II. THE BOULDER CREEK DRAINAGE BASIN

This section provides an overview of the watersheds and flood hazards associated with Boulder Creek and South Boulder Creek including descriptions of the drainage basins, historic floods, flood hydrology and flooding extents. Much of the information in this section of the warning plan was excerpted from the following flood studies:

1. *Early Flood Warning Planning, Boulder Creek* by Leonard Rice Consulting Water Engineers, July, 1977.
2. *Boulder Creek Flood Hazard Area Delineation* by Muller Engineering Company, January, 1983.
3. *South Boulder Creek Flood Hazard Area Delineation* by Greenhorne & O'Mara, Inc., July, 1986.
4. *South Boulder Creek Major Drainageway Planning, Alternative Formulation and Evaluation, Phase A Report* by Taggart Engineering Associates, Inc., January, 2001.

The following documents contain additional hydrologic data, flood history discussions, floodplain delineations and other pertinent information:

1. Boulder County and CWCB, Floodplain Information Report, Upper Boulder Creek and Fourmile Creek, prepared by Gingery Associates, Inc., December, 1981.
2. FEMA, Flood Insurance Rate Map (FIRM) and Flood Insurance Study for the City of Boulder, Revised May 3, 1990.
3. FEMA, Flood Insurance Rate Map (FIRM) and Flood Insurance Study for the Boulder County, Revised July 3, 1990.
4. UDFCD, Flood Hazard Area Delineation, Lower Boulder Creek, prepared by Muller Engineering Company, March, 1983.
5. UDFCD, Flood Hazard Area Delineation, Boulder and Adjacent County Drainageways, prepared by Greenhorne & O'Mara, Inc., May, 1987.

