Unspecified damage to Beaver Park Water District facilities, estimated to be less than $60,000.
- An access road to the Fremont Sanitation District air-drying site, southwest of Penrose was damaged when a storm water retention pond overflowed. The cost of repairing damages to the district's road and storage ponds was estimated to be less than $50,000.

It is noted that significantly greater damage might have occurred along Brush Hollow Creek without the storage and detention effects provided by the Brush Hollow Reservoir.

Flood Hazard Mitigation

A federal disaster declaration was not made for this event due to the limited geographic area of impact and due to the fact that damage costs did not reach levels that normally trigger a federal declaration.

Additional Support Information

Figure 1.20 – Brush Hollow Creek - Highway 115 Culvert Looking Upstream

Figure 1.21 – Brush Hollow Creek - Highway 115 Culvert Looking Downstream

Figure 1.22 – Brush Hollow Creek Highway 115 Culvert Overtopping

Figure 1.23 – Brush Hollow Creek Highway 115 Road Damage

Figure 1.24 – Brush Hollow Creek Highway 50 Bridge Looking Upstream
Note: high-water came up to low steel elevation resulting in minor overtopping of westbound lanes.

Figure 1.25 -- Brush Hollow Creek Highway 50 Bridge Looking Upstream – Utility Damage

Figure 1.26 – Brush Hollow Creek Highway 50 Bridge Utility Damage, Westbound Bridge

Figure 1.27 – Brush Hollow Creek Highway 50 Bridge – Eastbound Bridge
Note: no reported overtopping.

Figure 1.28 – Highway 50 Bridge – Eightmile Creek Looking Downstream
Note debris on top of pier cap.

Figure 1.29 – Highway 50 Bridge – Eightmile Creek Looking Upstream
Note minor erosion along toe of slope.

Figure 1.30 – County Road 123 at Eightmile Creek Bridge, Overtopping Upstream Face.

Figure 1.31 – County Road 123 Bridge – Eightmile Creek Bridge Overtopping, Downstream Face

Figure 1.32 – County Road 123 at Eightmile Creek Looking Upstream Towards Coffee Residence

Figure 1.33 – County Road 123 at Eightmile Creek Bridge Overtopping, Crest of Road at Bridge

Figure 1.34 – County Road 123 at Eightmile Creek, Downstream Wing-wall

NEWSPAPER ARTICLES

Source	Date	
The Pueblo Chieftain	July 6, 2006	
Colorado Springs Gazette	July 6, 2006	
The Denver Channel 7	July 6, 2006	
CDOT News Release	July 6, 2006	
Colorado Springs Gazette	July 6, 2006	
Canon City Daily Record	July 6, 2006	
The Pueblo Chieftain	July 7, 2006	
Colorado Springs Gazette	July 7, 2006	
Canon City Daily Record	July 7, 2006	
Canon City Daily Record	July 8, 2006	
National Weather Service	July 10,2006	
The Pueblo Chieftain	July 8, 2006	
9News	July 10,2006	
Canon City Daily Record	July 11, 2006	
Canon City Daily Record	July 12, 2006	
Canon City Daily Record	July 14, 2006	

FLOOD DOCUMENTATION REPORT – CHAPTER 2

Deckers, Colorado Flood of July 7th, 2006
West Creek
(Douglas County)

Introduction

On Friday night, July 7th, 2006, a large storm front extending along the foothills/plains interface of Douglas County produced a significant amount of rainfall that particularly impacted the Town of Deckers and the unincorporated areas of Douglas County adjacent to West Creek. There were confirmed rainfalls in excess of 2.3-inches occuring within a 3-hour period spanning 6:00 PM and 9:00 PM.

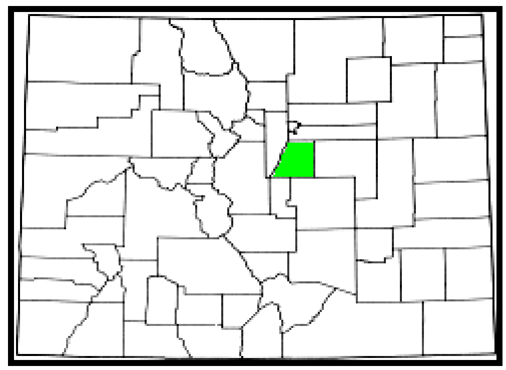


Figure 2.1 – Douglas County Location in the State of Colorado.
Map courtesy of the Colorado Herpetological Society.

Significant flooding was reported along West Creek which is a tributary to the South Platte River. The Town of Deckers lies near the West Creek/South Platte River point of confluence. A USGS gaging station on West Creek, approximately 10-miles upstream of the confluence with the South Platte River, recorded signficant flow increases. Extensive damage occurred to several county roads, culvert/bridge crossings, and highway structures on State Highway 67. In particular, the Highway 67 embankment and nearly all crossing structures were heavily damaged forcing the long term closure of the roadway. In addition to necessitating the re-building of nearly 10-miles of roadway, over 2-dozen small culverts (18-inch to 36-inch) were damaged to the point of requiring replacement, and an additional 30 to 40 other culverts required cleaning. CDOT estimated $17 million in damages to Highway 67. Several homes and out-bulidings were damaged along with the loss of bridges/culverts providing access to private land along the creek.

A water storage reservoir, know as the J.O. Hill Reservoir, experienced a rapid rise of water nearly to the crest of the dam. According to a USGS gage, which is located within the portion of West Creek which feeds the reservoir, the water rose over 4.1 feet in less than 2 hours. This led to a significant increase in water storage (approximately 50 acre-feet) however; the majority of flows continued unabated downstream of the dam through releases from the reservoir's emergency spillway.

Flooded Area Description

West Creek is located in southwestern Douglas County. Much of the tributary area was heavily burned as a part of the devastating 2002 Hayman Forest Fire.

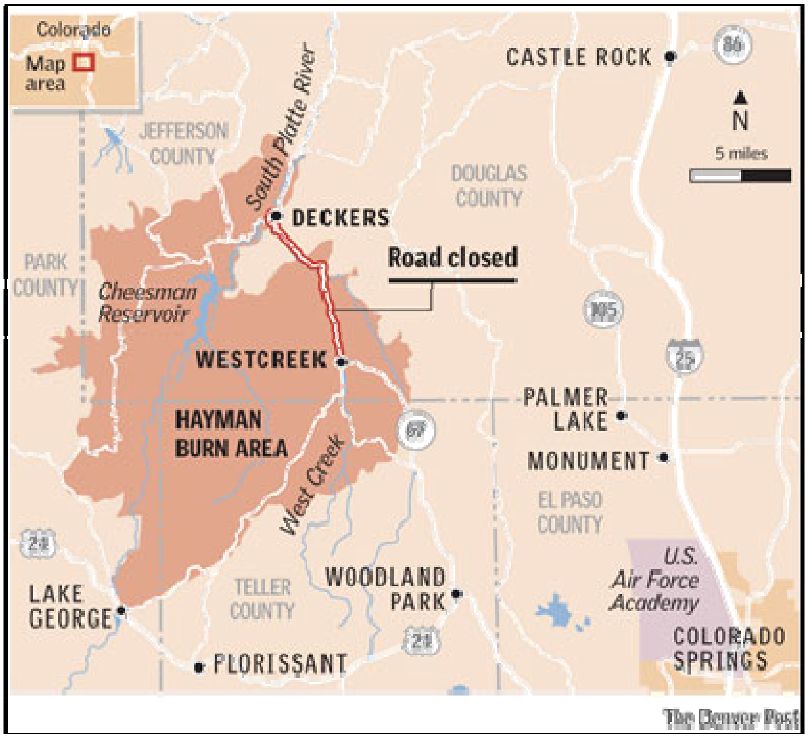


Figure 2.2 – Map of the Hayman Burn Area in Relation to SH 67 and West Creek.
Map courtesy of the Denver Post

Storm Characteristics and Rainfall Information

Information on storm characteristics, such as the recorded rainfall amount, was readily available for this event. Two separate field visits were conducted for this event which included talking directly to citizens and public officials regarding the characteristics of this storm. The personnel and dates of the site visits are listed below in Table 2.1.

Table 2.1 – Field visit dates and personnel.

Date of Site Visit	Entity Represented	Personnel
July 10, 2006	CWCB ICON Engineering	Kevin Houck Craig Jacobson Brian LeDoux
July 11, 2006	ICON Engineering	Penn Gildersleeve Brian LeDoux

Limited field surveying was also performed in order to obtain high-water marks and drainageway cross-sections along West Creek.

Total precipitation amounts for this storm event were obtained from several different sources. There are currently no volunteers in the West Creek area for the Community Collaborative Rain and Hail Study (CoCoRaHS) project so data from this source was unavailable. Figure 2.3 (below) shows the estimated weekly precipitation totals for the state of Colorado for the week including July 7th.

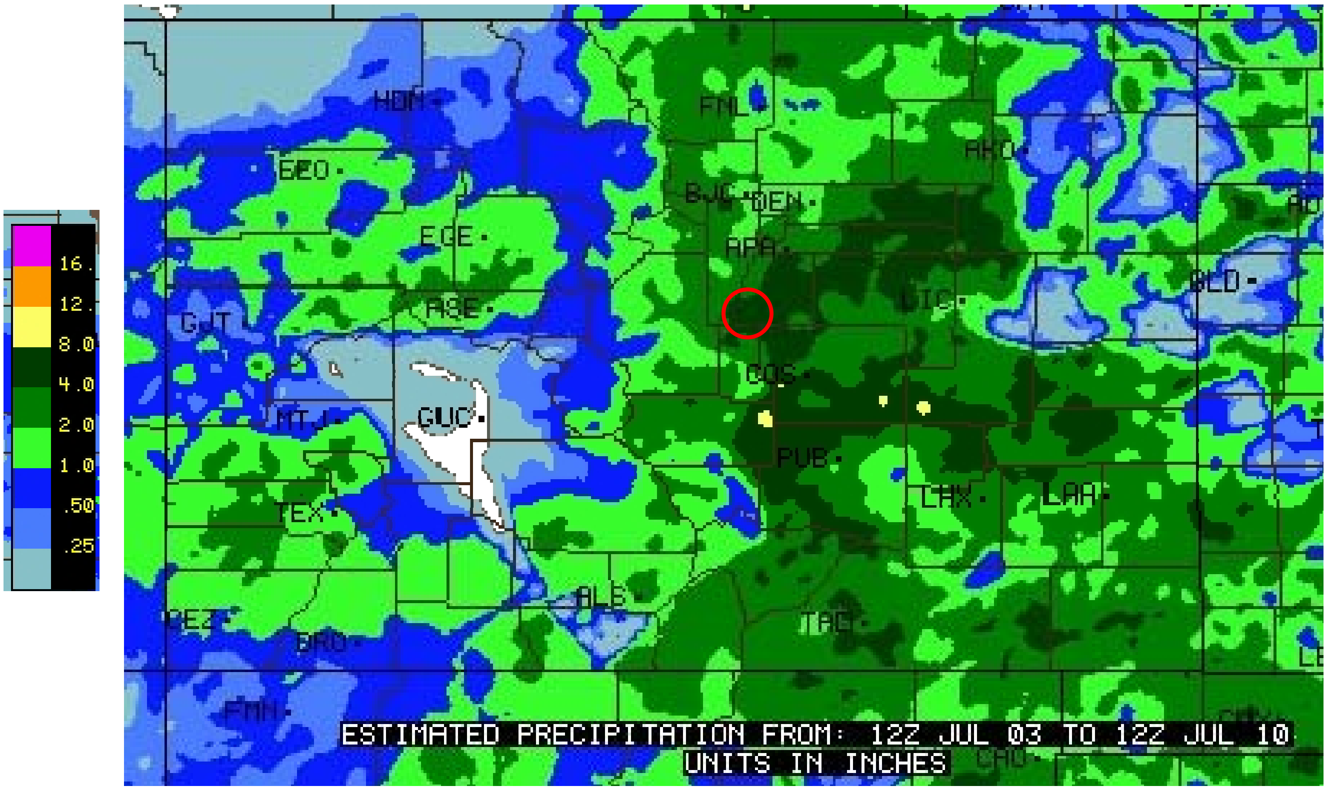
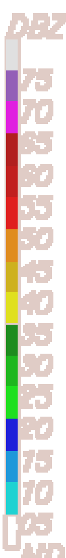


