# WATER AND RELATED
# LAND RESOURCES MANAGEMENT STUDY

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*September 1977*

## VOL. V
## SUPPORTING TECHNICAL REPORTS APPENDICES

## A ... HYDROLOGY

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*REVIEW REPORT FOR*

*Metropolitan Denver and South Platte River and Tributaries Colorado, Wyoming, and Nebraska*

# WATER AND RELATED LAND RESOURCES MANAGEMENT STUDY

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PREPARED BY THE

OMAHA DISTRICT CORPS OF ENGINEERS

DEPARTMENT OF THE ARMY

# REVIEW REPORT FOR WATER AND RELATED LAND RESOURCES MANAGEMENT STUDY METROPOLITAN DENVER AND SOUTH PLATTE RIVER AND TRIBUTARIES COLORADO, WYOMING, AND NEBRASKA

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# Purpose

The purpose of this study is to present the hydrologic and meteorologic analysis made in support of the Metropolitan Denver and South Platte River and Tributaries Study and Flood Hazard Evaluations for a portion of the South Platte River in the State of Colorado. The study begins at Chatfield Dam and extends to the Colorado-Nebraska State line. A hydrology report on the reach from Chatfield to West Hampden Avenue was included in Volume II of Supplement No. 1, Design Memorandum No. PC-20, Downstream Channel Improvement, Chatfield Dam and Lake, South Platte River, Colorado, December 1976, and will not be presented in this report.

# Basin Description

The South Platte River basin originates along the eastern slope of the Continental Divide in the Rocky Mountain Range of North Central Colorado. The drainage area of the basin at the Colorado-Nebraska State line is about 23,000 square miles. Of this total, 19,982 square miles lie downstream from Chatfield Dam. Topography of the basin is about one-third mountainous and two-thirds plains area. A basin map is shown on plate 1. Topography of the South Platte River in the headwaters area is extremely rugged with slopes up to several hundred feet per mile. Stream flow in this region is confined to well defined channels and narrow canyon walls and is typical of the headwaters area of most of the left-bank tributaries of the South Platte located along the eastern slope of the Rockies. At the mouth of the South Platte Canyon, the flow regime changes abruptly to the typical high plains geometry characteristic of most of the South Platte right-bank tributaries. Stream slopes in the plains are as much as about 40 feet per mile and channels are normally well defined with adjacent overbank areas relatively flat. Downstream from Chatfield to Greeley, Colorado, several mountain tributaries flow into the South Platte along the left bank and numerous small to moderate size high plains tributaries enter the stream along the right bank. Downstream from Greeley to the Colorado-Nebraska State line, the South Platte flows in an easterly direction. The tributaries joining the main stream in this reach from both right and left banks drain high plains areas. An inventory of the named tributaries which enter the South Platte between Chatfield Dam and the Colorado-Nebraska State line is presented in table 1. Location of each tributary is shown on the basin map on plate 1.

Table 1
South Platte River Tributary Data

| Stream | Approximate Routing Miles Downstream from Chatfield Dam | Approximate Drainage Area (sq.mi.) Left Bank | Approximate Drainage Area (sq.mi.) Right Bank |
|---|---|---|---|
| Big Dry Creek | 4 | | 19 |
| Bear Creek | 6 | 260 | |
| Little Dry Creek | 7 | | 25 |
| Lakewood Gulch | 12 | 16 | |
| Cherry Creek | 13 | | 410 |
| Sand Creek | 21 | | 189 |
| Clear Creek | 22 | 575 | |
| First Creek | 26 | | 42 |
| Second Creek | 31 | | 22 |
| Third Creek | 31 | | 28 |
| Big Dry Creek (Adams Co.) | 38 | 105 | |
| Little Dry Creek (Adams Co.) | 40 | 14 | |
| St. Vrain Creek | 54 | 977 | |
| Big Thompson River | 59 | 829 | |
| Cache la Poudre River | 69 | 1,058 | |
| Lone Tree Creek | 69 | 588 | |
| Crow Creek | 76 | 1,210 | |
| Boxelder Creek | 82 | | 329 |
| Lost Creek | 97 | | 359 |
| Kiowa Creek | 104 | | 824 |
| Bijou Creek | 118 | | 1,554 |
| Badger Creek | 131 | | 253 |
| Wildcat Creek | 132 | 167 | |
| Big Beaver Creek | 137 | | 1,269 |
| Pawnee Creek | 161 | 728 | |
| Cedar Creek | 173 | 381 | |
| Moores Creek | 206 | 90 | |
| Lodgepole Creek | 213 | 3,310 | |

## EXISTING RESERVOIRS

At the present time there are two reservoirs in the South Platte River basin that have a significant flood control function, Chatfield and Cherry Creek. Chatfield Reservoir controls the South Platte River and Plum Creek above Denver and Cherry Creek controls Cherry Creek above Denver. Bear Creek Dam, an additional flood control structure now under construction, will provide control for Bear Creek flows above Denver. In addition, there are numerous other reservoirs in the South Platte River basin, most of which are operated for irrigation, water supply, and recreation. Although the flood control effects of these structures are incidental, the cumulative effect on lower flows can be quite significant as water is diverted from the South Platte and tributary streams through canals to fill storage in the reservoirs. A summary of existing reservoirs in the South Platte River basin for which information is available is presented in table 2.

Table 2
Summary of Reservoirs in the South Platte Basin

| Reservoir | Drainage Basin | Storage Capacity | Purpose | Year Constructed | Operating Agency |
|---|---|---|---|---|---|
| Antero | South Fork of So. Platte R. | 58,600 | Water Supply | 1907 | City of Denver |
| Elevenmile Canyon | So. Platte R. | 97,780 | Water Supply & Recreation | 1932 | City of Denver |
| Montgomery | Mid. Fork of So. Platte R. | 5,090 | Water Supply | 1958 | City of Colorado Springs |
| Cheesman Lake | So. Platte R. | 79,060 | Water Supply | 1900 | City of Denver |
| Chatfield | So. Platte R. | 235,000 | Flood Control & Recreation | 1975 | Corps of Engineers |
| Marston Lake | So. Platte R. | 19,790 | Water Supply | 1890 | City of Denver |
| Bear Creek | Bear Creek | 55,290 | Flood Control & Recreation | (*) | Corps of Engineers |
| Cherry Creek | Cherry Creek | 80,040 | Flood Control & Recreation | 1950 | Corps of Engineers |
| Ralston | Ralston Creek | 11,270 | Irrigation & Water Supply | 1938 | City of Denver |
| Barr Lake | So. Platte R. | 32,150 | Irrigation | 1888 | Farmers Reservoir & Irrigation Co. |
| Standley Lake | So. Platte R. Tribs. | 17,660 | Irrigation & Recreation | 1902 | Farmers Reservoir & Irrigation Co. |
| Milton Lake | So. Platte R. | 43,030 | Irrigation & Recreation | 1909 | Farmers Reservoir & Irrigation Co. |
| Gross | South Boulder | 43,060 | Water Supply & Recreation | 1955 | City & County of Denver |
| Marshall Lake | South Boulder | 10,260 | Irrigation & Recreation | 1885 | Farmers Reservoir & Irrigation Co. |
| Base Line | South Boulder | 5,380 | Irrigation & Recreation | 1907 | Lower Boulder Ditch Company |
| Barker Meadows | Middle Boulder | 11,860 | Power & Recreation | 1910 | Public Service of Colorado |

Table 2 Cont'd.
Summary of Reservoirs in the South Platte Basin

| Reservoir | Drainage Area | Storage Capacity | Purpose | Year Constructed | Operating Agency |
|---|---|---|---|---|---|
| Lower Latham | So. Platte R. | 5,750 | Irrigation & Recreation | 1900 | Lower Latham Reservoir Co. |
| Ish | Little Thompson R. | 7,060 | Irrigation | 1875 | Boulder-Larimer & Ish Counties |
| Boyd Lake | Big Thompson R. | 31,200 | Irrigation & Recreation | 1902 | Boyd Lake Res. & Irrigation Co. |
| Carter Lake | Colorado R. | 113,500 | Irrigation & Recreation | 1952 | Bureau of Reclamation |
| Horseshoe | Big Thompson R. | 8,310 | Irrigation & Recreation | 1899 | Seven Lakes Res. & Irrigation Co. |
| Home Supply | Big Thompson R. | 9,270 | Irrigation & Recreation | 1882 | Con-Home Supply Reservoir Co. |
| Lake Loveland | Big Thompson R. | 14,240 | Irrigation & Recreation | 1893 | Loveland Res. Irrigation Co. |
| Boulder | Cache la Poudre R. | 13,500 | Flood Control & Water Supply & Recreation | 1955 | Northern Colo. Water Conservancy District |
| Calkins Lake | St. Vrain | 12,740 | Irrigation & Recreation | 1902 | Union Reservoir Company |
| Chambers Lake | Fall River | 8,820 | Irrigation & Recreation | 1882 | Water Supply & Storage Co. |
| Halligan | Cache la Poudre R. | 6,430 | Irrigation & Recreation | 1910 | North Poudre Irrigation Co. |
| Horsetooth | Colorado R. | 143,500 | Irrigation & Recreation | 1949 | Bureau of Reclamation |
| Fossil Creek | Cache la Poudre R. | 11,510 | Irrigation | 1901 | North Poudre Irrigation Co. |
| Windsor | Cache la Poudre R. | 17,690 | Irrigation & Recreation | 1890 | Windsor Res. & Canal Co. |
| Black Hollow | Cache la Poudre R. | 7,480 | Irrigation | 1906 | Water Supply & Storage Co. |
| Cobb Lake | Cache la Poudre R. | 22,300 | Irrigation | 1919 | Windsor Res. & Canal Co. |