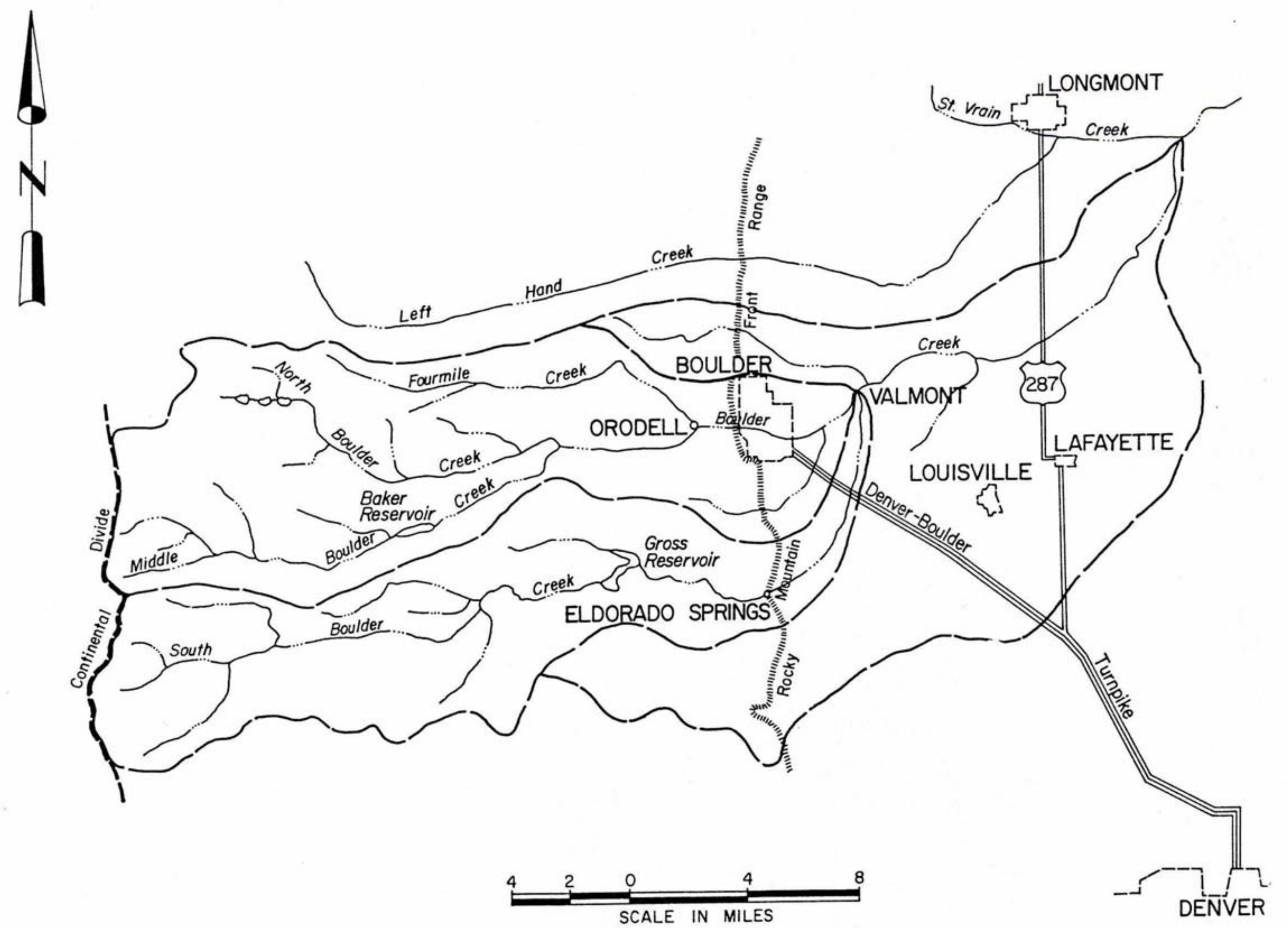
Drainage Basin Descriptions

BOULDER CREEK

Originating at the Continental Divide, the Boulder Creek basin encompasses 132 square miles above the City of Boulder. The basin is oriented in a generally west to east direction and includes the major tributaries of North Boulder Creek (45 square miles), Middle Boulder Creek (44 square miles) and Fourmile Creek (24 square miles). Figure II-1 shows the Boulder Creek drainage basin boundary.

Figure II-1

Boulder Creek Watershed



Within the basin there is scattered development along the streams. Nederland, the largest mountain town west of Boulder, is located on Middle Boulder Creek immediately above Barker Reservoir. Further upstream along Middle Boulder Creek is the town of Eldora and the Lake Eldora Ski Area. The communities of Sunnyside and Silver Spruce are located on Boulder Creek downstream of Barker Reservoir and the communities of Sunset, Wallstreet and Crisman are located along Fourmile Creek. The settlement called Orodell is located at the confluence of Fourmile Creek with Boulder Creek. Transportation routes within the basin include State Highway 119, which follows Middle Boulder and Boulder Creeks between Nederland and Boulder, State Highway 72 which runs north/south through Nederland, and County Road 118 which extends along Fourmile Creek.

Numerous small lakes fed by melting snows occur in the higher portions of the basin. Barker Reservoir, owned by the City of Boulder, stores water for electric power generation at a plant further downstream and for municipal water for the City of Boulder. A number of glaciers exist at the Continental Divide.

The Boulder Creek basin ranges in elevation from 13,409 feet above mean sea level at Navajo Peak to approximately 5,385 feet at Boulder. The basin is predominantly mountains and foothills, characterized by steep streams with rock and gravel beds. Fifteen percent of the basin lies above 11,000 feet and 46% above 9,000 feet. Main channel slopes average 2½% - 5% for Boulder Creek, 4% - 8% for North Boulder Creek, 2½% - 8½% for Middle Boulder Creek and 4% - 10% for Fourmile Creek.

Because of the steep slopes and generally elongated basins, Boulder Creek and its principal tributaries are susceptible to flash floods caused by high intensity, short duration thunderstorms which generally occur from May through September. Rainfall rates from such storms can exceed the infiltration capacity of the surface soil, producing large runoff in short periods of time. When high runoff converges on a stream, it generally exceeds the carrying capacity of the normal channel, resulting in flooding of the adjacent floodplain.