Figure 2.3 – Estimated Total Weekly Precipitation for the State of Colorado and Surrounding Area from July 3rd to July 10, 2006.
Map courtesy of www.intellicast.com

According to the National Climatic Data Center's NEXRAD radar images, a large front of severe storm activity formed in the mountains and intensified as it moved east. The storm front hit the Front Range area at approximately 5:00PM on July 7th and ended near 12:00PM the following day. The radar images are shown on the following pages, in Figures 2.5 through 2.14. The legend adjacent to Figures 2.5 and 2.7 indicates that the higher color numbers relate to higher precipitation intensities from the storm. In order to locate Deckers on the NEXRAD radar images, Figure 2.4 contains a map of the state of Colorado with the Deckers area marked with a red pushpin.

Figure 2.4 – Map of the Deckers Area in Relation to the State of Colorado.
Map courtesy of the Microsoft Live Local website.



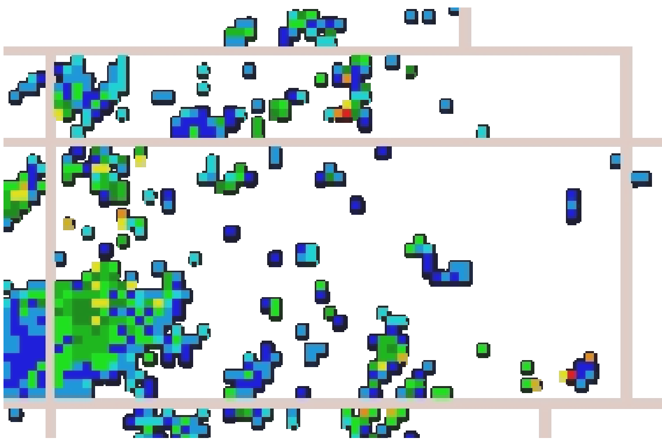


Figure 2.5 – State of Colorado NEXRAD Radar Image July 7, 2006 at 3:00PM MDT

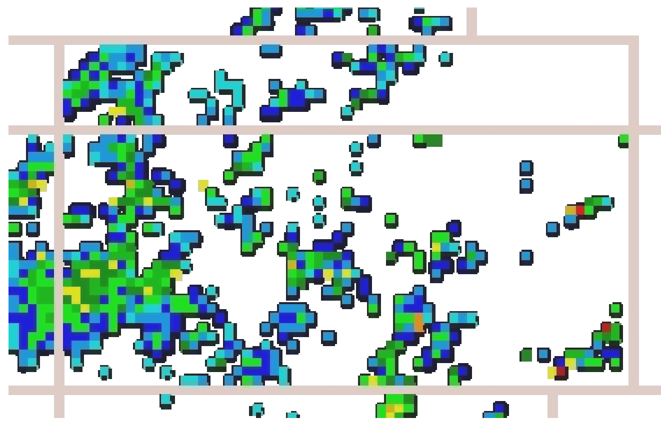


Figure 2.6 – State of Colorado NEXRAD Radar Image July 7, 2006 at 4:00PM MDT

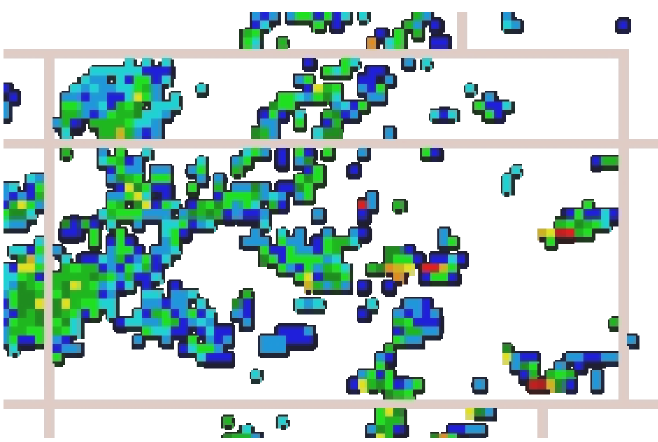


Figure 2.7 – State of Colorado NEXRAD Radar Image July 7, 2006 at 5:00PM MDT

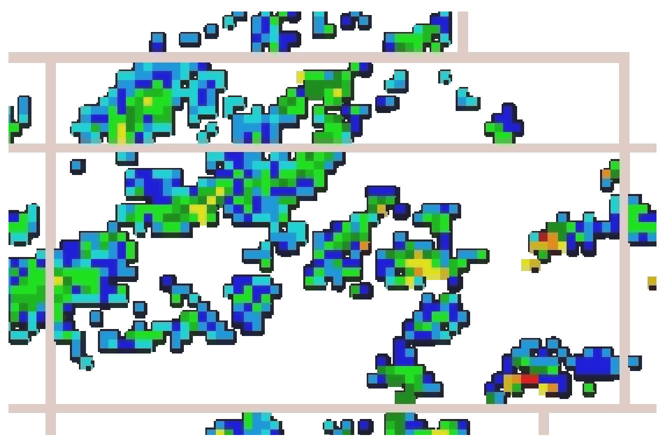


Figure 2.8 – State of Colorado NEXRAD Radar Image July 7, 2006 at 6:00PM MDT

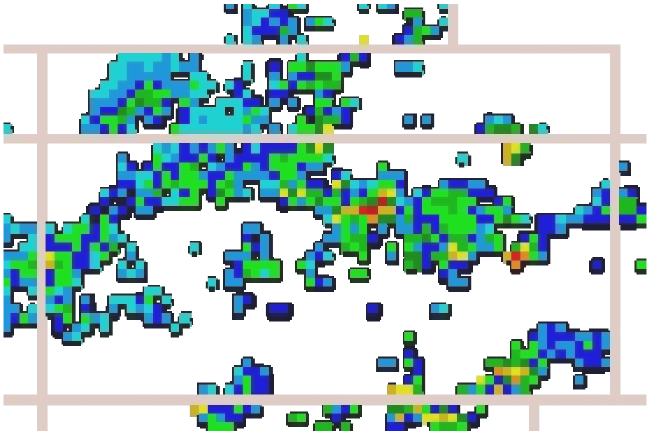


Figure 2.9 – State of Colorado NEXRAD Radar Image July 7, 2006 at 7:00PM MDT

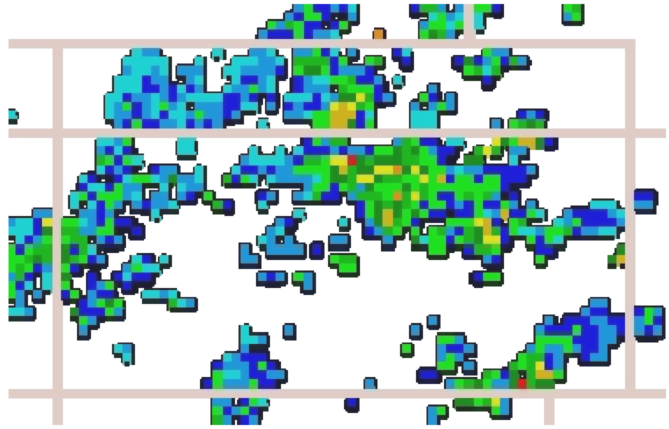


Figure 2.10 – State of Colorado NEXRAD Radar Image July 7, 2006 at 8:00PM MDT

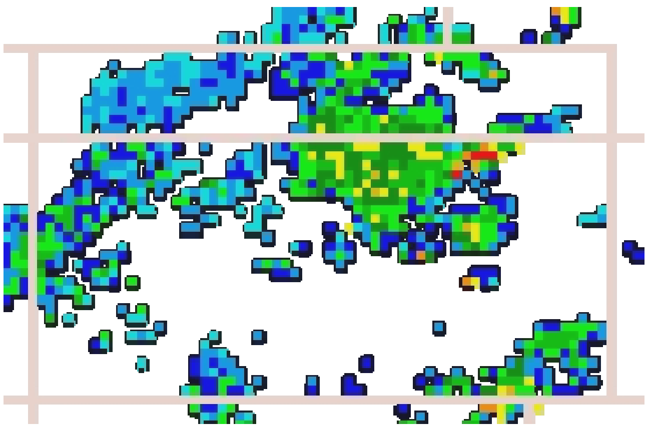


Figure 2.11 – State of Colorado NEXRAD Radar Image July 7, 2006 at 9:00PM MDT

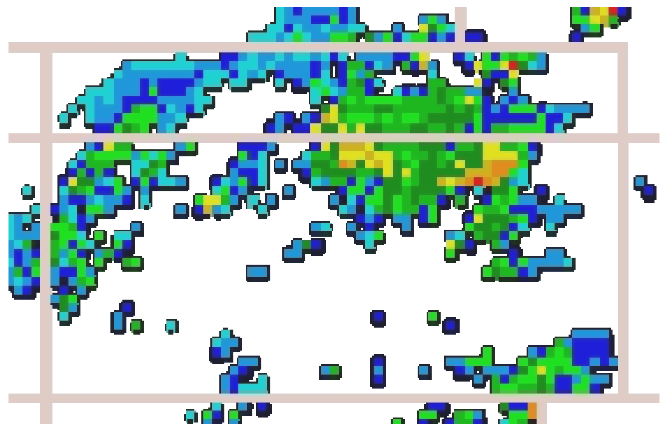


Figure 2.12 – State of Colorado NEXRAD Radar Image July 7, 2006 at 10:00PM MDT

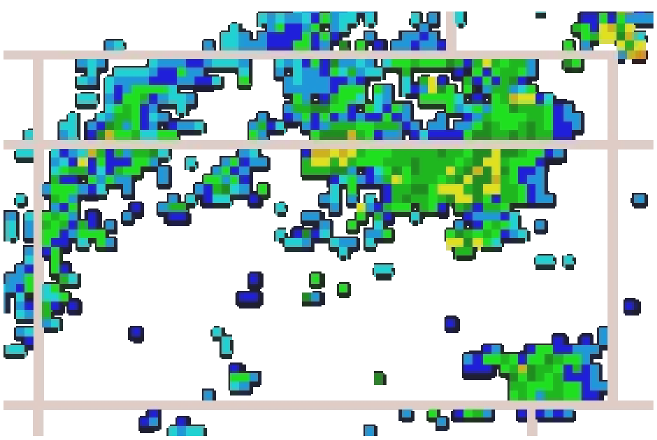


Figure 2.13 – State of Colorado NEXRAD Radar Image July 7, 2006 at 11:00PM

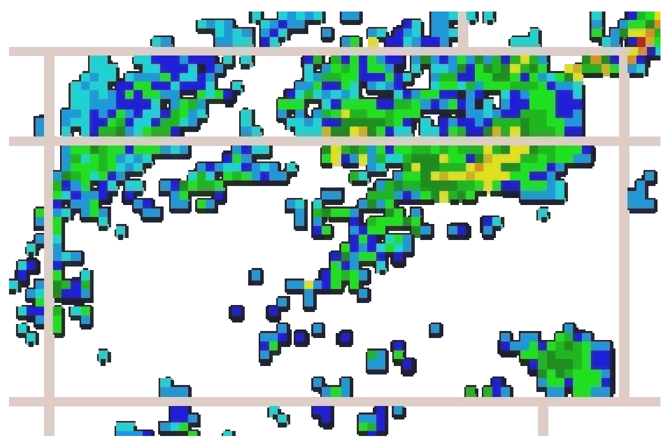


Figure 2.14 – State of Colorado NEXRAD Radar Image July 8, 2006 at 12:00AM MDT

Hydrologic and Hydraulic Investigations

As a result of the 2002 Hayman fire, this area has been the subject of a recent hydrology and hydraulic analysis sponsored in part by Douglas County and the Colorado Water