Table 2 Cont'd.
Summary of Reservoirs in the South Platte Basin

| Reservoir | Drainage Area | Storage Capacity | Purpose | Year Constructed | Operating Agency |
|---|---|---|---|---|---|
| Douglas Lake | Cache la Poudre R. | 8,830 | Irrigation | 1902 | West Colorado Power Co. |
| Reservoir #8 | Cache la Poudre R. | 10,520 | Irrigation | 1901 | Windsor Res. & Canal Co. |
| Terry Lake | Cache la Poudre R. | 8,140 | Irrigation | 1890 | Larimer & Weld Reservoir Co. |
| Timnath Lake | Cache la Poudre R. | 10,070 | Irrigation | 1892 | Cache la Poudre Reservoir Co. |
| North Poudre #5 | Cache la Poudre R. | 8,410 | Irrigation | 1894 | North Poudre Irrigation Co. |
| North Poudre #6 | Cache la Poudre R. | 9,990 | Irrigation | 1900 | North Poudre Irrigation Co. |
| North Poudre #15 | Cache la Poudre R. | 5,530 | Irrigation | 1909 | North Poudre Irrigation Co. |
| Jackson Lake | So. Platte R. | 35,630 | Irrigation & Recreation | 1903 | Jackson Lake Res. & Irr. Co. |
| Prospect | So. Platte R. | 5,610 | Irrigation | 1911 | Henrylen Irrig. District |
| Riverside | So. Platte R. | 57,510 | Irrigation | 1902 | Riverside Res. |
| Empire | So. Platte R. | 37,710 | Irrigation & Recreation | 1906 | Bijou Irrig. District |
| Horse Creek | So. Platte R. | 15,000 | Irrigation | 1911 | Henrylen Irrig. District |
| Bijou #2 | So. Platte R. | 9,180 | Irrigation | 1889 | Bijou Irr. Dist. |
| Julesburg | So. Platte R. | 67,220 | Irrigation & Recreation | 1905 | Julesburg Irrig. District |
| Point of Rocks | So. Platte R. | 81,400 | Irrigation & Recreation | 1903 | No. Sterling Irrig. District |
| Prewitt | So. Platte R. | 32,820 | Irrigation & Recreation | 1912 | Iliff Irrig. District |

*Closure effected 19 July 1977

# Climatology and Meteorology

Because of the diversified topography of the South Platte River basin, there is a remarkable variety of climates occurring between the plains and foothills regions, and the mountain and valley regions. These differences are discussed below.

## PLAINS AND FOOTHILLS

The climate of the plains is distinctly continental. Situated a long distance from any moisture source, and separated from the Pacific source by a high mountain barrier, the plains area experiences light rainfall, low relative humidity, a large daily range in temperature, high daytime temperatures in summer, a few extended cold spells in winter, moderately high wind movement, and a large amount of clear sunshine. The annual mean temperatures for the area range from 47 to 50 degrees. Temperatures of 100 degrees or over have been observed at all stations, and daytime temperatures of 95 degrees or higher are common. In the foothills temperatures as high as 100 degrees are rare as summer afternoon temperatures are frequently lowered by afternoon cloudiness and thunderstorms over and near the mountains. Invasion of cold air from the north, intensified by the altitude, can be abrupt and severe. On the other hand, many of the cold air masses that spread southward out of Canada over the Northern Great Plains are too shallow to reach the relatively high altitude in the area and move off over the lower plains to the east. The lowest temperatures observed generally range from 30 to 40 degrees below zero. The annual mean precipitation averages about 12 to 19 inches, the amounts increasing with proximity to the mountains. About 70 percent of the annual precipitation falls in the 6-month period, April through September, much of it in heavy downpours accompanying summer thunderstorms. The month of May is generally the peak of the rainy season. Winter snowfall averages from 2 to 5 feet on the plains and 4 to 6 feet in the foothills.

## MOUNTAINS AND VALLEYS

Climatic conditions observed at mountain stations have greater differences between stations compared to climatic differences observed at plains stations. In general, there is a decrease in temperature and an increase in precipitation and wind movement with increasing altitude; however, conditions can modify this relationship substantially. The diurnal fluctuation is small on the mountain slopes and quite large in the valleys. At the summits the mean temperatures are low, averaging less than 32 degrees annually. The low extremes are not more severe than the plains, but readings of zero or lower are much more common. The rainfall in the mountain areas depends largely on elevation and exposure to moisture-bearing winds. On the Continental Divide precipitation in the form of winter snow is usually substantially greater than the summer rain resulting in total annual average precipitation values almost double that experienced on the plains.

## CLIMATIC SUMMARY

The variable climatic conditions existing throughout the basin are illustrated by the precipitation, snowfall, and temperature data for selected stations presented in table 3. The approximate locations of these stations are shown on the basin map on plate 1.

Table 3
Climatological Data

| Index to Basin Map | Station | Elevation | Period of Record | Type of Record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HIGH MOUNTAINS | | | | | | | | | | | | | | | | | |
| 1 | Leadville | 10,158 | Normal | Temp (°F) | 18.1 | 19.1 | 22.2 | 31.4 | 41.8 | 50.6 | 56.6 | 54.9 | 48.7 | 38.9 | 26.3 | 19.4 | 35.7 |
| | | | " | Precip (in) | 1.42 | 1.35 | 1.43 | 1.70 | 1.22 | 1.05 | 1.98 | 1.86 | 1.22 | 1.16 | 1.06 | 1.37 | 16.82 |
| 2 | Dillon 1E | 9,065 | Normal | Temp (°F) | 16.0 | 17.9 | 22.4 | 32.8 | 42.4 | 49.9 | 55.6 | 54.0 | 47.7 | 38.9 | 25.9 | 18.5 | 35.2 |
| | | | " | Precip (in) | 1.27 | 1.22 | 1.60 | 1.82 | 1.49 | 1.27 | 1.69 | 1.76 | 1.23 | 1.07 | 1.14 | 1.20 | 16.76 |
| | | | 62 Years | Snowfall (in) | 20.2 | 20.4 | 24.6 | 19.3 | 7.4 | 0.8 | 0 | 0 | 1.6 | 8.4 | 15.6 | 19.3 | 137.6 |
| 3 | Fraser | 8,560 | Normal | Temp (°F) | 11.6 | 14.6 | 19.8 | 31.6 | 41.8 | 49.0 | 54.5 | 52.6 | 44.9 | 35.7 | 22.3 | 13.7 | 32.7 |
| | | | " | Precip (in) | 1.61 | 1.32 | 1.54 | 1.87 | 1.70 | 1.74 | 1.59 | 1.77 | 1.51 | 1.21 | 1.24 | 1.42 | 18.52 |
| | | | 45 Years | Snowfall (in) | 24.4 | 23.3 | 21.7 | 21.1 | 6.2 | 0.7 | 0 | 0 | 1.2 | 10.1 | 16.9 | 20.2 | 145.8 |
| 4 | Climax | 11,300 | 13 Years | Temp (°F) | - | - | - | - | - | - | - | - | - | - | - | - | 31.0 |
| | | | 34 Years | Precip (in) | - | - | - | - | - | - | - | - | - | - | - | - | 27.0 |
| | | | 26 Years | Snowfall (in) | - | - | - | - | - | - | - | - | - | - | - | - | 270.0 |
| MOUNTAIN VALLEYS | | | | | | | | | | | | | | | | | |
| 5 | Cheesman | 6,875 | Normal | Temp (°F) | 27.8 | 29.8 | 33.8 | 43.2 | 52.0 | 60.8 | 66.4 | 64.9 | 58.3 | 48.4 | 37.4 | 31.2 | 46.2 |
| | | | " | Precip (in) | 0.49 | 0.60 | 1.06 | 1.78 | 1.91 | 1.36 | 2.57 | 2.34 | 1.03 | 1.13 | 0.73 | 0.43 | 15.46 |
| | | | 64 Years | Snowfall (in) | 5.4 | 7.5 | 11.0 | 12.0 | 2.1 | 0.2 | 0 | 0 | 1.5 | 4.0 | 7.2 | 7.6 | 58.5 |
| 6 | Idaho Springs | 7,555 | Normal | Temp (°F) | 26.8 | 28.5 | 31.6 | 40.6 | 48.9 | 56.8 | 62.7 | 61.2 | 54.1 | 45.4 | 34.8 | 28.9 | 43.4 |
| | | | " | Precip (in) | 0.46 | 0.56 | 1.03 | 2.03 | 2.21 | 1.77 | 2.47 | 2.04 | 1.16 | 0.95 | 0.76 | 0.48 | 15.92 |
| | | | 60 Years | Snowfall (in) | 6.2 | 8.5 | 13.3 | 16.5 | 5.1 | 0.3 | 0 | 0 | 1.8 | 7.4 | 9.4 | 5.3 | 76.8 |
| 7 | Estes Park | 7,497 | Normal | Temp (°F) | 27.1 | 28.3 | 31.1 | 40.0 | 48.4 | 56.2 | 62.2 | 60.9 | 53.8 | 45.5 | 35.1 | 29.5 | 43.2 |
| | | | " | (Precip (in) | 0.55 | 0.59 | 1.00 | 1.72 | 2.15 | 2.05 | 2.29 | 1.93 | 1.20 | 1.02 | 0.73 | 0.59 | 15.87 |
| | | | 65 Years | Snowfall (in) | 8.1 | 11.9 | 16.2 | 16.7 | 5.4 | 0.5 | 0 | 0 | 1.8 | 6.4 | 10.4 | 11.0 | 88.4 |