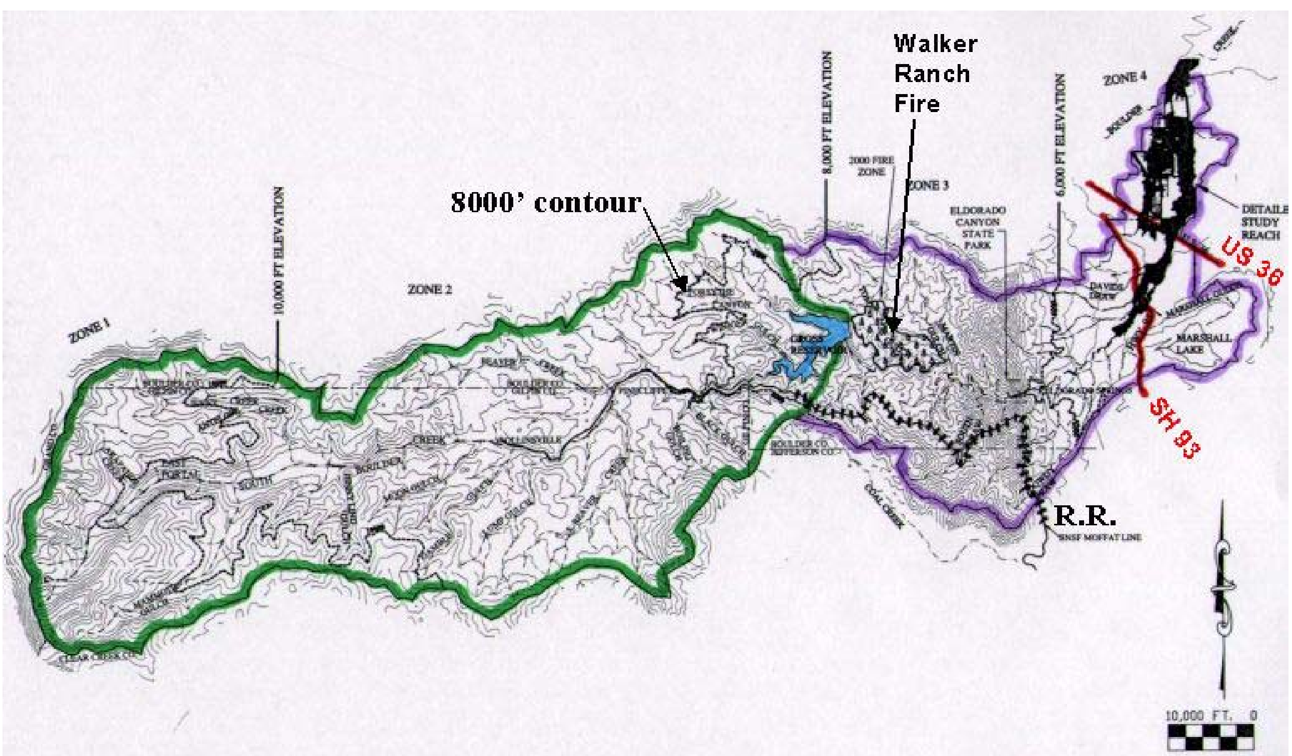
SOUTH BOULDER CREEK

South Boulder Creek, which drains an area of 132 square miles, is a right-bank tributary of Boulder Creek. From its headwaters at the Continental Divide, South Boulder Creek flows in an easterly direction through relatively steep, narrow mountain canyons for nearly 22 miles whereupon it emerges onto the high plains at Eldorado Springs, Colorado. From Eldorado Springs, the creek flows northeasterly through a moderately wide valley over a distance of about 9.7 miles to its confluence with Boulder Creek.

Gross Reservoir is a water storage facility located on South Boulder Creek approximately 3.5 miles upstream of Eldorado Springs. The reservoir was constructed in 1955 and has a storage capacity of 43,000 acre-feet. The reservoir is operated by the Denver Water Department and provides conservation storage for municipal use. A U.S. Geological Survey stream gaging station is situated approximately 6.7 miles downstream of the reservoir. The drainage area at the gaging station is about 109 square miles.). Figure II-2 shows the South Boulder Creek drainage basin boundary.

Figure II-2

South Boulder Creek Watershed



Flood History

BOULDER CREEK

Since 1864, the City of Boulder has experienced five major flood events on Boulder Creek, ranging in estimated discharge from 2,500 cubic feet per second (cfs) to 13,000 cfs, resulting in light to severe property damage. All floods for which dates are known occurred in either May or June. The flood of June 1894 was the flood of record at Boulder and had an estimated peak discharge of 13,000 cfs. The estimated frequencies of these five major events range between 10- and 100-years as determined from discharge probability relationships developed by the U.S. Army Corps of Engineers (COE). The following is a brief description of what is known of each of these five major flood events:

1876, May 21-23

Little is known about the 1876 flood. The Greeley Tribune reported: "*The Boulder, swollen into a great river, in many places fully a mile and a half wide, inundated the land and farms and meadows and swept away fences and bridges.*"

1894, May 29 - June 2

Heavy rains fell over the northern Colorado mountains in this period. Rainfall over the Boulder Creek basin was particularly heavy. Mountain rainfall of 4.5 to 6 inches combined with snowmelt runoff from heavy snowfall. The resulting flood came roaring down the valley during the night of May 30.