Conservation District. A 100-year floodplain boundary for West Creek was plotted on new LIDAR based mapping obtained for the study. Copies of the workmaps and HEC-RAS hydraulic model were provided for this report courtesy of Moser & Associates Engineering.

Peak flow estimates from the July 2006 event were estimated using the following three methods:

- Calibration of the Moser HEC-RAS hydraulic model using multiple high-water marks on the overtopped roadway at several locations along the lower 10-miles of West Creek
- Surveyed high-water marks at the J.O. Hill Dam emergency spillway located directly on West Creek
- Calculation of flows through and over the Abbey Avenue culvert and roadway located downstream of the J.O. Hill Dam using a combination of weir and inlet control hydraulic calculations. This area was selected as being representative of the flood event in that the road and culvert created a backwater with easily discernable high-water marks.

Each of the methods is discussed in more detail below.

HEC-RAS Model: During a site visit on July 11th, locations where the water crossed Highway 67 were noted using a handheld GPS unit. These high-water marks were then plotted on the 100-year floodplain map obtained from Moser & Associates Engineering. Cross-sections at these locations were then inserted into the HEC-RAS model, and multiple runs completed in an effort to match flows to observed high-water marks. This analysis indicated that flows ranged anywhere from about 1,500 cfs to 6,000 cfs. The high variability of the flows is indicative of the radically turbulent, supercritical flow that created the high-water marks. It is also worth mentioning that the high-water marks could have been influenced by any of the following:

- Debris
- Bank erosion
- High-water marks left by local flows rather than main channel flows of West Creek
- Turbulent waves and/or superelevation around bends

J.O Hill Dam: The J.O Hill Dam and reservoir is located approximately 10-miles upstream of the Town of Deckers. The reservoir is owned by the West Creek Water District and is located directly on West Creek. The drainage area tributary to the dam is approximately 56 square miles. This dam falls under the jurisdiction of the State Engineer's office and is classified as a "Small, Class 2 dam". The dam has an embankment height of 29-feet, a normal reservoir capacity of 154 acre-feet, and a maximum capacity of approximately 250 acre-feet of storage. An emergency spillway is located on the right abutment and has a 2-feet wide concrete-crest weir leading to a baffle block energy dissipating chute. The design drawings call for the spillway crest and wingwalls to be 5.5-feet above the crest. Actual field measurement of the constructed spillway indicates that the actual height of the wingwalls is closer to 5.3 feet. The spillway has a maximum capacity of approximately 2900-cfs corresponding with 5.3-feet of head. This spillway is concrete-lined and has a 75-feet wide crest. Figure 2.15 (below) was taken from the dam construction drawings.

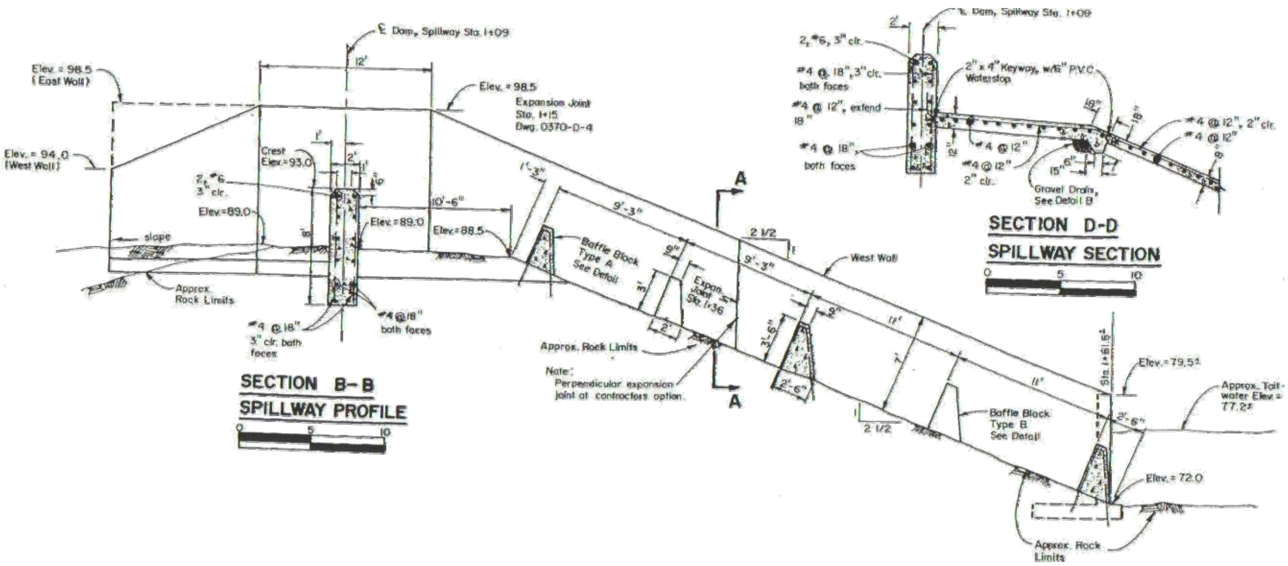


Figure 2.15 – J.O. Hill Dam Spillway Design

A USGS reservoir and precipitation gage is located upstream of the dam crest along the bank of the reservoir. Based upon the information provided by the State Engineer's office, a total of 2.28 inches of precipitation was recorded (with a corresponding maximum outflow of 2170-cfs) from 6:00PM to midnight on July 7, 2006. It is worth noting that the method for determining the flow rate was not indicated. Table 2.2 summarizes this data and Figure 2.16 shows a graph of the gage height at this location.

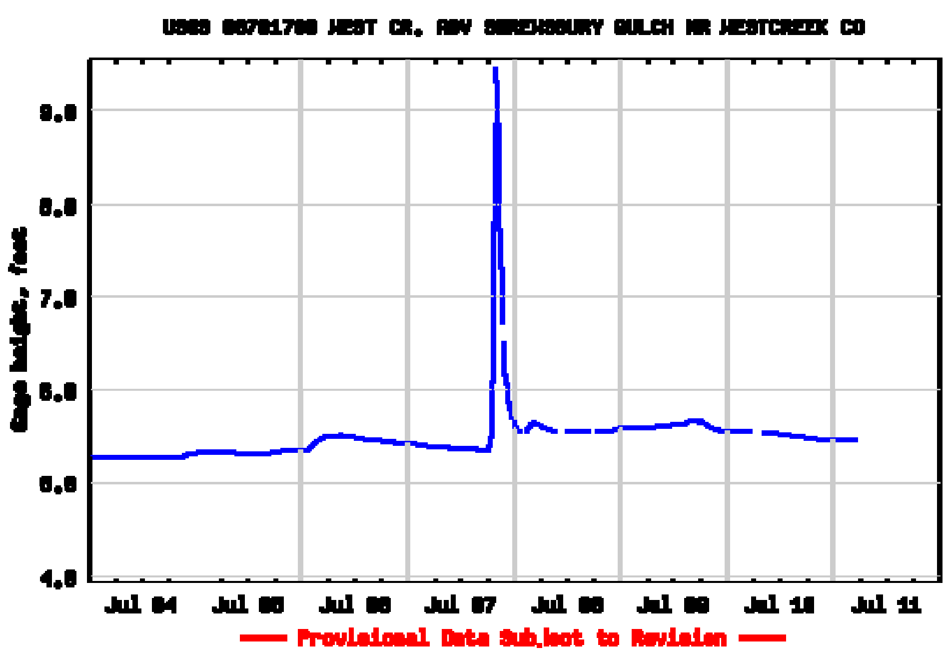


Figure 2.16 – Gage Height at USGS Gage Located Upstream of the J.O. Hill Dam

Table 2.2 – Precipitation and Flow at J.O. Hill Reservoir
Data furnished by Dam Safety Branch of State Engineer's office, Memorandum dated 7/10/06 from Bill McCormick to Mark Haynes

Date	Time	Gage Height (ft)	Precipitation (in.)	Flow (cfs)
7/7/06	18:00	5.36	0.00	13
	18:15	5.36	0.02	13
	18:30	5.42	0.42	22
	18:45	5.55	0.98	45
	19:00	5.63	0.56	62
	19:15	6.53	0.11	357
	19:30	9.06	0.04	1860
	19:45	9.46	0.04	2170
	20:00	9.17	0.02	1940
	20:15	8.56	0.03	1500
	20:30	7.96	0.01	1110
	20:45	7.5	0	834
	21:00	7.15	0	6.45
	21:15	6.86	0	503
	21:30	6.62	0	395
	21:45	6.41	0	308
	22:00	6.24	0	244
	22:15	6.11	0	198
	22:30	6	0	162
	22:45	5.91	0.02	135
	23:00	5.84	0	115
	23:15	5.78	0.01	99
	23:30	5.73	0.02	86
	23:45	5.68	0	73
7/8/06	0:00	5.65	0	66
		TOTAL PRECIPITATION =	2.28	

According to the State Engineer's office, the existing spillway for the dam was rebuilt following a failure due to a overtopping that occurred in 1976. The hydrology study for the dam and spillway indicates that the inflow-design-flood for the spillway design was 2,550-cfs of runoff resulting from a 6-hour, 2.28-inch storm which occurred over the entire basin producing 0.41-inches of excess precipitation. It is interesting to note that the total recorded rainfall at the reservoir was 2.28-inches which occurred over a 6-hour period. However, most of the total rainfall (2.23-inches) occurred within a 3-hour time period.