Table 3 (Cont'd)
Climatological Data

| Index to Basin Map | Station | Elevation | Period of Record | Type of Record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FOOTHILLS | | | | | | | | | | | | | | | | | |
| 8 | Kassler | 5,495 | Normal | Temp (°F) | 32.5 | 34.9 | 38.7 | 49.2 | 58.2 | 67.0 | 73.4 | 72.1 | 64.3 | 54.2 | 41.7 | 35.1 | 51.8 |
| | | | " | Precip (in) | 0.74 | 0.84 | 1.54 | 2.40 | 2.95 | 1.93 | 1.63 | 1.46 | 1.20 | 1.52 | 1.05 | 0.56 | 17.82 |
| | | | 63 Years | Snowfall (in) | - | - | - | - | - | - | - | - | - | - | - | - | 70.0 |
| 9 | Boulder | 5,445 | Normal | Temp (°F) | 33.0 | 35.5 | 38.9 | 49.2 | 58.3 | 67.2 | 73.9 | 72.4 | 64.0 | 54.0 | 42.0 | 35.8 | 52.0 |
| | | | " | Precip (in) | 0.77 | 0.75 | 1.73 | 2.31 | 3.21 | 2.30 | 1.75 | 1.68 | 1.31 | 1.50 | 1.01 | 0.59 | 18.91 |
| | | | 77 Years | Snowfall (in) | 8.5 | 10.6 | 16.1 | 11.1 | 2.4 | 0 | 0 | 0 | 0.9 | 5.1 | 9.4 | 9.8 | 73.9 |
| 10 | Fort Collins | 5,001 | Normal | Temp (°F) | 26.8 | 30.7 | 35.4 | 46.4 | 55.6 | 64.3 | 70.8 | 68.9 | 60.0 | 49.6 | 37.2 | 30.3 | 48.0 |
| | | | " | Precip (in) | 0.45 | 0.43 | 1.04 | 1.82 | 2.90 | 2.14 | 1.47 | 1.55 | 0.96 | 1.28 | 0.54 | 0.36 | 14.94 |
| | | | 79 Years | Snowfall (in) | 5.3 | 7.3 | 10.2 | 6.1 | 0.9 | 0 | 0 | 0 | 0.4 | 2.8 | 5.3 | 5.8 | 44.1 |
| HIGH PLAINS | | | | | | | | | | | | | | | | | |
| 11 | Parker 9E | 6,300 | Normal | Temp (°F) | 27.5 | 30.4 | 34.2 | 44.9 | 54.1 | 63.3 | 70.3 | 68.6 | 60.4 | 49.8 | 37.0 | 30.7 | 47.6 |
| | | | " | Precip (in) | 0.35 | 0.34 | 0.65 | 1.55 | 2.26 | 1.84 | 1.94 | 1.78 | 0.91 | 0.99 | 0.55 | 0.23 | 13.39 |
| | | | 41 Years | Snowfall (in) | 6.6 | 7.5 | 10.2 | 9.4 | 1.8 | 0.1 | 0 | 0 | 1.6 | 3.1 | 8.0 | 5.8 | 54.1 |
| 12 | Denver WSFO | 5,283 | Normal | Temp (°F) | 29.9 | 32.8 | 37.0 | 47.5 | 57.0 | 66.0 | 73.0 | 71.6 | 62.8 | 52.0 | 39.4 | 32.6 | 50.1 |
| | | | " | Precip (in) | 0.61 | 0.67 | 1.21 | 1.93 | 2.64 | 1.93 | 1.78 | 1.29 | 1.13 | 1.13 | 0.76 | 0.43 | 15.5 |
| | | | 41 Years | Snowfall (in) | 8.1 | 7.9 | 12.6 | 9.5 | 1.5 | 0 | 0 | 0 | 1.9 | 3.5 | 7.0 | 6.4 | 58.4 |
| 13 | Greeley | 4,653 | Normal | Temp (°F) | 24.5 | 29.6 | 35.6 | 47.4 | 57.3 | 66.6 | 73.3 | 71.0 | 61.5 | 50.0 | 36.0 | 28.0 | 48.4 |
| | | | " | Precip (in) | 0.35 | 0.30 | 0.75 | 1.48 | 2.41 | 1.81 | 1.34 | 1.05 | 0.97 | 1.02 | 0.44 | 0.28 | 12.20 |
| EAST PLAINS | | | | | | | | | | | | | | | | | |
| 14 | Byers 5NE | 5,200 | Normal | Temp (°F) | 28.7 | 32.3 | 36.5 | 47.2 | 57.0 | 66.3 | 72.9 | 71.4 | 62.8 | 51.8 | 38.6 | 31.4 | 49.7 |
| | | | " | Precip (in) | 0.52 | 0.44 | 0.92 | 1.57 | 2.64 | 2.17 | 2.23 | 1.66 | 1.34 | 0.97 | 0.56 | 0.38 | 15.4 |
| | | | 38 Years | Snowfall (in) | 7.1 | 6.3 | 9.7 | 6.2 | 0.6 | 0 | 0 | 0 | 1.1 | 2.3 | 5.7 | 5.2 | 44.2 |

Table 3 (Cont'd)
Climatological Data

| Index to Basin Map | Station | Elevation | Period of Record | Type of Record | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | Ft Morgan | 4,321 | Normal | Temp ($^{o}F$) | 24.3 | 29.8 | 36.0 | 48.2 | 58.0 | 67.5 | 74.0 | 71.9 | 62.2 | 51.0 | 36.7 | 28.2 | 49.0 |
| | | | " | Precip (in) | 0.35 | 0.24 | 0.64 | 1.27 | 2.56 | 2.13 | 1.90 | 1.45 | 1.08 | 0.93 | 0.38 | 0.27 | 13.20 |
| | | | 40 Years | Snowfall (in) | 3.5 | 3.9 | 6.1 | 2.8 | 0.6 | 0 | 0 | 0 | 0.2 | 1.7 | 3.0 | 3.9 | 25.7 |
| 16 | Sterling | 3,939 | Normal | Temp ($^{o}F$) | 24.7 | 29.8 | 35.1 | 47.6 | 57.4 | 66.6 | 73.5 | 71.6 | 61.2 | 50.2 | 36.7 | 27.9 | 48.5 |
| | | | " | Precip (in) | 0.25 | 0.21 | 0.59 | 1.31 | 2.87 | 2.82 | 2.47 | 1.62 | 1.09 | 1.02 | 0.43 | 0.28 | 14.96 |

## STORMS

The weather patterns in the South Platte River basin produce intense isolated thunderstorms quite frequently, although the moisture inflow into the region is usually not of sufficient quantity to cause a major storm. Occasionally, however, a quasi-stationary front fed by heavy moisture supply from the Gulf and/or the Pacific Ocean forms along the eastern slope or out in the plains. These air masses, when triggered by a cold air mass from Canada, can cause unusually large amounts of precipitation to occur in just a few hours. Some of the major storms which have occurred in the basin are discussed in the following paragraphs.