In the mountains above Boulder, numerous bridges, several miles of roads and railroads, mountain communities, and mining properties were damaged. Estimates were made of the peak discharge of this flood 18 years after its occurrence. These ranged from 9,000 to 13,000 cfs.

In Boulder, floodwaters covered the entire area between Water Street (now called Canyon Boulevard) and University Hill to depths as great as eight feet. Every bridge in Boulder and a number of residences were swept away. Other types of damage included: commercial establishments, public utilities, railroad property, roads and streets, and irrigation structures. Many people were trapped in their homes and had to be rescued. Only one life was lost; this was due, in part, to the flood's slow onset.

In the valley downstream from Boulder, the floodplain was reported to have inundated an average width of approximately one-mile for several days. Agricultural damages included: loss of livestock, crops, pastures, fences, roads, and deposition of sand and silt on floodplain lands. In addition, considerable crop losses were suffered on lands outside the floodplain which were dependent on irrigation diversions from Boulder Creek.

1914, June 1-2
Heavy rains in the mountains that hastened the melting of a deep snowpack, estimated at 50 percent above normal, produced what newspaper accounts called "the worst flood on Boulder Creek following the 1894 flood." Boulder's water supply system and the Boulder County farm were severely damaged. Numerous roads and bridges in the mountains were also damaged or destroyed.

1921, June 2-7
Little is known of this flood except that it produced the highest peak discharge ever recorded at the U.S. Geological Survey Orodell gage, located about three miles upstream from Boulder and one mile upstream from Fourmile Creek. The Orodell gage has been continuously operated since 1916. A peak discharge of 2,500 cfs was recorded on June 6. Rainfall totaled 3.36 inches at Boulder through the six-day period.

1969 May 4-8
The 1969 flood resulted from a long duration storm. Runoff resulted from a combination of rainfall and snowmelt which was reported heaviest in the mountains. In the Boulder and South Boulder Creek basins, the rainfall continued at a moderate rate for nearly four days. Total precipitation for the storm amounted to 7.60 inches at Boulder and 9.34 inches at the Boulder Hydroelectric Plant located about three miles up the canyon from Boulder. Peak flooding at Boulder occurred on May 7. Estimates of discharge at the Orodell gage indicate a peak of 1,220 cfs. The discharge near Broadway in Boulder was estimated to be between 2,500 and 3,000 cfs. Instances of erosion damage to bridges and streets, trees, and agricultural lands were recorded. Large areas were flooded downstream from Boulder.

SOUTH BOULDER CREEK

The USGS has maintained a stream gaging station on South Boulder Creek near Eldorado Springs since 1888, however, there have been lapses in its operation. The gage was not in operation from October 1892 to May 1895, and from September 1901 to August 1904. It should be noted that a major flood event occurred on May 29, 1894 during the period in which records were not kept.

The following briefly describes three of the largest recorded flooding events on South Boulder Creek. Due to the relatively undeveloped nature of the South Boulder Creek basin, information and observations related to major flood events is somewhat lacking in comparison to the adjacent, more heavily developed Boulder Creek floodplain.

1894, May 29 - June 2
Heavy rains fell over the mountains extending from the Colorado-Wyoming border southward into the Republican and Arkansas River basins. Rainfall over the Boulder and South Boulder Creek basins was particularly heavy. Rainfall records for a 96-hour period ending at 3 AM on June 2 indicate that the mountain drainage area received from 4.5 to 6.0 inches of precipitation. Rainfall amounts over the high plains gradually decreased from west to east

and varied from 5 inches at Boulder to approximately 2.5 inches at the mouth of Boulder Creek. The mountain rainfall combined with the snowmelt runoff produced the greatest flood known at Boulder, inundating the valley during the night of 30 May, 1894. Buildings, bridges, roads, and railroads were washed away. Computations made 18 years later produced estimates of the peak discharge on Boulder Creek in Boulder that ranged from 9,000 cubic feet per second to 13,600 cubic feet per second. The Eldorado Springs stream gaging station was not functioning during this flood event.

In Boulder, floodwaters covered the entire area between Water Street (Canyon Boulevard) and University Hill to depths as great as eight feet. Every bridge in Boulder and a number of residences were swept away. Other types of damage included commercial establishments, public utilities, railroad property, roads and streets, and irrigation structures. Many people were trapped in their homes and had to be rescued. Only one life was lost; this was due, in part, to the flood's slow onset.