During the July 7th flood event, the reservoir was filled nearly to capacity but the flows did not overtop the dam. On July 11th, 2006, ICON Engineering, Inc. (ICON) surveyed some high-water marks on the face of the dam which indicate that the water-level in the reservoir rose to a depth of 3.56-feet above the crest of the emergency spillway which was within 1.4-feet of the designed crest elevation of the dam. Observations made after the storm event also indicate that the low-point of the dam crest was actually less than the elevation called out in the design drawings for the dam. Further field observations indicate that the reservoir came to within 0.5-foot of overtopping at the dam low-point. After the July 7th flood, this low point, which was adjacent to the emergency spillway, received several loads of fill which built-up the crest of the dam.

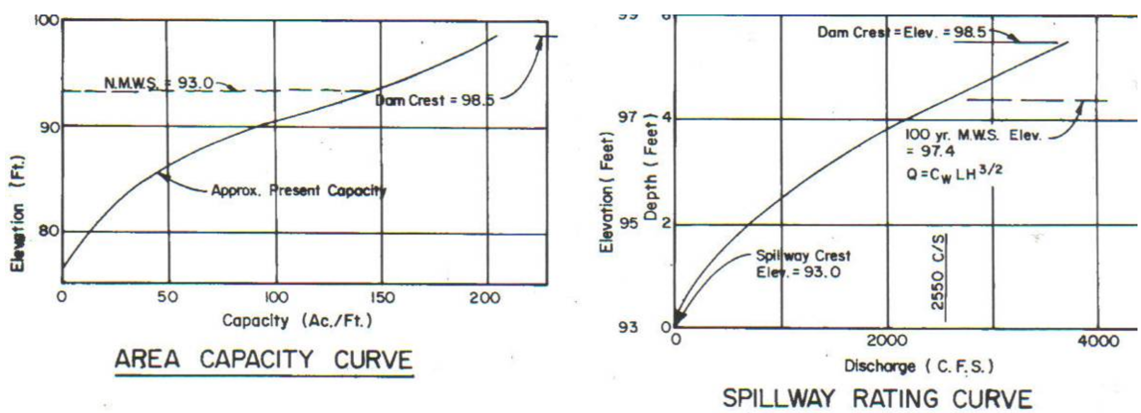


Figure 2.17 – Area Capacity and Spillway Rating Curves for the J.O. Hill Dam Spillway

Figure 2.17 shows the area capacity curve and spillway rating curve taken from the dam design drawings. Note that the elevations shown in the design drawing curves are not necessarily on the same vertical datum as the USGS Gage information provided in Table 2.2.

The spillway rating curve in Figure 2.17 shows that the 100-year maximum water-surface was designed to be at an elevation of 97.4, with a corresponding discharge of 2550-cfs, and a depth of flow equal to 4.4-feet above the spillway crest. Using this depth and discharge, the spillway crest length of 75-feet, and the design weir equation of: $Q=C_w LH^{3/2}$, the design value of C_w can then be determined as 3.68. Next, using the flow equation taken from the design drawings of the emergency spillway and the field surveyed high-water marks, the calculated flow over the crest at the height of the flood can be calculated.

$$Q=C_w LH^{3/2} \quad \text{or}$$
$$Q_{flood} = (3.68)(75)(3.56)^{3/2}$$
$$Q_{flood} = 1854 \text{ cfs}$$

Based upon the information provided, it appears that the maximum flow over the spillway was somewhere in the range of 1,850 to 2,170-cfs.

Using the point rainfall information obtained from the State Engineer's office (Table 2.2), a hydrologic analysis could also be performed using available baseline data from NOAA Atlas 2 in order to generate Intensity Duration Frequency, or IDF, curves for rainfall events within the Deckers area. Using the peak rainfall amount of 2.23 inches and the duration for that amount (3 hours) one can estimate the frequency as an event less than the 100-year event.

Abbey Avenue Culvert: Abbey Avenue crosses West Creek just upstream of Highway 67 and downstream of the J.O Hill Reservoir. Prior to the storm, the roadway had an 84-inch and a 48-inch corrugated-metal-pipe (CMP) culvert at this location. These culverts, and the gravel roadway above them, were extensively damaged during the flood. High-water marks upstream of the roadway indicate that the roadway crossing created a large backwater area behind the roadway before the road was eventually overtopped. ICON was not able to determine the degree to which the culverts were plugged with debris, nor could they determine the time frame between the creation of the high-water marks and the culvert/road failure. However, for the purposes of this analysis, ICON assumed that the road and culvert were intact at the time of the high-water.

Figure 2.18 – Picture of Abbey Avenue Crossing Along West Creek before July 7, 2006 Flood
Picture courtesy of Moser and Associates Engineering

Using the Moser provided HEC-RAS model to prepare a rating curve for this reach of the creek, and assuming varying percentages of culvert capacity resulting from debris, the surveyed high-water marks upstream indicate the flow to be between 2,700-cfs (85% of culvert depth blocked) and 3,000-cfs (un-obstructed). Due to the relatively long weir width represented by the roadway, the rating curve is fairly sensitive to the depth of flow used in the weir calculation. Changes in the elevation of the high-water marks of as little as plus or minus 0.2-feet, result in a reduction or increase of calculated flow of approximately 500-cfs.

An effective FEMA Flood Insurance Study (FIS) was published in September 2005 for Douglas County which included the results from the Moser hydraulic analysis for West

Creek. According to the Summary of Discharges Table in the FIS, flows were calculated for the 100-year event only and included three flow changes along West Creek. Together with the calculated peak discharges mentioned above, this information was used to estimate the frequency of the July 7th event.

A summary of the results from the hydraulic and hydrologic analyses is shown in Table 2.3. Since the analysis based on the J.O. Hill Dam produced several peak flow estimates and a measured point rainfall value at the dam, both sets of data were analyzed and are shown in the table below.

Table 2.3 – Hydrologic and Hydraulic Investigation Results

SOURCE	Est. Flow (cfs)	Est. Storm Frequency
Method 1: HEC-RAS Model Cailbration Based on Surveyed High-water Marks	1,500 to 6,000	1.1 to 4.8 Times the 100-Year Event
Method 2a: J.O. Hill Dam Point Rainfall Analysis (2.23 inches in 3 Hours)	--	Less Than the 100-Year Event (~ 87-Year)
Method 2b: J.O. Hill Dam Spillway Analysis	1,850 to 2,170	1.5 to 1.75 Times the 100-Year Event
Method 3: Abbey Avenue Culvert Analysis	2,700 to 3,000	2.2 to 2.4 Times the 100-Year Event

Table 2.3 shows that there was some variation in the frequency analysis depending on the data source used however, the analysis clearly identifies that the July 7th event was a severe storm for this area.

Estimated Flood Damages & Any Special Factors Affecting the Flood

Damage from this event was extensive with total costs ranging from an estimated $17 million (according to CDOT) to a total of $20 million (according to the Douglas County Office of Emergency Management). An 8 to 10-mile section of State Highway 67 from West Creek to Deckers had to be closed for up to 4 months as repairs were made to the highway and the various crossings along the creek.

At least 5 homes were declared total losses with damage reported to several outbuildings along the West Creek corridor. In addition, nearly all road crossings along this stretch of highway sustained moderate to severe damage ranging from overtopping and erosive damage to total destruction of the crossing.

The J.O Hill Dam and Reservoir, which is located approximately 10-miles upstream of the Town of Deckers, is thought to have had an impact on the flow within West Creek as the reservoir is estimated to have provided 50-acre-feet of storage for the July 7th event.

The 2002 Hayman Fire was a unique factor that likely affected the storm event analyzed in this report. In fact, it is reasonable to conclude that the damage from this fire caused, or at least increased, the effects from this storm but, taking into account the severity of the storm (around a 100-year event), it is unknown how much of an impact the fire actually had on the severity of this specific storm.

Flood Hazard Mitigation

A state disaster declaration was made for this event which allowed access to state and federal funds for emergency assistance. CDOT was also expected to ask for emergency federal funds to aid in the repair costs to SH 67.

Additional Support Information

Figure 2.19 – West Creek – J.O. Hill Reservoir Emergency Spillway

Figure 2.20 – West Creek – High-water Mark on USGS Gaging Station at J.O. Hill Reservoir

Figure 2.21 – West Creek – Private Bridge Downstream of J.O. Hill Reservoir

Figure 2.22 – West Creek – Bailey Residence at 15590 West Creek Road. Box culvert is 16' x 6' in size. Water surface was 6 to 8-inches above first floor level in house.

Figure 2.23 – West Creek – J.O Hill Reservoir Emergency Spillway Panorama. High water mark is approximately 12-inches below wall.

Figure 2.24 – West Creek – High-water Mark on Residence Upstream of Culvert Crossing at Abbey Avenue.

Figure 2.25 – West Creek – Abbey Road Crossing

Figure 2.26 – West Creek – Miller Residence at 14570 West Creek Road. Water ponded behind Abbey Road up to approximately 4-feet above garage slab.

Figure 2.27 – West Creek - Highway 67 Culvert Looking Upstream

Figure 2.28 – West Creek - Highway 67 Shoulder Damage
Photo courtesy of CDOT

Figure 2.29 – West Creek Highway 67 Shoulder Damage
Photo courtesy of CDOT

Figure 2.30 – West Creek Highway 67 Road Damage

Figure 2.31 – West Creek - Highway 67 Box Culvert Damage

Figure 2.32 – West Creek - Highway 67 Damage

Figure 2.33 – West Creek - Highway 67 Damage

Figure 2.34 – West Creek - Highway 67 Damage

Figure 2.35 – West Creek – Private Road Crossing. Note proximity of Hayman burn.

Figure 2.36 – West Creek – Private Residence Isolated by Bank Erosion

Figure 2.37 – West Creek – Highway 67 Road Overtopping

Figure 2.38 – West Creek – Highway 67 Road Damage

Figure 2.39 – Picture Taken of State Highway 67 along West Creek during July 7th Flood
Photo Courtesy of the Douglas County Office of Emergency Management

Figure 2.40 – Picture Taken of Residence along West Creek during July 7th Flood
Photo Courtesy of the Douglas County Office of Emergency Management

Figure 2.41 – Picture Taken of Residence along West Creek during July 7th Flood
Photo Courtesy of the Douglas County Office of Emergency Management

Figure 2.42 – Picture Taken of Residence along West Creek during July 7th Flood
Photo Courtesy of the Douglas County Office of Emergency Management

Figure 2.43 – Panoramic Pictures Taken from Road Crossing on July 11th of Residence in Pictures 2.40 thru 2.42

Figure 2.44 – Picture Taken from Upstream of Box Culvert at Road Crossing on July 11th

NEWSPAPER ARTICLES

Source	Date	
9-News	July 10th, 2006	
7-News	July 8th, 2006	
9-News	July 7th, 2006	
Denver Post	July 8th, 2006	
Denver Post	July 11th, 2006	
Denver Post	July 10th, 2006	
Denver Post	July 9th, 2006	
Rocky Mountain News	July 8th, 2006	
Rocky Mountain News	July 10th, 2006	

FLOOD DOCUMENTATION REPORT – CHAPTER 3

East Of Grand Junction, Colorado Flood of August 1st, 2006
Bosley Wash
(Mesa County)

Introduction

On August 1, 2006, James C. Smith, 84 of Murray, Utah , was killed near Interstate 70 east of Grand Junction, when a car driven by his wife, Ruth, 86, may have hydroplaned on mud and rain and rolled several times. Reportedly, the Smith's car left I-70 on the north side of the highway and flipped over, nearly submerging in a pond of water and mud that had formed at the Bosley Wash culvert crossing under the highway. Mr. Smith was unfortunately trapped upside down in the car. His death was later ruled a drowning.