### STORM OF 30 MAY-3 JUNE 1894

Warm moist air from the Gulf was moved into Eastern Colorado by a low pressure system centered over New Mexico. This air was forced up the eastern slopes of the Rockies by a high pressure system centered over the Dakotas and Minnesota. The greatest depths of rainfall recorded during the storm were 7.5 inches in 54 hours at Lake Morraine, Colorado, and 8.54 inches in 78 hours at Ward District, Colorado. Both of these amounts were recorded above elevation 9,000 feet. The isohyetal pattern for this event is shown on plate 2.

### STORM OF 14-16 APRIL 1921

A low pressure area centered in Arizona and New Mexico coupled with a high pressure area centered north of Colorado caused a major air flow into the mountains. The storm began as rain, but as the temperature dropped during the night of 14 April, it turned to snow. Most of the precipitation fell in the form of snow between 6 p.m. on 14 April and 6 p.m. on 15 April. The highest amounts of precipitation for 24 hours during the storm were 7.5 inches at Fry's Ranch, 5.7 inches at Fremont Experimental Station, and 5.5 inches at Silver Lake. An isohyetal pattern for the total storm period of 43 hours is shown on plate 2.

STORM OF 30-31 MAY 1935

Heavy precipitation during this storm resulted from waves forming on a quasi-stationary front that extended in an east-west direction across the Central United States. There were two very intense centers in this storm, one near Elbert, Colorado, and the other at Hale, Colorado. The total rainfall in each center was 24.0 inches. At Elbert it was estimated that the rain fell in about 6 hours. A 2-hour rainfall of 9.0 inches was reported to have occurred at Seibert, Colorado. The average 6-hour rainfall over 1,000 square miles was 5.8 inches as determined from Storm Study MR 3-28A. The isohyetal pattern for this storm is shown on plate 3.

STORM OF 30 AUGUST-4 SEPTEMBER 1938

The rainfall from this storm began on the afternoon of 30 August as convective thunderstorms along the eastern slope. On 31 August, a cold front passed southward over the South Platte River basin and became quasi-stationary across the Texas Panhandle and Northern New Mexico. Tropical moist air, flowing up from the Gulf, was lifted above the cold front and also deflected westward against the eastern slopes of the mountains. The orographic lifting of the polar air and the maritime tropical air above it resulted in intense thunderstorms and shower activity over both the mountains and plains region. Although rainfall for the period was general and widespread over the South Platte River basin, several intense storm cells did occur over the Front Range west of Fort Collins, and over Bear Creek west of Denver. The rainfall pattern for this storm is shown on plate 3.

STORM OF 16-17 JUNE 1965

The intense precipitation in this storm was triggered by squall lines which were generated along a quasi-stationary front oriented approximately north-south along the mountains in Colorado and Southern Wyoming. During the afternoon of the 16th, heavy amounts of rain fell on the drainage areas of East and West Plum Creeks in the foothills near the Palmer Lake area. The average depth of 6-hour rainfall over 1,000 square miles was 4.8 inches. Again on the 17th, heavy rains occurred over the upper reaches of Kiowa and Bijou Creeks in the South Platte River basin and Big Sandy and Black Squirrel Creeks in the Arkansas River basin. The average depth of 6-hour rainfall for this storm burst over 1,000 square miles was 7.8 inches. The isohyetal pattern is shown on plate 4.

STORM OF 5-6 MAY 1973

A low pressure cell, with its associated frontal system and a closed circulation aloft, moved slowly across Colorado from west to east during the period of 5-6 May 1973. Shower activity began over the South Platte River basin in Colorado during the evening of 5 May and turned into steady rain in the plains and snow in the mountains. Rainfall and snow accumulations at the end of the storm during the evening of 6 May were heavy east of the Continental Divide. Rainfall amounts of 6 inches or more were reported in the Kiowa Creek basin and amounts of 4 inches or more were reported in the Plum Creek, Cherry Creek, Boxelder Creek, Bijou Creek and Beaver Creek basins. In addition, 31 inches of new snow was reported at Squaw Mountain. The isohyetal pattern shown on plate 5 was drawn from data as reported by regular National Weather Service observers. These results indicated an average 24-hour rainfall value for 1,000 square miles of 5.5 inches.

STORM OF 31 JULY 1976

During the afternoon of 31 July, a quasi-stationary front oriented east to west through Missouri, Kansas and Central Colorado and curving northward along the eastern slopes of the Rockies into Central Wyoming caused development of intense convective cells over the Front Range. The slow northerly movement of these formations coupled with rapid development of new cells to the south resulted in very heavy precipitation over the Big Thompson basin below Estes Park and northward into the Cache la Poudre basin. The storm ended at about 11 p.m. The isohyetal map for this storm, based on "bucket" survey data, is shown on plate 6.

# Runoff Characteristics

Runoff in the South Platte River basin can occur from snowmelt, rainfall, or a combination of both. Most of the disastrous flood experience in the basin has been caused by intense convective thunderstorm rainfall on tributaries which produces high peak discharges that rapidly attenuate in the lower reaches of the tributary flood plains or in the South Platte River main channel. Snowmelt augmented by general spring rains can also produce serious flooding due to the high volume of runoff associated with this type of event. However, the threat to human life is minimal because of the long lead time available for dissemination of flood warning information.

## STREAMFLOW RECORDS

A summary of available stream gaging records on the South Platte River and its tributaries is presented in table 4. The stations listed are those currently published by the United States Geological Survey. The approximate location of each station is shown on the basin map on plate 1.

Table 4
South Platte Basin
Stream Gaging Stations

| Basin Map Index No. | Stream and Location | Drainage Area (sq.mi.) | Period of Record | Maximum Discharge Date | Maximum Discharge Magnitude (c.f.s.) |
|---|---|---|---|---|---|
| 1 | So. Platte R. above Elevenmile Canyon Res. | 880 | 1935-1975 | Apr 1970 | 3,970(1) |
| 2 | So. Platte R. near Lake George | 963 | 1929-1975 | Apr 1970 | 3,000 |
| 3 | Goose Cr. above Cheesman Lake | 88.6 | 1924-1975 | Jun 1957 | 487 |
| 4 | So. Platte R. below Cheesman Lake | 1,752 | 1924-1975 | Apr 1970 | 4,640 |
| 5 | No. Fork So. Platte R. below Geneva Cr. | 127 | 1908-1913<br>1942-1975 | Jun 1912 | 990 |
| 6 | No. Fork So. Platte R. at So. Platte | 479 | 1913-1975 | Jun 1949 | 2,050 |
| 7 | So. Platte R. at So. Platte | 2,579 | 1887-1891<br>1895-1897<br>1898-1900<br>1900-1975 | Jun 1921 | 6,320 |
| 8 | So. Platte R. at Waterton | 2,621 | 1926-1975 | Apr 1942 | 5,700 |
| 9 | Plum Cr. near Louviers | 302 | 1947-1975 | Jun 1965 | 154,000 |
| 10 | So. Platte R. at Littleton | 3,069 | 1941-1975 | Jun 1965 | 110,000 |
| 11 | Bear Cr. at Morrison | 164 | 1887-1891<br>1895-1900<br>1919-1975 | Jul 1896 | 8,600 |
| 12 | Bear Cr. at Mouth | 260 | 1927-1975 | May 1969 | 8,150 |
| 13 | Cherry Cr. at Franktown | 169 | 1939-1975 | Aug 1945 | 9,170 |
| 14 | Cherry Cr. below Cherry Cr. Lake | 385 | 1950-1975 | Jul 1956 | 1,440 |
| 15 | So. Platte R. at Denver | 3,804 | 1895-1975 | Jun 1965 | 40,300 |

Table 4 Cont'd.
South Platte Basin
Stream Gaging Stations

| Basin Map Index No. | Stream and Location | Drainage Area (sq.mi.) | Period of Record | Maximum Discharge Date | Maximum Discharge Magnitude (c.f.s.) |
|---|---|---|---|---|---|
| 16 | Clear Cr near Lawson | 147 | 1946-1975 | Jun 1956 | 6,130(2) |
| 17 | Clear Cr. at Golden | 400 | 1911-1975 | Aug 1888 | 8,700(3) |
| 18 | Clear Cr. at Mouth | 575 | 1927-1975 | Jul 1965 | 5,070 |
| 19 | So. Platte R. at Henderson | 4,713 | 1926-1975 | May 1973 | 33,000 |
| 20 | St. Vrain Cr. at Lyons | 212 | 1887-1891<br>1895-1975 | Jun 1941 | 10,500 |
| 21 | Middle Boulder Cr. at Nederland | 36.2 | 1907-1975 | Jun 1914 | 811 |
| 22 | Boulder Cr. near Orodell | 102 | 1906-1914<br>1916-1975 | Jun 1921 | 2,500 |
| 23 | So. Boulder Cr. near Eldorado Springs | 109 | 1888-1892<br>1895-1901<br>1904-1975 | Sep 1938 | 7,390 |
| 24 | Coal Cr. near Plainview | 15.1 | 1959-1975 | May 1969 | 2,060 |
| 25 | St. Vrain Cr. at Mouth | 976 | 1904-1906<br>1927-1975 | Sep 1938 | 11,300 |
| 26 | Big Thompson R. at Estes Park | 137 | 1946-1975 | Jun 1949 | 1,660 |
| 27 | Big Thompson R. near Estes Park | 156 | 1930-1975 | Jun 1933 | 2,800 |
| 28 | Big Thompson R. at Mouth of Canyon | 304 | 1887-1892<br>1895-1903<br>1926-1933<br>1938-1949<br>1951-1975 | Aug 1976 | 31,200(4) |
| 29 | Big Thompson R. at Mouth | 828 | 1914-1915 | Aug 1951 | 6,100 |