In the valley, downstream from Boulder, the floodplain was reported to have been inundated to an average width of approximately one-mile for several days. Agricultural damages included loss of livestock, crops, pastures, fences, roads and deposition of sand and silt on floodplain lands. In addition, considerable crop losses were suffered on lands outside the floodplain which were dependent on irrigation diversions from Boulder Creek.

1938, August 31-September 4

This storm produced general rains over all of eastern Colorado. The largest amounts of precipitation occurred in the mountains where more than 6 inches was reported west of Eldorado Springs. Eldorado Springs recorded 4.42 inches of rainfall. Approximately 80 percent of the total precipitation falling in the South Boulder Creek basin fell in the late afternoon and evening of September 2. The resulting flood, with a peak discharge of 7,390 cfs passed through Eldorado Springs at 10:00 PM on September 2. The resort community of Eldorado Springs suffered heavy damage and numerous buildings were destroyed when floodwaters eroded their foundations. The valley from Eldorado Springs to Boulder Creek and down Boulder Creek to St. Vrain Creek was in shambles. This flood is the highest recorded flood on South Boulder Creek.

1969, May 4-8

The 1969 flood resulted from a long duration general storm. Runoff resulted from a combination of rainfall and snowmelt, with the heaviest precipitation reported in the mountains. Rainfall continued at a moderate rate for nearly four days. Total precipitation for the storm amounted to 7.60 inches at Boulder and 9.34 inches at the Boulder Hydroelectric Plant on Boulder Creek located about 3 miles up the canyon from Boulder. Precipitation amounts totaled 8.11 inches at Eldorado Springs and 10.05 inches at Gross Reservoir on South Boulder Creek. Peak flooding occurred on May 7 at Boulder and Eldorado Springs. A peak discharge of 1,690 cfs occurred on South Boulder Creek at Eldorado Springs. Large portions of the floodplain were inundated below the confluence of South Boulder and Boulder Creeks.

Few people who presently live in the South Boulder Creek floodplain have experienced the major historic floods that have spilled over the creek's low banks flooding an area up to a mile-wide. The last major flood in the South Boulder Creek watershed occurred in 1969. Flooding occurred several times in the 1950's. The flood of record occurred in 1938. The following table lists historic flood events with peak discharges exceeding 1000 cfs.

Historic Floods on South Boulder Creek at Eldorado Springs (Drainage Area 109 sq.mi.)

DATE	CFS	DATE	CFS
1895 June 3	1,130	1947 June 21	1,290
1900 May 9	1,100	1949 June 6	1,430
1909 June 20	1,340	1951 June 18	2,370
1914 May 24	1,240	1952 June 4	1,080
1921 June 6	1,440	1969 May 7	1,690
1938 September 2	7,390		

Hydrology and Flooding Extents

BOULDER CREEK

The U. S. Army Corps of Engineers (USACOE) conducted a hydrologic study of the Boulder Creek basin in connection with a flood management study for the City of Boulder. The Corps' analysis included generation of the 10-, 25-, 50-, 100- and 500-year frequency floods over the entire basin. The 100-year design storm rainfall totaled 2.8 inches over a 6-hour period with about 1.2 inches falling in the first half of the fourth hour. While flash flood rainfall can have greater intensities than the maximum of 2.6 inches per hour used in the Corps' model, it was felt that the model could be used as the basis for estimating lead times. The relation between rainfall and runoff for the five frequency events was obtained from the Corps for 11 hydrologic design points along the stream channels.

Analysis of the data indicates which portions of the Boulder Creek basin are responsible for generating floods at specific locations, and the amount of warning time available after flood producing rainfall occurs. Figure II-3 shows the elapsed time from the midpoint of flood producing rainfall to the peak of the 100-year flood for the 11 design points within the basin. The elapsed time between rainfall and flood peak is longer for less intense storms and shorter for more intense storms. From Figure II-3 it can be seen that Barker Reservoir, located on Middle Boulder Creek, delays the flood peak.