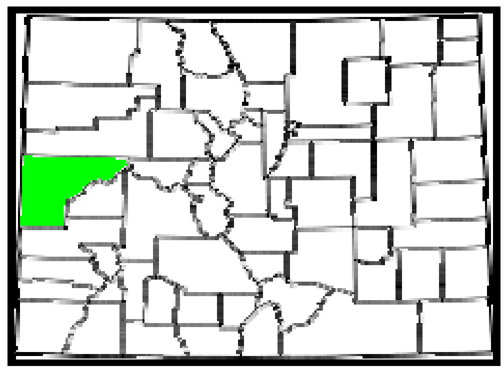


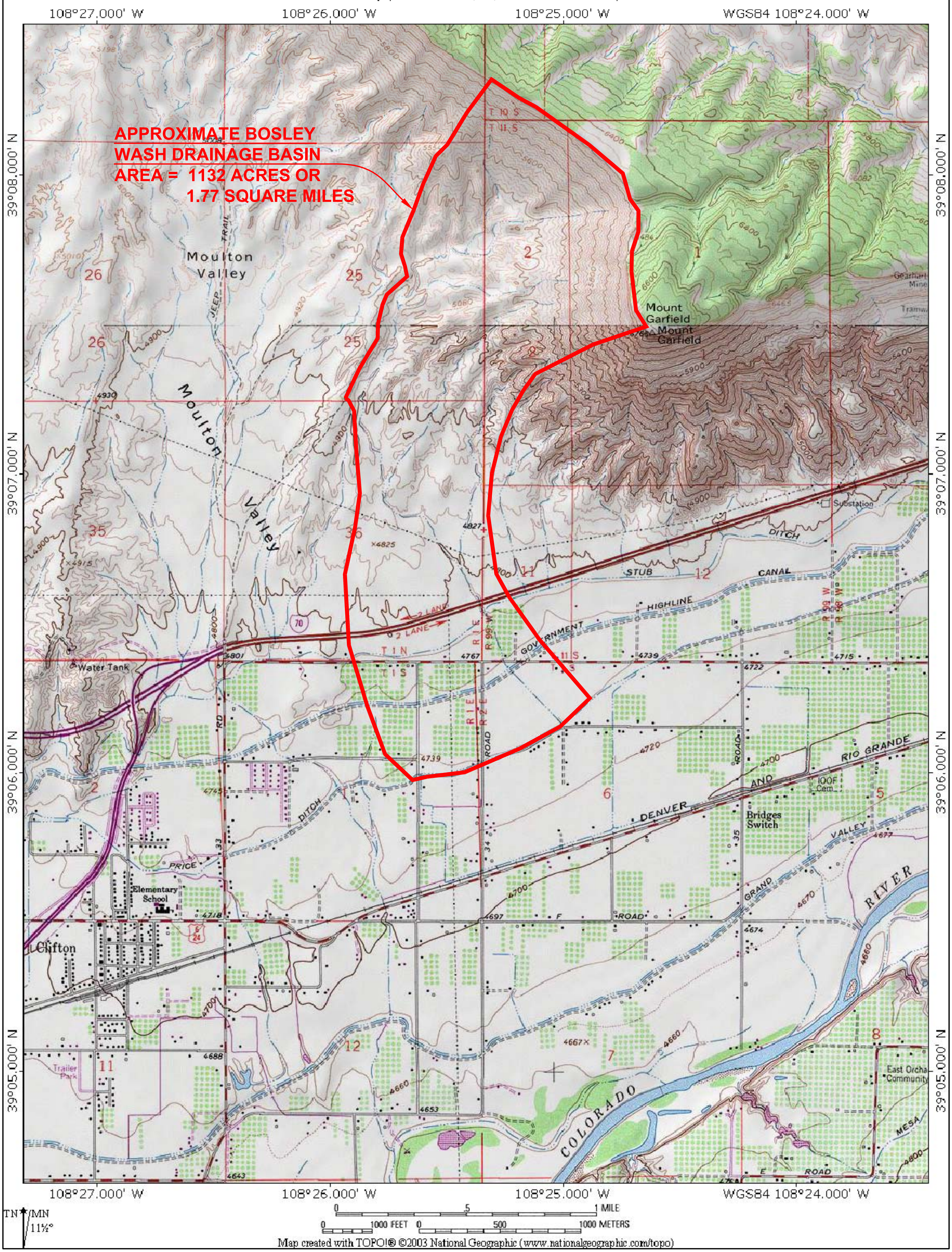
Figure 3.1 – Mesa County Location in the State of Colorado.
Map courtesy of the Colorado Herpetological Society.

This is in the area where a storm hit Mt. Garfield and stalled resulting in a brief but intense rainstorm over the Bosley Wash Basin. Although there were no reported rain gage data in the immediate vicinity, the Airport (approximately 3 miles west) had 0.2 to 0.5 inches of rain the previous day, followed by an additional 0.3 inches of rain on the 1st, which reportedly came within a 45 minute period. There were unsubstantiated reports that the rainfall in the basin resulted in a total of 1" to 2" of rainfall. According to officials with the 5-2-1 Drainage Authority, this storm is similar to events that have occurred on a regular basis over the last 6 or 7 years.

Bosley Wash crosses the Interstate in an 8-feet high by 6-feet wide reinforced concrete box culvert. Apparently, the peak flows from the runoff event did not entirely "crest" the Interstate, but apparently encroached upon the outside right-hand lane of traffic. Run-off off the flank of Mt. Garfield was mixed with mud that had a bulking effect. There is a delineated floodplain for this drainage basin; however it is not a FEMA regulated one. According to reports, the culvert did not get plugged with debris. The Bosley Wash Drainage Master Plan estimated that the culvert has a capacity of approximately 470-cfs. Based on observed depths of flow in the culvert, the culvert flowed at near capacity. The 100-Year frequency flow for the basin at this location is estimated to be about 1,700 cfs. A General Location Map of the area is shown on Figure 3.2, and an approximate location of the Bosley Wash Drainage Basin is shown on Figure 3.3.

Figure 3.2 – Vicinity Map of Bosley Wash Area
Map courtesy of Google Maps

TOPO! map printed on 08/01/07 from "Untitled.tpo"



There is essentially no development upstream (north) of Interstate 70. Damage downstream (south) of the culvert crossing was mostly related to mud and debris deposition. No local residents were reported to have been displaced from there homes.

Three properties where significant damage was reported include:

- Cynthia Thompson – 10- to 14-inches of deposited silt
- Gene Elder – Damaged septic tank and leach field
- Bill Baker – Silt in crawl space

The Basin Authority provided a rough estimate for the cost to cleanup the mud and debris at about $25,000.

Flooded Area Description

Mesa County provided the figure on the next page (Figure 3.4), which shows land parcels near Bosley Wash which reported damage from the storm. No apparent structural damage was noted. In addition to the death of Mr. Smith, damage appeared limited to accumulated mud and debris.

Location and Watershed Description

Bosley Wash is a north-bank tributary to the Colorado River. The point of confluence is approximately five river miles upstream along the Colorado River above Grand Junction.

Storm Characteristics and Rainfall Information

Information on storm characteristics, such as the recorded rainfall amount, was not readily available for this event. Any available information was provided by personnel from CDOT (Stuart Gardner), the 5-2-1 Basin Authority (John Ballagh), and Mesa County. A field visit was conducted by ICON Engineering, Inc., personnel on August 10th, 2006, which included talking directly to citizens and public officials regarding the characteristics of this storm.

Total precipitation amounts for this storm event were obtained from several different sources including both amateur weather data monitoring volunteers and national weather bureaus. According to the data produced by the Community Collaborative Rain and Hail Study, (CoCoRaHS) which is a science education project managed by the Colorado Climate Center at Colorado State University and driven by volunteer participants, total rainfall amounts in the Mesa County area ranged from a trace up to 0.4 inches for August 1st. These reported rainfall amounts, as well as their respective locations in relation to the County, are shown in Figure 3.5.

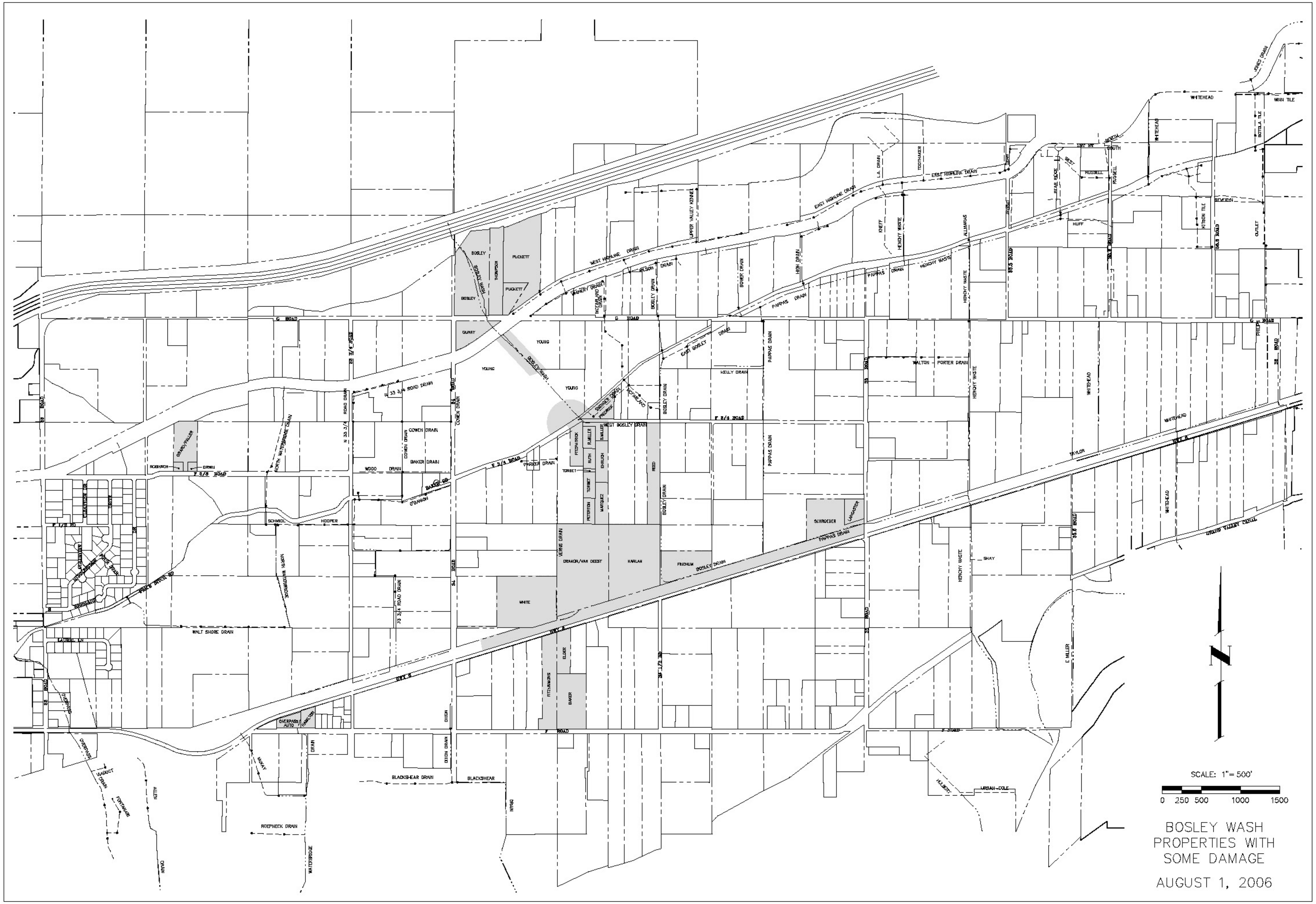


Figure 3.4 – Bosley Wash Properties with Some Damage from August 1, 2006 Storm
Map courtesy of Mesa County.