Table 4 Cont'd.
South Platte Basin
Stream Gaging Stations

| Basin Map Index No. | Stream and Location | Drainage Area (sq.mi.) | Period of Record | Maximum Discharge Date | Maximum Discharge Magnitude (c.f.s.) |
|---|---|---|---|---|---|
| 30 | So. Fork Cache la Poudre R. near Rustic | 90.3 | 1956-1975 | Jun 1965 | 1,260 |
| 31 | Cache la Poudre R. at Mouth of Canyon | 1,055 | 1883-1975 | May 1904 | (5) |
| 32 | Cache la Poudre R. near Greeley | 1,877 | 1914-1919<br>1924-1975 | Jun 1917 | 4,220(6) |
| 33 | So. Platte R. near Kersey | 9,598 | 1901-1903<br>1905-1975 | May 1973 | 31,500 |
| 34 | So. Platte R. near Weldona | 13,245 | 1952-1975 | May 1973 | 26,800 |
| 35 | So. Platte R. at Balzac | 16,852 | 1916-1975 | Jun 1965 | 123,000 |
| NA | Lodgepole Cr. at Bushnell, NB | 1,361 | 1931-1975 | Sep 1950 | 16,500 |
| NA | Lodgepole Cr. at Ralton, NB | 3,307 | 1951-1975 | Aug 1968 | 4,560 |
| 36 | So. Platte R. at Julesburg | 23,138 | 1902-1975 | Jun 1965 | 37,600 |

(1) Estimated maximum mean daily.
(2) Caused by failure of White Reservoir.
(3) At former gage site 7 miles above Golden.
(4) Provisional data.
(5) Not determined.
(6) Maximum mean daily.

# FLOOD HISTORY

Some of the floods that have occurred in the South Platte basin are described in the following paragraphs. These floods do not comprise the complete flood history but were selected for discussion because they demonstrate the runoff characteristics experienced in the basin. In addition, a summary of tributary peak discharges for significant flood events for which data are available is presented in table 5. The data are also shown on plate 7 which presents a graphical comparison of historical peak discharges plotted versus drainage area.

## SPRING OF 1844

According to legend a major flood occurred on the South Platte River during the spring of 1844. An article in the 22 June 1864 Denver Commonwealth indicated that Major James Bridger in relating his travel experiences told of a flood "extending from the bluff on Cherry Creek to the extreme bluff on the South Platte River." He indicated he was compelled to wait 9 days before being able to cross the river and continue his journey. The apparent high volume associated with this event would support the references to deep snow and continuous rain recorded in Major James Bridger's diary.

## FLOOD OF SEPTEMBER 1933

On 10 September 1933 a cloudburst occurred over the South Platte River between Denver and the foothills, with the center over Plum Creek, Little Dry and Big Dry Creek basins. Although information on tributary flows is limited, it was estimated that the Plum Creek peak discharge below the confluence of the East and West branches was about 30,000 cubic feet per second attentuating to about 5,500 cubic feet per second at the mouth. On Cherry Creek a peak value of about 15,000 cubic feet per second was estimated to have occurred near the mouth while upstream near the site of the Cherry Creek Dam a peak of 34,000 cubic feet per second was estimated. The peak values on Cherry Creek were partially the result of failure of a small dam located in the upper reaches of the basin. On the South Platte at the Denver gaging station, the peak discharge was 22,000 cubic feet per second, which was the largest flood of record prior to the 1965 event (gaging station established in 1895).

## FLOOD OF MAY-JUNE 1935

The flood of 31 May 1935 was caused by a storm centered over the Kiowa and Bijou Creek basins which empty into the South Platte near Fort Morgan, Colorado, about 100 miles downstream from Denver. On Bijou Creek a peak discharge of 144,000 cubic feet per second was estimated from a drainage area of 230 square miles. On Kiowa Creek a peak of 110,000 cubic feet per second was estimated from a drainage area of 190 square miles. At Fort Morgan, which is only a short distance downstream from where these two tributaries flow into the South Platte River, the estimated discharge was 84,000 cubic feet per second indicating an appreciable attentuation of the sharp tributary peaks. At the Julesburg gaging station, located about 30 miles downstream from Fort Morgan near the Colorado-Nebraska State line, a peak discharge of 31,300 cubic feet per second was recorded.

FLOOD OF APRIL-MAY 1942

The flood of April-May 1942 on the South Platte River and tributary streams was the result of snowmelt runoff being augmented by heavy precipitation during the last half of April and the first part of May. The mountain area above Chatfield Dam produced most of the volume that passed the Denver gage and, although peak values during this flood were not high in comparison to other floods, the volume of runoff was excessive, with a 30-day runoff of 265,000 acre-feet flowing past the Denver gage and a 60-day runoff of 395,000 acre-feet. Four separate flood crests occurred at the Denver gage with the maximum peak of 10,200 cubic feet per second recorded on 25 April. Peak flows in excess of 8,500 cubic feet per second were, however, recorded on 19, 23 and 30 April. The minimum flow at Denver during the 24-day period from 19 April to 13 May was about 4,500 cubic feet per second.

FLOOD OF 16-17 JUNE 1965

The flood of June 1965 is without question the most disastrous flood event in terms of dollar damage that has ever occurred in the South Platte basin. In the Denver area the flood was the result of runoff from heavy intense rainfall occurring on the evening of 16 June, centered over the high plains area of the Plum Creek and Cherry Creek basins. Runoff from the Cherry Creek area was controlled by Cherry Creek Dam as the entire hydrograph from that area (estimated peak 58,000 cubic feet per second) was stored in the Cherry Creek reservoir with zero release. Runoff from the uncontrolled Plum Creek area, however, produced a major disaster not only along the tributary itself, but also along the South Platte River through Denver, beginning at the point where Plum

Creek empties into the South Platte and extending downstream through Denver and on below through the rural area along the South Platte. About 100 miles downstream from Denver near Fort Morgan, Colorado, major flooding was produced by heavy intense rainfall occurring during the evening of 17 June over Bijou Creek of the South Platte River basin and Fountain Creek of the Arkansas River basin. Near the mouth of Bijou Creek, a peak discharge of 466,000 cubic feet per second was estimated from a drainage area of 1,314 square miles. Farther up the basin on East Bijou Creek, a peak discharge of 274,000 cubic feet per second was estimated from a drainage area of 302 square miles. On Fountain Creek in the Arkansas River basin, a peak discharge of 124,000 cubic feet per second was estimated from a drainage area of 54.3 square miles. Although runoff from the rainfall on the 17th had no effect on flows at Denver, it did produce flood conditions along the South Platte that extended from Fort Morgan, Colorado, downstream to below the Colorado-Nebraska State line. A considerable amount of post-flood data was collected on both the storm that caused this flood and the flood itself. Since the runoff on the tributaries came so fast and was over so quickly, the peak discharge estimates were mostly based on slope-area measurements. Flood hydrographs for this event on Cherry Creek and at selected stations on the South Platte River are shown on plates 8 through 11.

## FLOOD OF 6-11 MAY 1973

Snowmelt runoff from the lower mountain area of the South Platte River basin began about the middle of April. By the first of May, flows had increased to about 500 cubic feet per second at Waterton, Colorado; about 1,000 cubic feet per second in the Denver area; and about 2,000 cubic feet per second in the reach from Kersey to the state line. Rainfall runoff, which was the major causative factor of the flooding, began on 5 May. Sharp increases in flow as a result of the rainfall runoff were recorded at all gaging stations along the South Platte River from Littleton to the Colorado-Nebraska State line. The rainfall runoff was augmented by mountain snowmelt runoff which was also increasing during this period. The result was general flooding throughout the South Platte River basin which was characterized by high, sharp hydrograph peaks from the rainfall runoff followed by a slow recession because of the continuing mountain snowmelt runoff. Record peaks were established at the Kersey and Weldona stations on the South Platte River. Major South Platte River tributary streams that experienced flooding or that contributed to flood flows on the South Platte River are Bear Creek, Cherry Creek downstream from the dam, Clear Creek, St. Vrain Creek, Big Thompson River, and Cache la Poudre River. Information on tributary streams downstream from the mouth of the Cache la Poudre River is not available. Flood hydrographs for this event on Cherry Creek and at selected stations on the South Platte River are shown on plates 12 through 17.