During a regional rainfall event, two flood peaks can be expected for Middle Boulder Creek above its confluence with North Boulder Creek. The first peak is smaller and comes from the tributary area below Barker Reservoir. Below the confluence of North Boulder and Middle Boulder Creeks, the timing and magnitude of the flood peak is due to the contribution of North Boulder Creek. Boulder Creek between North Boulder Creek and Orodell has several tributary basins that contribute significant amounts of floodwater before the peak from the upper basin arrives. This causes Boulder Creek above Orodell to peak before it does below the confluence of North and Middle Boulder Creeks. A similar situation exists at the confluence of Boulder Creek and Fourmile Creek. Fourmile Creek is an elongated basin that contributes a significant amount of floodwater ahead of the peak on Boulder Creek above Orodell. In other words, Fourmile Creek peaks earlier than Boulder Creek above Fourmile Creek.

Figure II-4 shows the most probable mountain canyon areas for loss of life and property damage along Fourmile Creek and Boulder Creek.

SOUTH BOULDER CREEK

The basin characteristics for South Boulder Creek are similar to Boulder Creek and design flood hydrology was also developed by USACOE (see above discussion for Boulder Creek). During a major flood on South Boulder Creek, floodwaters will split between two major flow paths and a number of irrigation and small drainage ditches. The South Boulder Creek main channel, located on the east or right side of the valley looking downstream, will carry moderate flows. At a number of locations floodwaters will spill to the west side of the valley into a second main flow path referred to as the "West Valley Overflow" or WVO. Some of the WVO floodwaters eventually make it back to the South Boulder Creek channel. However, in larger floods, spillage to Bear Canyon Creek and Boulder Creek would occur. In 1969 floodwaters followed many of the WVO routes.

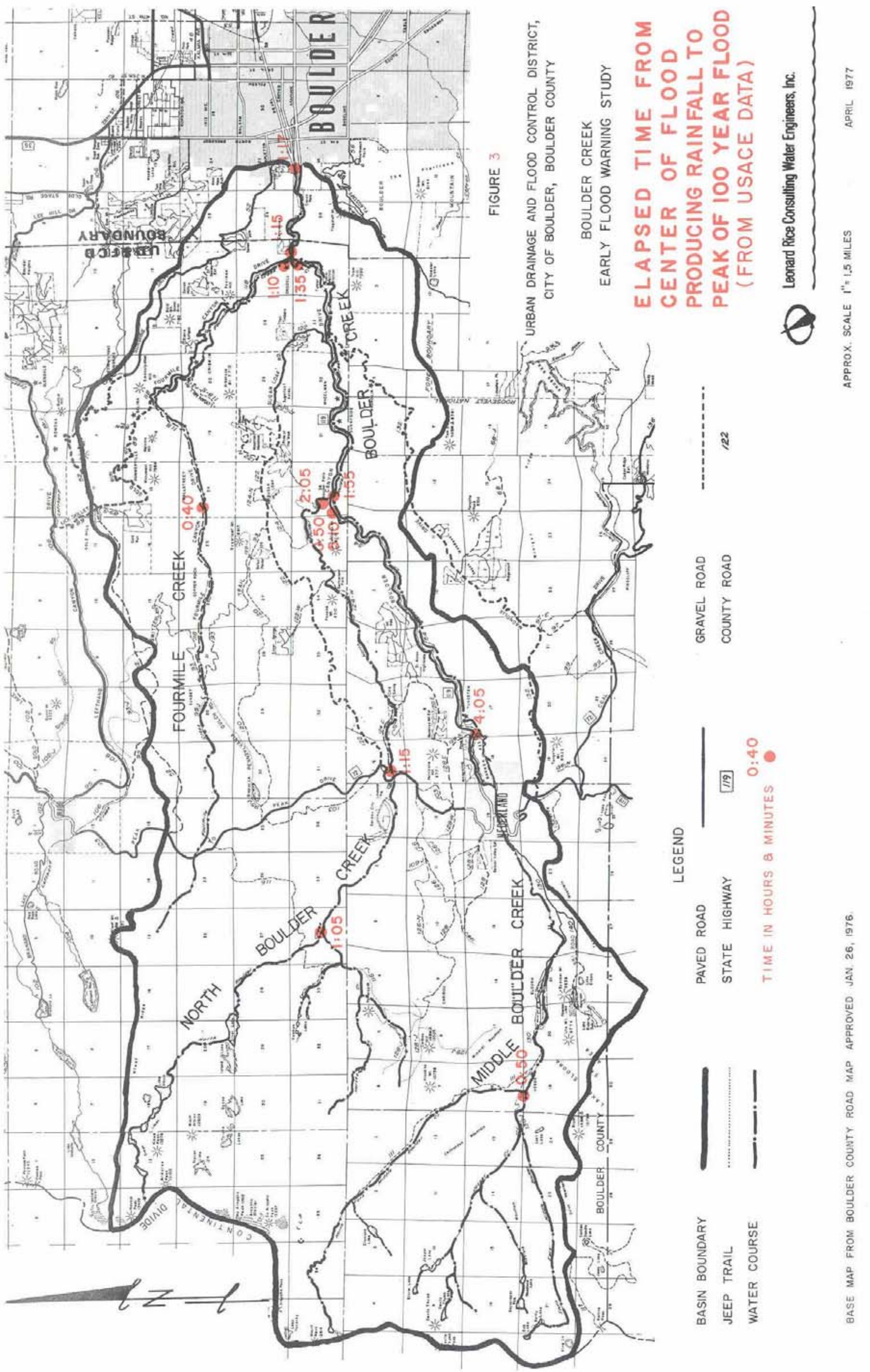
Since 1954, Gross Reservoir has attenuated floods originating upstream of the dam. A significant volume of mountain runoff was trapped in Gross during the 1969 flood, which appears to have reduced downstream flooding. It should be noted that Gross Reservoir's primary function is water supply, not flood control. The reservoir is owned, operated and maintained by the Denver Water Department. Consequently, there is no guarantee that this inadvertent floodwater storage below the spillway will be available to attenuate future floods. The railroad line to the Moffat Tunnel also provides some inadvertent flood storage.