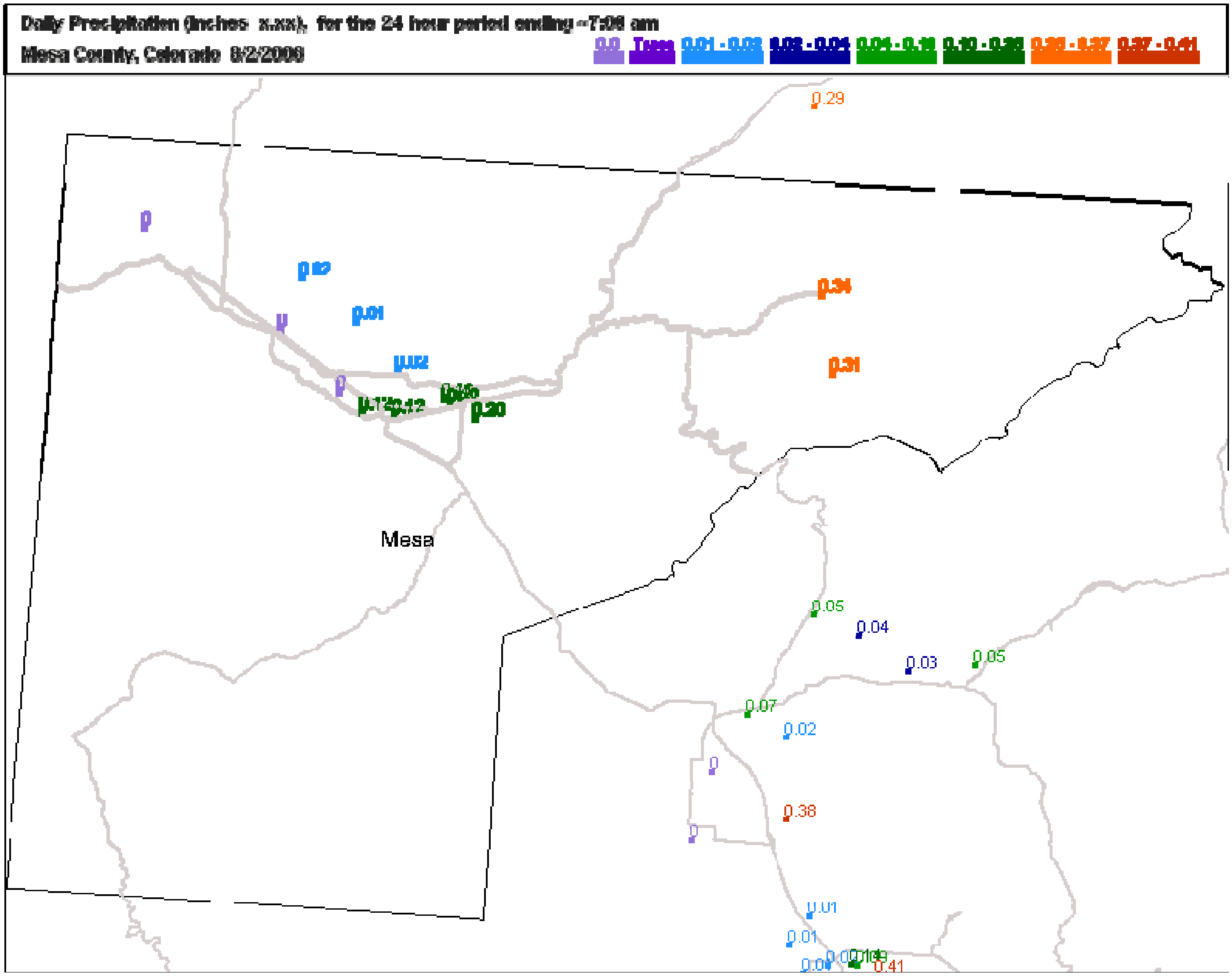


Figure 3.5 – Mesa County, Colorado CoCoRaHS Map for 24-Hour Period Ending 7:00AM on 8/2/2006

Flood Hazard Mitigation

A federal disaster declaration was not made for this event due to the limited geographic area of impact and due to the fact that damage costs did not reach levels that normally trigger a federal declaration. A Drainage Master Plan for the Bosley Wash area was prepared prior to the rainfall event. The primary structural recommendation from that report was the construction of a detention pond upstream of the I-70 culvert. Conceptual level designs of several pond locations and sizes were examined in the Master Plan, ranging in size, and resulting peak flow attenuation as follows:

Pond Option	Storage Capacity (acre-feet)	Flow Release Rate (cfs)	Construction Cost (2003 dollars)
1. Large Pond	75.5	50	$1,150,000
2. Intermediate	63.5	100	$980,000

Pond – Option A			
3. Intermediate Pond –Option B	57.5	150	$900,000
4. Small Pond	48.5	300	$775,000

As of the date of this report, final design of improvements has not been initiated.

Additional Support Information

Note: All photos courtesy of CDOT

Figure 3.6 – Bosley Wash – I-70 Culvert looking west along north side of road.

Figure 3.7 – Bosley Wash – I-70 Culvert looking east along north side of road.

Figure 3.8 – Bosley Wash – I-70 Culvert mud level on guard rail

Figure 3.9 – Bosley Wash – I-70 High-water mark on guard rail, upstream end of culvert

Figure 3.10 – Bosley Wash – I-70 Ponding along northern edge of roadway

Figure 3.11 – Bosley Wash – I-70 Ponding along northern edge of roadway

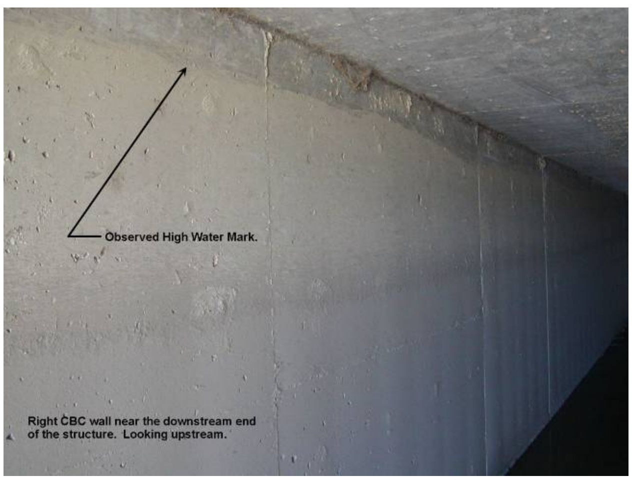


Figure 3.12 – Bosley Wash – I-70 Culvert Highwater Marks

Figure 3.13 – Bosley Wash – I-70 Culvert Highwater Marks

Figure 3.14 – Panorama picture looking upstream of I-70 Culvert

FLOOD DOCUMENTATION REPORT – CHAPTER 4

Pueblo, Colorado Flood of August 26th, 2006
Wild Horse Creek
(Pueblo County)

Introduction

On Saturday August 16th, 2006, a rainstorm moving east from Fremont County into the City of Pueblo impacted several drainage watersheds in the area including the Wild Horse and Dry Creek Basin. Rainfall totals for the City ranged from 0.52 inches to as much as 3 inches of reported precipitation.

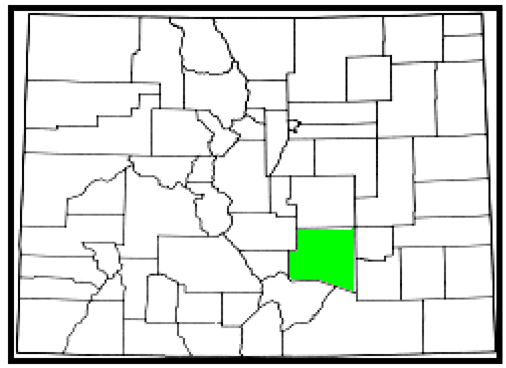


Figure 4.1 – Pueblo County Location in the State of Colorado.
Map courtesy of the Colorado Herpetological Society.

Reports indicate damage to several businesses and several breaks in a levee along the Arkansas River were also reported. According to local news agencies, the Peppersauce Bottoms neighborhood seemed to experience the most damage due to flooding with reports of heavy sedimentation and several basements inundated by as much as 3 feet of standing water. Additional low-lying areas throughout the City were flooded requiring the rescue of several motorists from their vehicles. Several injuries due to the storm were reported with the worst one from a falling tree.

Flooded Area Description

Most areas of the City experienced varying degrees of flooding and/or damage related to this storm. Figure 4.2 shows a vicinity map of the Wild Horse Creek area where some of the damage was reported. Figure 4.3 shows an overall view of the Pueblo area with the reported injuries called out as well as the reported flooding in the Peppersauce Bottoms neighborhood.

Figure 4.2 – Vicinity Map of Wild Horse Creek Area
Map courtesy of Google Maps

Figure 4.3 – Map of the Pueblo Area with Flooding and Injury Locations
Map courtesy of Google Maps

Storm Characteristics and Rainfall Information

Information on storm characteristics, such as the recorded rainfall amount, was readily available for this event. A field visit to the Wild Horse Creek area was conducted on October 26, 2006, by ICON Engineering, Inc., personnel. The visit included talking directly to citizens and public officials regarding the characteristics of this storm. The personnel and date of the site visit is listed below in Table 4.1.

Table 4.1 – Field visit dates and personnel.

Date of Site Visit	Entity Represented	Personnel
October 27, 2006	ICON Engineering	Justen Hamann Brian LeDoux

Limited field surveying was also performed during the site visit in order to obtain high-water marks and drainageway cross-sections along Wild Horse Creek. More information regarding the site visit is discussed in the next section of this report.

Total precipitation amounts for this storm event were obtained from several different sources including both amateur weather data monitoring volunteers and national weather bureaus. According to the data produced by the Community Collaborative Rain and Hail Study, (CoCoRaHS) which is a science education project managed by the Colorado Climate Center at Colorado State University and driven by volunteer participants, total rainfall amounts in City of Pueblo area ranged from 0.52 inches to 2.11 inches for the 24-Hour period of August 26th. These reported rainfall amounts, as well as their respective locations in relation to the Pueblo County area, are shown on the next page in Figure 4.4.

According to an article by the Pueblo Chieftain, which was published on August 27th, 2006, recorded rainfall amounts ranged from 1 inch in Blende to up to 3 inches according to the National Weather Service (NWS). It is unknown what location the NWS used for its reported precipitation amount.