## FLOOD OF 31 JULY-1 AUGUST 1976

The flood of July-August 1976 in the Big Thompson River was the most disastrous flood event in terms of human lives lost that has occurred in the South Platte River basin. At least 135 persons out of an estimated 2,500 to 3,500 in Big Thompson Canyon on the night of 31 July were killed by a rapid rise in the Big Thompson River. The peak discharge of 31,200 cubic feet per second at the mouth of the canyon was generated by intense rainfall over a relatively small portion of the basin. It is estimated that the drainage area contributing to the flood hydrograph at the canyon mouth was about 70 square miles out of the total drainage area of 304 square miles at this point. Flooding of considerably less severity also occurred in the Cache la Poudre basin to the north.

Table 5
Maximum Flood Discharges
For South Platte River Tributaries

| Index | Stream and Location | Date | DA* (sq.mi.) | Q (c.f.s.) | Q/DA (cfs per sq.mi.) |
|---|---|---|---|---|---|
| | **PLAINS TRIBUTARIES** | | | | |
| 1 | Bayou Gulch near Mouth | 1922 | (19) | 8,670 | 456 |
| 2 | Cherry Cr, Sec 4, T6S, R66W | 1922 | (87) | 17,000 | 195 |
| 3 | Cherry Cr Above Castlewood Dam | 1933 | (100) | 35,000 | 350 |
| 4 | Kiowa Cr near Elbert | 1935 | (60) | 43,500 | 725 |
| 5 | Kiowa Cr, Sec 21, T6S, R63W | 1935 | (190) | 110,000 | 579 |
| 6 | Kiowa Cr at Bennett | 1935 | (266) | 75,300 | 283 |
| 7 | West Bijou Cr, Sec 13, T8S, R62W | 1935 | (118) | 34,250 | 290 |
| 8 | West Bijou Cr near Peoria | 1935 | (187) | 44,400 | 237 |
| 9 | Middle Bijou Cr, Sec 26, T7S, R60W | 1935 | (151) | 71,720 | 472 |
| 10 | Middle Bijou Cr, Sec 28, T4S, R60W | 1935 | (230) | 143,640 | 625 |
| 11 | Toll Gate Cr at 6th Ave | 1959 | 35.8 | 10,400 | 291 |
| 12 | Sand Cr North of Stapleton Airport | 1959 | 175 | 25,500 | 146 |
| 13 | Russellville Gulch near Frankton | 1961 | 16.9 | 2,900 | 172 |
| 14 | Black Wolf Cr 13 miles South of Wray | 1962 | (25) | 17,800 | 712 |
| 15 | McIntyre Gulch at Denver Federal Center | 1963 | 3.22 | 968 | 301 |
| 16 | Newlin Cr near Parker | 1963 | 13.6 | 7,620 | 560 |
| 17 | Trib to Cottonwood Cr near Parker | 1963 | 0.65 | 223 | 343 |
| 18 | Cottonwood Cr near Parker | 1963 | 7.81 | 3,330 | 426 |
| 19 | Lone Tree Cr near Parker | 1963 | 1.38 | 930 | 674 |
| 20 | East Plum Cr Above West Plum Cr | 1965 | (108) | 126,000 | 1,167 |
| 21 | Piney Cr near Melvin | 1965 | (21.9) | 14,100 | 644 |
| 22 | Sand Cr at Sable Ave | 1965 | 113 | 13,400 | 119 |
| 23 | Toll Gate Below East and West Toll Gate | 1965 | (35.8) | 16,000 | 447 |

Table 5 Cont'd.
Maximum Flood Discharges
For South Platte River Tributaries

| Index | Stream and Location | Date | DA* (sq.mi.) | Q (c.f.s.) | Q/DA (cfs per sq.mi.) |
|---|---|---|---|---|---|
| 24 | Sand Cr Below Toll Gate | 1965 | 187 | 18,900 | 101 |
| 25 | Kiowa Cr sub-watershed near Eastonville | 1965 | (1.12) | 2,600 | 2,321 |
| 26 | Kiowa Cr sub-watershed near Elbert | 1965 | (2.82) | 2,010 | 713 |
| 27 | Kiowa Cr near Bennett | 1965 | 236 | 24,900 | 106 |
| 28 | East Bijou Cr at Deer Trail | 1965 | (302) | 274,000 | 907 |
| 29 | Middle Bijou Cr near Deer Trail | 1965 | (190) | 145,000 | 763 |
| 30 | West Bijou Cr near Kiowa | 1965 | (85.7) | 67,200 | 784 |
| 31 | Bijou Cr near Wiggins | 1965 | 1,314 | 466,000 | 355 |
| 32 | Cherry Cr at Cherry Cr Reservoir | 1965 | (146) | 58,000 | 397 |
| 33 | Plum Cr near Louviers | 1965 | 302 | 154,000 | 510 |
| 34 | Kennedy Drive Drain at Northglenn | 1968 | 0.1 | 85 | 850 |
| 35 | Sand Cr Trib near Landon | 1969 | 3.85 | 1,540 | 400 |
| 36 | Kiowa Cr Trib near Bennett | 1970 | 6.41 | 2,170 | 339 |
| 37 | Middle Bijou Cr Trib near Deer Trail | 1970 | 2.27 | 465 | 205 |
| 38 | Darby Cr near Buchanan | 1971 | 7.39 | 1,740 | 235 |
| 39 | Concourse "D" Drain at Stapleton Airport | 1972 | 0.12 | 119 | 992 |
| 40 | Boulder Cr Trib at Boulder | 1972 | 0.2 | 152 | 760 |
| 41 | Big Dry Cr at Littleton | 1973 | 19 | 4,400 | 232 |
| 42 | Toll Gate Cr Trib at Aurora | 1974 | 0.3 | 146 | 487 |
| 43 | Sand Cr Trib at Denver | 1974 | 0.6 | 250 | 417 |
| 44 | Hillcrest Drain at Northglenn | 1975 | 0.28 | 107 | 382 |
| 45 | Kennedy Drive Drain at Northglenn | 1975 | 0.1 | 125 | 1,250 |

MOUNTAIN TRIBUTARIES

| Index | Stream and Location | Date | DA* (sq.mi.) | Q (c.f.s.) | Q/DA (cfs per sq.mi.) |
|---|---|---|---|---|---|
| 46 | Bear Cr at Morrison | 1896 | (50) | 8,600 | 172 |
| 47 | Buckhorn Cr | 1923 | 40 | 10,500 | 262 |
| 48 | Missouri Canyon near Mouth | 1923 | 2.4 | 4,350 | 1,812 |
| 49 | Cold Spring Gulch | 1938 | 4.48 | 9,000 | 2,009 |
| 50 | Trib of Cold Spring Gulch | 1938 | 0.63 | 2,050 | 3,254 |

Table 5 Cont'd.
Maximum Flood Discharges
For South Platte River Tributaries

| Index | Stream and Location | Date | DA* (sq.mi.) | Q (c.f.s.) | Q/DA (cfs per sq.mi.) |
|---|---|---|---|---|---|
| 51 | Mt. Vernon Cr near Morrison | 1938 | 5.7 | 3,900 | 684 |
| 52 | Mt. Vernon Cr near Morrison | 1938 | 9.45 | 9,230 | 977 |
| 53 | So. Boulder Cr at Eldorado Springs | 1938 | (20) | 7,390 | 370 |
| 54 | Cedar Cr | 1938 | 18.9 | 2,940 | 156 |
| 55 | Dixon Gulch | 1938 | 2.15 | 3,620 | 1,684 |
| 56 | Green Ridge Glade | 1938 | 1.26 | 980 | 778 |
| 57 | Redstone Cr at Masonville | 1938 | 31 | 8,400 | 271 |
| 58 | Spring Cr Trib to Dry Cr | 1938 | 7.31 | 11,600 | 1,587 |
| 59 | Trib to No. St. Vrain Cr | 1961 | 0.45 | 235 | 522 |
| 60 | Dry Gulch near Estes Park | 1976 | 2.00 | 3,210** | 1,605 |
| 61 | Dry Gulch at Estes Park | 1976 | 6.12 | 4,460** | 729 |
| 62 | Big Thompson Trib Below Loveland Heights | 1976 | 1.37 | 8,700* | 6,350 |
| 63 | Dark Gulch at Glen Comfort | 1976 | 1.00 | 6,090** | 6,090 |
| 64 | Noels Drain at Glen Comfort | 1976 | 3.37 | 6,910** | 2,050 |
| 65 | Rabbit Gulch near Drake | 1976 | 3.41 | 3,540** | 1,038 |
| 66 | Long Gulch near Drake | 1976 | 1.99 | 18,400* | 9,246 |
| 67 | Big Thompson R Above Drake | 1976 | 189 | 31,200** | 165 |
| 68 | Devils Gulch near Glen Haven | 1976 | 0.91 | 2,810** | 3,088 |
| 69 | No. Fork Big Thompson Trib near Glen Haven | 1976 | 1.38 | 9,670** | 7,007 |
| 70 | Black Cr near Glen Haven | 1976 | 3.17 | 1,790** | 565 |
| 71 | No. Fork Big Thompson Trib near Drake | 1976 | 1.26 | 3,240** | 2,571 |
| 72 | No. Fork Big Thompson R above Drake | 1976 | 80.2 | 8,710** | 109 |
| 73 | Big Thompson R below Drake | 1976 | 276 | 30,100** | 109 |
| 74 | Big Thompson R at Mouth of Canyon near Drake | 1976 | 305 | 31,200** | 102 |
| 75 | Big Thompson R below Green Ridge Glade | 1976 | 311 | 27,000** | 87 |
| 76 | Little Thompson R near Estes Park | 1976 | 2.77 | 1,940** | 700 |
| 77 | Dale Cr Trib at Virginia Dale | 1976 | 0.68 | 727** | 1,069 |
| 78 | Deadman Cr near Virginia Dale | 1976 | 23.7 | 7,400** | 312 |
| 79 | Rist Canyon near Bellvue | 1976 | 5.27 | 2,710** | 514 |