Access in and out of Boulder would effectively be cut off during a large flood on South Boulder Creek. This would exacerbate problems and impact the use and movement of emergency vehicles and equipment. The following roads are at risk of being overtopped and possibly washed out:

- State Highway 170 (Eldorado Springs Dr.)
- U.S. Highway 36
- Baseline Road
- McSorley Lane
- 55th Street
- State Highway 93 (South Broadway)
- Foothills Parkway
- Gapter Road
- Old Tale Road
- many local streets between Foothills Parkway and South Boulder Creek
- Marshall Road
- South Boulder Road
- Dimmit Avenue
- Arapahoe Road

In 1993 it was estimated that 1050 homes, 107 apartment buildings, 132 businesses, and 87 small structures are located within the floodplain of South Boulder Creek. Additional structures have been built since then, increasing the estimate to roughly 1400 structures. Hundreds more homes located above estimated flood levels would be isolated by surrounding floodwaters in the area between Foothills Parkway and South Boulder Creek.

Figure II-3



URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,
CITY OF BOULDER, BOULDER COUNTY
BOULDER CREEK
EARLY FLOOD WARNING STUDY
ELAPSED TIME FROM
CENTER OF FLOOD
PRODUCING RAINFALL TO
PEAK OF 100 YEAR FLOOD
(FROM USACE DATA)
FIGURE 3
Leonard Rice Consulting Water Engineers, Inc.
APPROX. SCALE 1" = 1.5 MILES
APRIL 1977
LEGEND
BASIN BOUNDARY
JEEP TRAIL
WATER COURSE
PAVED ROAD
STATE HIGHWAY
119
GRAVEL ROAD
COUNTY ROAD
122
TIME IN HOURS & MINUTES
0:40
BASE MAP FROM BOULDER COUNTY ROAD MAP APPROVED JAN. 26, 1976.
BOULDER
FOURMILE CREEK
NORTH BOULDER CREEK
MIDDLE BOULDER CREEK
BOULDER CREEK
NEDERLAND
CONTINENTAL DIVIDE
BOULDER COUNTY
1:17
1:15
1:10
1:35
0:40
2:05
1:55
0:50
4:05
1:15
1:05
0:50