According to the National Climatic Data Center's NEXRAD radar images, a large front of severe storm activity formed in the mountains and intensified as it moved east. According to the NEXRAD images, the storm front hit the Pueblo area sometime after 5:00PM on August 26th and continued moving east leaving the Pueblo area sometime after 7:00PM. The radar images are shown on the following pages, in Figures 4.6 through 4.12. The legend adjacent to Figures 4.7 and 4.9 indicates that the higher color numbers relate to higher precipitation intensities from the storm. In order to locate the City of Pueblo on the NEXRAD radar images, Figure 4.5 contains a map of the State of Colorado with the Pueblo area marked with a red pushpin.

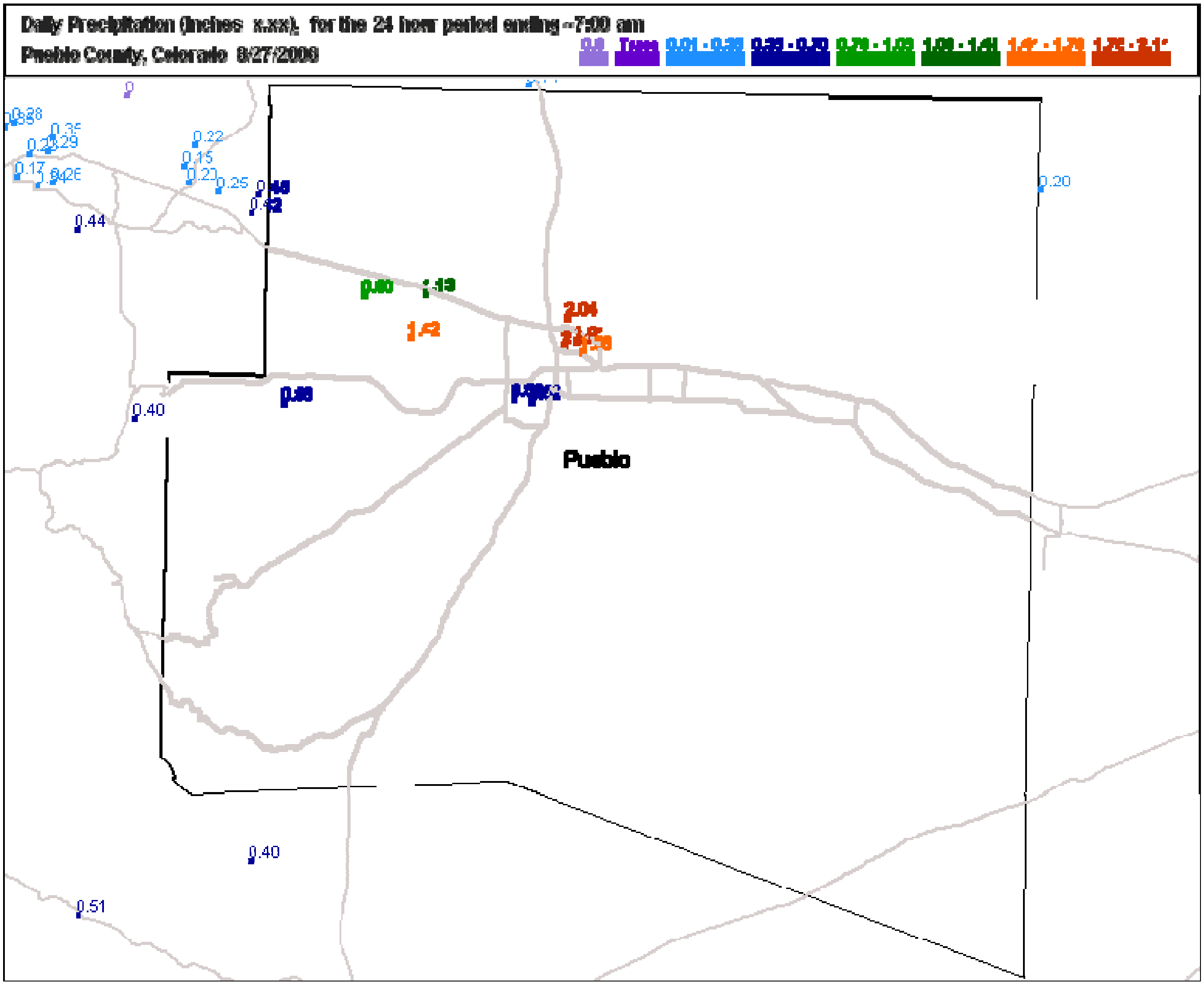


Figure 4.4 – Pueblo County, Colorado CoCoRaHS Map for 24-Hour Period Ending 7:00AM on 8/27/2006

Figure 4.5 – Map of the City of Pueblo in Relation to the State of Colorado.
Map courtesy of the Microsoft Live Local website.

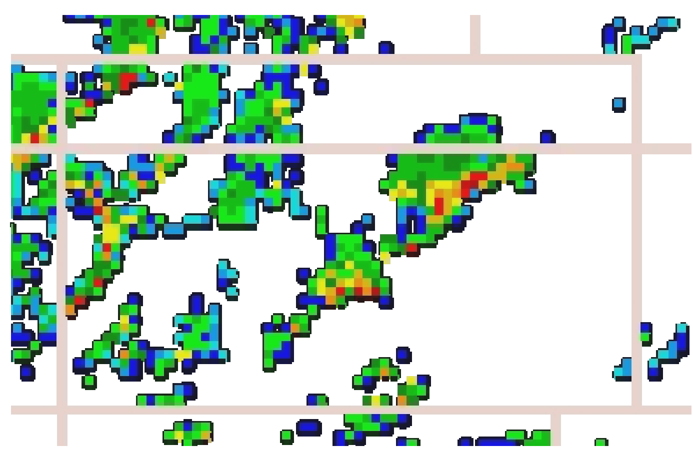
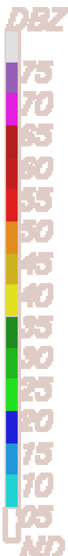


Figure 4.6 – State of Colorado NEXRAD Radar Image August 26, 2006 at 4:00PM MDT



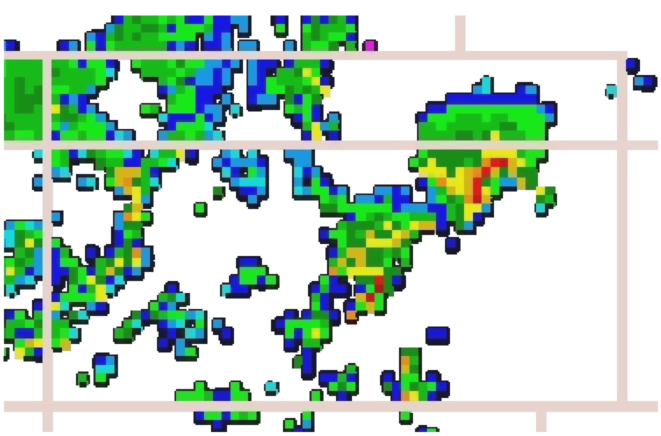


Figure 4.7 – State of Colorado NEXRAD Radar Image August 26, 2006 at 5:00PM MDT

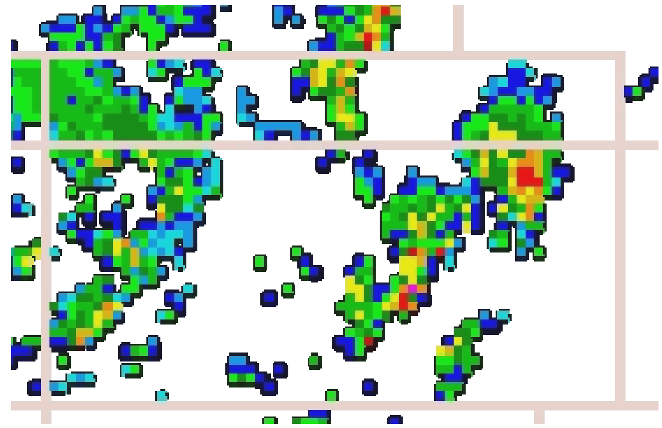


Figure 4.8 – State of Colorado NEXRAD Radar Image August 26, 2006 at 6:00PM MDT

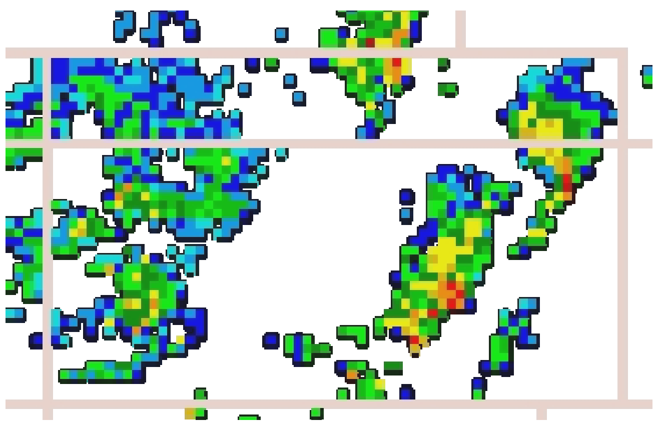


Figure 4.9 – State of Colorado NEXRAD Radar Image August 26, 2006 at 7:00PM MDT

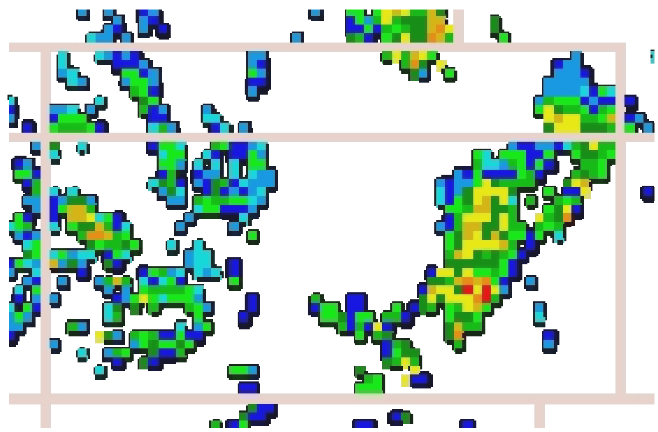


Figure 4.10 – State of Colorado NEXRAD Radar Image August 26, 2006 at 8:00PM MDT

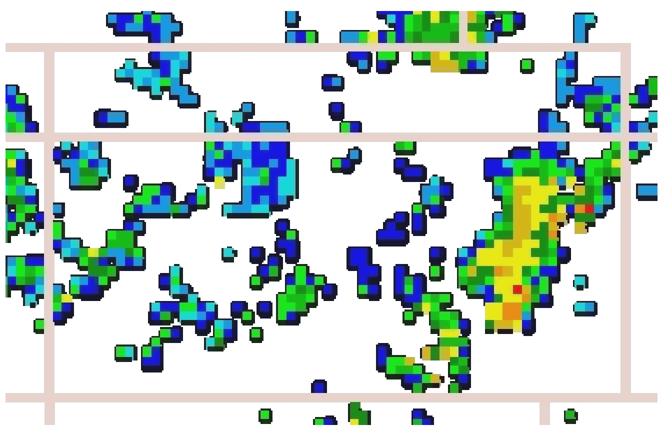


Figure 4.11 – State of Colorado NEXRAD Radar Image August 26, 2006 at 9:00PM MDT

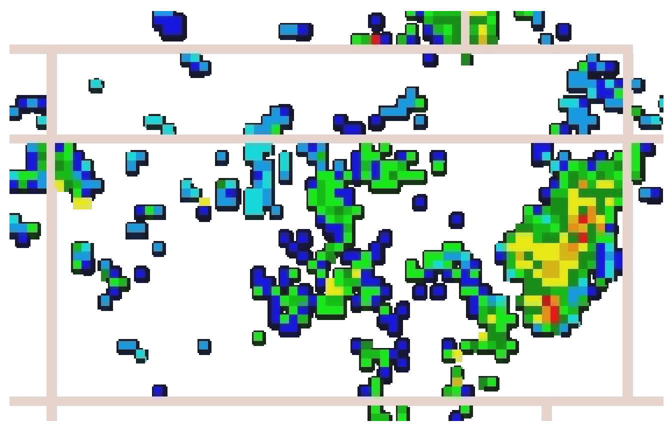


Figure 4.12 – State of Colorado NEXRAD Radar Image August 26, 2006 at 10:00PM MDT