* Drainage areas shown in parenthesis are contributing areas. Other areas shown are total areas for which the contributing area is unknown.

** Provisional Data.

# Hydrologic Studies

Hydrologic studies were accomplished in the South Platte basin in order to define discharge-probability relationships along the South Platte River from Chatfield Dam to the Colorado-Nebraska State line for existing conditions and for projected future urbanized conditions. In addition, detailed studies were made for two major tributary areas in the South Platte basin, Sand Creek and Boulder Creek, and preliminary discharge-probability relationships were developed for Kiowa Creek and Bijou Creek. These studies were accomplished using historical flow data, watershed modeling techniques and regional relationships. A discussion of the methods used and the results obtained is presented in the following paragraphs.

The discussion is presented in three parts: (1) the main stem of the South Platte River; (2) the tributary studies made for Sand Creek, Boulder Creek, Kiowa Creek, and Bijou Creek; and (3) a presentation of the modeling techniques and parameters used in the studies.

## MAIN STEM - SOUTH PLATTE RIVER

Discharge profiles for the 500-, 100-, 50- and 10-year flood events were developed for the main stem of the South Platte from Chatfield Dam to the Colorado-Nebraska State line. This analysis was accomplished for both existing basin conditions with Chatfield, Cherry Creek and Bear Creek dams operating and with existing urbanization development, and for projected future urbanization development in the Denver metropolitan area. This analysis was accomplished using a step-by-step procedure as outlined below.

- Maximum annual peak discharges at six South Platte River stations where flow records are available were adjusted for the controlling effects of Chatfield, Cherry Creek, and Bear Creek dams.

- Peak discharge-probability curves were developed at these six stations from the adjusted record.

- A basin model of the South Platte River was developed and used to determine probability relationships for locations between the six gaging stations and to estimate the urbanization effects on probability values.

- A description of these studies is presented in the following discussion.

PEAK DISCHARGE ADJUSTMENT

Maximum annual peak flows recorded at the Denver, Henderson, Kersey, Weldona, Balzac and Julesburg gaging stations were adjusted for the controlling effects of Chatfield, Cherry Creek and Bear Creek dams. It was assumed that these reservoirs were in operation during the period of record and holding outflows as the operating criteria for each structure indicated. Mean daily holdouts estimated from available records were routed to each gaging station using the lag-average technique. The travel times used for these routings, shown in table 6 below, were determined from the 1965 and 1973 floods and from studies presented in the Cherry Creek Dam and Reservoir Regulation Manual.

Table 6
South Platte River Travel Times

| From Chatfield Dam | Elapsed Time (hours) |
|---|---|
| To Denver Gage | 9 |
| To Henderson Gage | 15 |
| To Kersey Gage | 33 |
| To Weldona Gage | 45 |
| To Balzac Gage | 60 |

The routings were done on a mean daily basis. The longest period averaged was a 2-day mean. The routed holdout values were used to adjust the natural flood peaks using a mean discharge-peak relationship. Holdouts were based on a reservoir system release criteria which assumed that reservoir outflow would be shut down to zero when the Denver gage indicates a flow of 5,000 cubic feet per second. This theoretical operation of the South Platte reservoir system affected peak flows occurring in 1912, 1914, 1921, 1933, 1935, 1942, 1947, 1949, 1957, 1965, 1969 and 1973. The adjustments are illustrated on plates 18 through 20 where the magnitude of the actual event is plotted at the frequency occupied by the modified flow. Although these studies indicated an apparent controlling effect at the gaging stations downstream from Kersey, it was so slight that it was considered negligible and no gaging station flows were adjusted past that point.

## DISCHARGE-PROBABILITY CURVES

Discharge-probability curves were developed from the adjusted gaging records discussed above. Although the statistical techniques used varied somewhat from station to station, they were all based on a log Pearson Type III distribution. A top half analysis was used on the flows at the Denver, Henderson and Kersey stations because it more nearly reflected the bias introduced by regulation at these stations. The longer records at Kersey and Julesburg were used to extend respectively the shorter records at Weldona and Balzac. The correlation coefficients between Kersey and Weldona and between Balzac and Julesburg were 0.95 and 0.74 respectively. The record extensions were 35 years for Weldona and 7 years for Balzac. A zero skew coefficient was used at all stations except Balzac. Its proximity downstream from the mouth of Bijou Creek, which has experienced frequent extreme flooding, resulted in a computed skew slightly less than +0.5. Adjustments for expected probability were based on the total years of record, or, in the case where the extension of record was used, the expected probability adjustment was based on the equivalent years of record. Because of the positively skewed distribution used at the Balzac station, no expected probability adjustment was used at this location. This was in accordance with procedures prior to publication of the Water Resources Council Bulletin 17. The Balzac curve has not been revised, however, since the expected probability adjustment was less than 8 percent at the 100-year level. All curves were adjusted to partial duration by using an annual series-partial duration relationship developed by Langbein. The adjusted curves are shown on plates 18 through 23. A summary of pertinent statistical parameters is shown in table 7.

Table 7
Statistical Analysis of Main Stem Gaging Records

| Gaging Station | Type of Analysis | Long Term Station | Years/Or Equivalent Years of Record | Adopted Mean | Adopted Standard Deviation | Adopted Skew Coefficient | Adjustments |
|---|---|---|---|---|---|---|---|
| Denver | Top Half | - | 76 | 3145 | 0.26 | 0 | Partial Duration & Expected Prob. |
| Henderson | Top Half | - | 48 | 2900 | 0.40 | 0 | Partial Duration & Expected Prob. |
| Kersey | Top Half | - | 70 | 5260 | 0.36 | 0 | Partial Duration & Expected Prob. |
| Weldona | Extension | Kersey | 56 | 2970 | 0.48 | 0 | Partial Duration & Expected Prob. |
| Balzac | Extension | Julesburg | 60 | 4030 | 0.51 | +0.5 | Partial Duration |
| Julesburg | Complete | - | 66 | 3100 | 0.53 | 0 | Partial Duration & Expected Prob. |

## BASIN MODEL STUDIES - SOUTH PLATTE RIVER

In addition to the discharge-probability curves developed for the six South Platte River gaging station locations, it was also necessary to develop peak flow probability values for locations between the gaging stations. A simple interpolation between values obtained at the gaging stations would not be valid for most flood events since the discontinuities in the probability profiles would likely occur at the points where larger tributary streams empty into the South Platte. In order to estimate the probability values for the South Platte at the mouths of the tributaries and other points between gaging stations, a basin model of the entire South Platte River between Chatfield and the Colorado-Nebraska State line was developed. Tributary inflow used in the model was based on unit hydrographs developed for the tributary areas or, where available, on detailed model studies using the EPA Storm Water Management Model (SWMM). The flood routing portion of the model along the main stem of the South Platte was developed using the Missouri River Division adaptation of Harder's diffusion routing technique. The procedures used in estimating discharge-probability profiles through use of the model are described in the following paragraphs. A detailed description of model development and the modeling parameters used is presented on pages 54 through 59.