Figure II-4

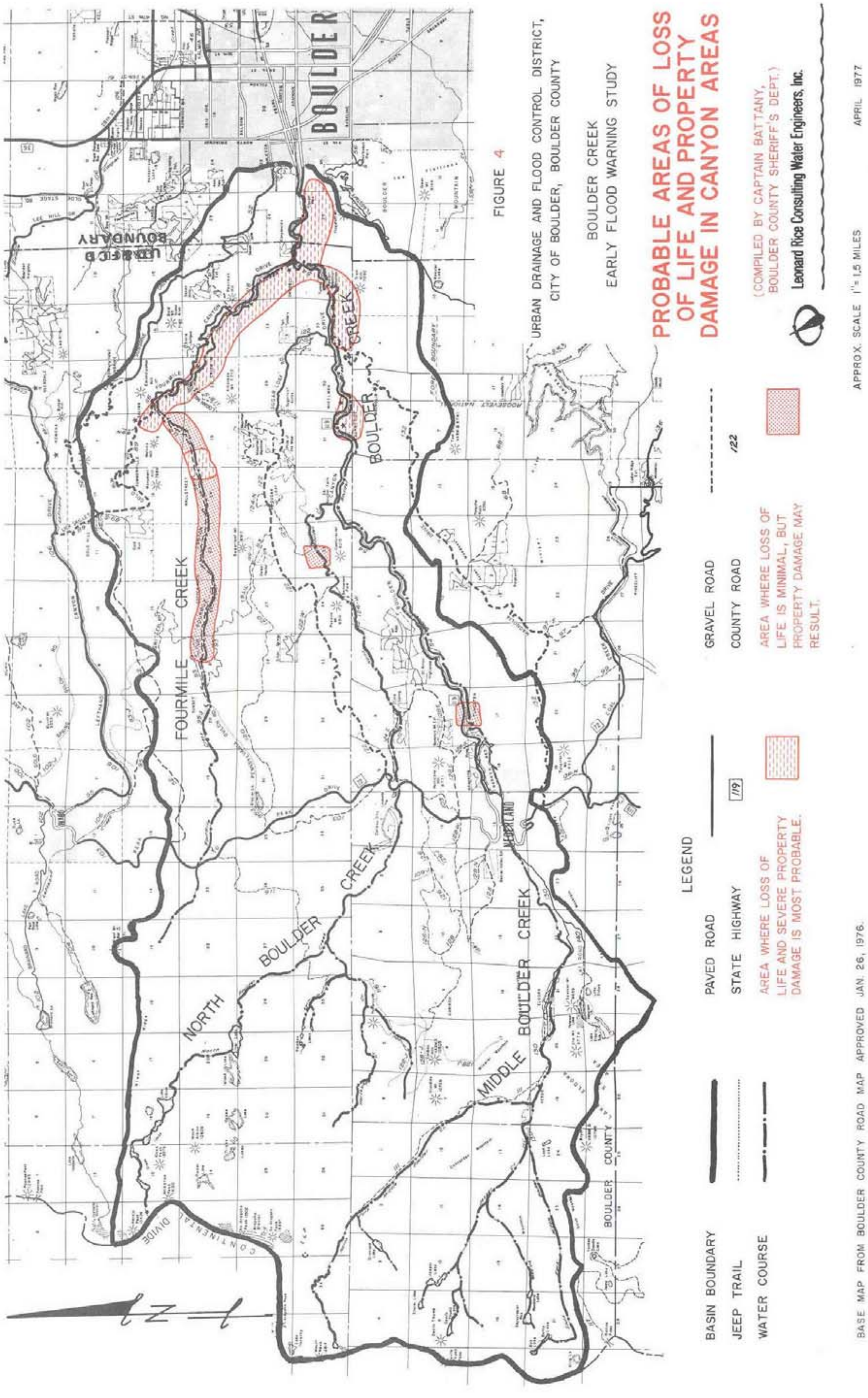


FIGURE 4
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,
CITY OF BOULDER, BOULDER COUNTY
BOULDER CREEK
EARLY FLOOD WARNING STUDY
PROBABLE AREAS OF LOSS
OF LIFE AND PROPERTY
DAMAGE IN CANYON AREAS
(COMPILED BY CAPTAIN BATTANY,
BOULDER COUNTY SHERIFF'S DEPT.)
Leonard Rice Consulting Water Engineers, Inc.
APPROX. SCALE 1" = 1.5 MILES
APRIL 1977
LEGEND
BASIN BOUNDARY
JEEP TRAIL
WATER COURSE
PAVED ROAD
STATE HIGHWAY
119
AREA WHERE LOSS OF LIFE AND SEVERE PROPERTY DAMAGE IS MOST PROBABLE.
GRAVEL ROAD
COUNTY ROAD
122
AREA WHERE LOSS OF LIFE IS MINIMAL, BUT PROPERTY DAMAGE MAY RESULT.
BASE MAP FROM BOULDER COUNTY ROAD MAP APPROVED JAN. 26, 1976.
BOULDER
FOURMILE CREEK
BOULDER CREEK
NORTH BOULDER CREEK
MIDDLE BOULDER CREEK
NEDERLAND
BOULDER COUNTY
CONTINENTAL DIVIDE
URBAN BOUNDARY