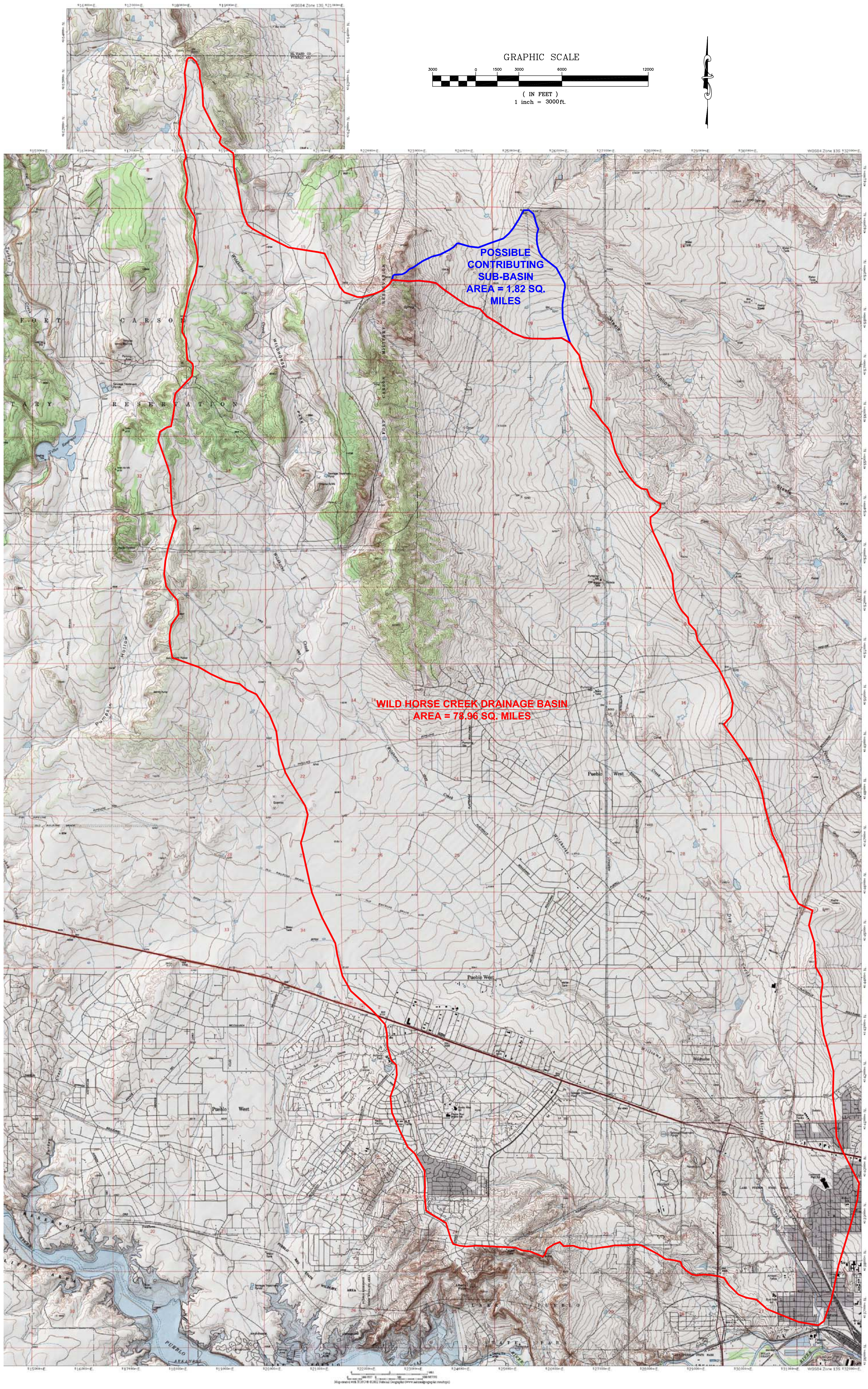
Hydrologic and Hydraulic Investigations

As previously mentioned, a field visit was conducted in order to determine the elevation of high-water marks. In addition, several typical hydraulic cross-sections were also surveyed along the locations of known high-water marks. With this information, a normal depth calculation was then used in order to estimate the peak flows in Wild Horse Creek during the August 26th event.

In summary, the normal depth calculations indicate that the peak flows ranged from a low of 1,124-cfs to as high as 3,790-cfs. The variation in the peak flow estimates is the result of different high-water mark locations along the drainageway (different cross-section locations) as well as different high-water mark elevations on each side of the channel at the same cross-section (left-bank vs. right-bank elevations). It is also worth mentioning that the variation in flows could also be attributed to other factors such as the accuracy of the observed high-water marks. The field survey did not take place until a month after the flood event so it is likely that the visible high-water mark locations were slightly different than what they might have been right after the flood. City personnel did mark the visible high-water marks for later survey however, they also informed us that they mowed one bank of the channel area and then “repositioned” the flags marking the high-water and this likely lead to some discrepancies in the high-water elevations.

Once the flow estimates were obtained, known discharges for specific storm frequencies were needed for comparison purposes. Wild Horse Creek is currently mapped as a detailed study area by FEMA which includes known discharges at various locations along the drainageway. According to the effective Flood Insurance Study for the City of Pueblo (dated September 29, 1986), the discharges for Wild Horse Creek just downstream of the Denver and Rio Grande Western Railroad (the closest location to the surveyed high-water marks) are 39,500-cfs, 19,500-cfs, 14,000-cfs, and 5,700-cfs for the 500-, 100-, 50-, and 10-Year events respectively. Since the 10-Year FEMA Discharge is significantly more than the maximum estimated discharge of 3,790-cfs, another flow source had to be used for comparison purposes.

Using a USGS TopoQuad Map for the area, the estimated drainage basin for Wild Horse Creek was then calculated (see Figure 4.13) as 78.96 square miles. A small sub-basin was noted during the basin delineation process which, according to the contours, appeared to flow into the Wild Horse Creek drainage basin however, the quad map also showed some small ditches for this sub-basin which appear to impact another basin entirely. Therefore, this sub-basin was not included in the regression calculations although it is marked in blue in Figure 4.13.



GRAPHIC SCALE
3000 0 1500 3000 6000 12000
(IN FEET)
1 inch = 3000ft.
POSSIBLE
CONTRIBUTING
SUB-BASIN
AREA = 1.82 SQ.
MILES
WILD HORSE CREEK DRAINAGE BASIN
AREA = 78.96 SQ. MILES
FORT CARSON
MILITARY RESERVATION
Pueblo West

Using this information, and the Regression Equations published in the report entitled "USGS Report 99-4190, Analysis of the Magnitude and Frequency of Floods in Colorado," the flow estimates for Wild Horse Creek were calculated as follows:

Table 4.2 – Regression Equation Flow Results

2-Year Frequency	**326 cfs**
5-Year Frequency	**1,119 cfs**
10-Year Frequency	**2,093 cfs**
25-Year Frequency	**4,074 cfs**
100-Year Frequency	**8,934 cfs**

These flows are significantly less than the ones published in the effective FEMA FIS. In fact, the FEMA flows are on the order of 2 to 3 times as much as the regression equation flows. It is unknown why there is such a large discrepancy between the two sets of flows. An update to the City of Pueblo FIS (which includes new hydrology) is currently being performed during the DFIRM conversion for the county although it is unknown how the DFIRM flows for this drainageway will compare to the effective FIS flows or the flows calculated using the regression equations.

Using the estimated flows from the normal depth calculations, and the two sets of known discharges, a frequency for the August 26th event can be estimated. The results are summarized below in Table 4.3.

Table 4.3 – Hydraulic Investigation Results

COMPARISON SOURCE	Known Flow (cfs)	Known Frequency	Est. Flow (cfs)	Est. Storm Frequency
Effective FEMA Flood Insurance Study Summary of Discharge Table	5,700	10-Year	1,124	Less Than the 10-Year Event
	14,000	50-Year	3,790	Less Than the 10-Year Event
USGS Regression Equations	1,119	5-Year	1,124	5-Year Event
	2,093	10-Year	3,790	Greater Than the 10-Year Event but Less Than the 25-Year Event
	4,074	25-Year		

Estimated Flood Damages & Any Special Factors Affecting the Flood

Damage from this event varied according to the respective location in the City. Several businesses sustained damage to their roofs requiring the closure of the business until repairs could me made. Reports of downed power poles and trees were seen throughout the City. Debris accumulation and sedimentation was most prevalent at bridge and culvert crossings for major drainageways. A levee along the Arkansas River had several breaks attributed to the storm but no property damage was reported. The most extensive damage was reported in the Peppersauce Bottoms neighborhood where at least a dozen homes sustained damage from a wall of mud and water.

Flood Hazard Mitigation

A federal disaster declaration was not made for this event due to the limited geographic area of impact and due to the fact that damage costs did not reach levels that normally trigger a federal declaration.

Additional Support Information

Figure 4.14 – Wild Horse Creek – Park (West) Side of Typical Cross-section

Figure 4.15 – Wild Horse Creek – Natural Grassland (East) Side of Typical Cross-section

Figure 4.16 – 18th Street Bridge – Eastern Culvert at Wild Horse Creek

Figure 4.17 – 18th Street Bridge – Middle Culvert at Wild Horse Creek – Note sediment and trash.

Figure 4.18 – Upstream Panoramic Picture of 18th Street Bridge at Wild Horse Creek

Figure 4.19 – Downstream Panoramic Picture of 24th Street Bridge at Wild Horse Creek

Figure 4.20 – Panoramic Picture of 1st Surveyed Cross-section Along Wild Horse Creek

Figure 4.21 – Panoramic Picture of 2nd Surveyed Cross-section Along Wild Horse Creek

NEWSPAPER ARTICLES

Source	**Date**	
Pueblo Chieftain	**August 27th, 2006**	
Pueblo Chieftain	**August 31st, 2006**	
Pueblo Chieftain	**August 31st, 2006**	
Denver Post	**March 11th, 2007**	