Chatfield to Sand Creek - Discharge-Probability Profiles. The discharge-probability profiles for this reach were developed using the SWMM procedures for determining tributary inflow and the diffusion routing technique for routing of flows down the South Platte River. These studies were detailed in nature and included both the effects of future urbanization and the South Platte channel improvement proposed for the reach from Chatfield Dam to Hampden Avenue. The discharge-probability profiles developed for this reach of the South Platte are presented on plates 33 and 34. The probability values developed from this study are significantly lower than the discharge-probability profiles developed for the reach from Chatfield Dam to Hampden Avenue which were presented in Supplement No. 1, Design Memorandum No. P.C. 20, Downstream Channel Improvement, Volume II, Appendix 4, dated December 1976. The reasons for the changes are the result of the following factors: (1) the earlier study did not consider the effects of McClellan Dam which controls runoff from about 9 square miles of the Dad Clark Gulch basin, and (2) the earlier study did not consider the effects of 6.5 square miles of non-contributing drainage area located on the South Platte left bank just downstream from Chatfield Dam. In addition, the difference in methodology between the two studies also accounted for some of the difference in results. The earlier study used a unit hydrograph approach to develop tributary inflow while this study used the detailed subarea analysis technique which is part of the SWMM methodology. After reviewing the results from both studies, it was our judgment that the profiles developed for this reach, which are shown on plates 33 and 34, represent the best estimate of probability relationships for the South Platte River from Chatfield Dam to the mouth of Sand Creek. The existing condition profiles shown on plate 33 for this reach reflect urbanized conditions as they existed in the early part of 1979. This study was approved by Missouri River Division by letter dated 31 July 1979.

Sand Creek to State Line - Profile for 1-Inch Runoff. For this reach of the South Platte a peak discharge profile was developed representing 1 inch of runoff occurring uniformly over the entire basin from Sand Creek to the State line. This profile is shown on plates 24 to 32. Although a profile representing 1 inch of runoff from a 20,000 square mile area in this region is an unrealistic condition, it was felt that it provided a reliable guide in determining the relative magnitude of the discontinuity that should be reflected in the discharge-probability profiles along the South Platte at the confluence of major tributary streams. Discharge profiles were also developed for the urbanized conditions existing in the basin in 1975 and the projected conditions that are estimated will prevail in 1990. This was accomplished by determining the effect of the urbanization development on the 1-inch profile discussed above. Unit hydrographs for areas affected by urbanization were adjusted to reflect both the estimated increase in peak discharge and higher runoff that would be associated with the increase in impervious area and improved drainage conditions. The amount of impervious area was based on applying the land use ratings presented in table 11 to development projections for 1990. The discharge profiles developed for these two conditions are also shown on plates 24 to 32. As shown on these plates, the effects on peak discharges along the South Platte as a result of urbanization in the Denver metro area become negligible from Kersey downstream.

<u>Sand Creek to State Line - Discharge-Probability Profiles</u>. Discharge-probability profiles along the South Platte River for this reach for the 500-, 100-, 50-, and 10-year floods with 1975 and 1990 urbanized conditions are shown on plates 33 to 44. In general, the profiles were developed by determining the appropriate runoff to apply to the South Platte model in order to reproduce the peak discharge-probability values developed from records at the gaging station locations. In some cases, because of differing slopes in probability curves at the gaging stations, inconsistencies developed in the attenuation of discharge-probability profiles and the attenuation indicated on the 1-inch model discharge profile. Adjustments were therefore made in tributary inflows to restore consistency to the probability profiles.

# TRIBUTARY STUDIES

Detailed studies were made to determine discharge-probability profiles along two tributary streams in the South Platte basin, Sand Creek and Boulder Creek. In addition, preliminary studies were made to develop a discharge-probability curve for Kiowa Creek at Wiggins and discharge-probability profiles for Bijou Creek. These studies are discussed below.

## SAND CREEK (INCLUDING TOLL GATE CREEK)

Discharge profiles for the 500-, 100-, 50-, and 10-year flood events were developed for Sand Creek from near the Elbert-Arapahoe County line to the mouth and on East and West Toll Gate Creeks from near the Cherry Creek emergency spillway to the mouth. These profiles were developed by using the modeling concepts discussed on pages 54 through 59. A brief description of the basin and its flood history followed by a detailed discussion of the hydrologic development is presented below. A detailed hydrologic study of Westerly Creek, which is a small left-bank tributary to Sand Creek, is in progress and will be submitted as a separate report.

Basin Description. Sand Creek is located in the high plains region southeast of Denver. The headwaters of the stream are located about 6 miles northeast of Franktown. It flows in a northwesterly direction to join the South Platte River just north of Denver. The basin is about 32 miles long with a maximum width of about 8.5 miles and a drainage area of 189 square miles. Topography varies from sharply to gently rolling, with channel slopes averaging about 44 feet per mile. Most of the basin is range land except for the downstream 10 miles, which is urbanized. The principal tributary is Toll Gate Creek, which drains an area of 39 square miles and empties into Sand Creek about 8 miles upstream from the South Platte River. The ungated emergency spillway of Cherry Creek Dam is designed to discharge into West Toll Gate Creek. Since discharge through the spillway would require a flood in excess of standard project magnitude into Cherry Creek reservoir, the probability of spillway discharge is remote. However, the potential for damage along Toll Gate and Sand Creeks from an occurrence of this nature is significant. A map of the Sand Creek basin is presented on plate 45.

Flood History. Available data indicate that major flood events in the Sand Creek basin are caused by runoff from intense thunderstorm-type rainfall. Although no gaging records are available, at least 28 events of this type have been identified in the basin since 1896. Descriptions of two of the largest events are presented below.

- Flood of 8 and 9 May 1957. A heavy rainstorm occurred over the Sand Creek basin and adjacent areas on 8 and 9 May 1957. Over 4.0 inches of rainfall occurred at the storm center. Major flooding resulted on Sand and Toll Gate Creeks. Runoff from the Sand Creek basin caused severe flooding along the South Platte River. The floodwaters in the Sand Creek basin receded in less than 12 hours, but high flow conditions along the South Platte River continued for several days as higher than average snowmelt lasted almost to the end of the month. On Sand Creek, near Stapleton International Airport, the flow was estimated to be 25,000 cubic feet per second and upstream from Toll Gate Creek, the Sand Creek discharge was estimated to be 8,000 cubic feet per second. The Toll Gate Creek discharge was estimated to be 10,500 cubic feet per second at East 6th Avenue in Aurora, which is about 2 miles upstream from the mouth of Toll Gate Creek. Peak discharge on the South Platte River at the Henderson gaging station, located about 7 miles downstream from the mouth of Sand Creek, was estimated to be 12,000 cubic feet per second.

- Flood of 16 and 17 June 1965. The catastrophic rainstorms of June 1965 also produced major flooding in the Sand Creek basin. Rainfall up to 14 inches fell on the Plum Creek basin during the afternoon and evening of 16 June 1965. The storm pattern extended over Sand and Toll Gate Creeks with rainfall averaging 2 to 4 inches over the Sand Creek basin. Resulting discharges on Sand Creek were estimated to be 13,400 cubic feet per second at Sable Avenue, located about 0.5 mile upstream from Toll Gate Creek, and 18,900 cubic feet per second downstream from Toll Gate Creek. The peak flow on Toll Gate Creek was estimated to be 17,000 cubic feet per second at East 6th Avenue in Aurora. Heavy runoff from Sand and Toll Gate Creeks caused extensive damage in the Aurora vicinity and contributed additional flood volume to the South Platte River north of Denver. Nearly every highway and railroad bridge crossing Sand and Toll Gate Creeks was either damaged or destroyed. About 750 acres of land adjoining Sand Creek and 120 acres of land adjoining Toll Gate Creek were inundated. Flooding along the downstream 10 miles of Sand Creek spread to widths ranging between 500 to 1,500 feet. On the downstream 6 miles of Toll Gate Creek, the flood width ranged from 300 to 1,000 feet.

Discharge-Probability Profiles. The rainfall, loss and runoff concepts and the modeling techniques discussed on pages 54 through 59 of this report were used to developed the discharge-probability profiles along Sand and Toll Gate Creeks shown on plates 46 through 57. One of the primary purposes of the studies in the Sand and Toll Gate Creek basins was to determine the effects of projected urbanization on flood peaks throughout the basin. EPA's surface water management model was used in this analysis since it is easily adaptable to changing land use patterns. MRD's diffusion routing model was used to combine and route the Sand Creek sub-basin hydrographs from near the Elbert-Arapahoe County line to the mouth. In absence of a gaged event, a Snyder's 1-hour unit hydrograph was developed at the mouth of Sand Creek to compare with a model developed hydrograph with about 1 inch of runoff volume. This comparison is shown on plate 58.

Development in the Sand and Toll Gate Creek basins was determined from 1975 aerial photographs and a field reconnaissance made the same year. The amount of impervious area associated with this development was based on the land use ratios presented in table 11.

Future conditions were based on several projections of development. In the Toll Gate Creek basin consideration was given to total development by 1990 using a large lot residential condition and a normal residential condition, both with and without improved channel conditions. The Sand Creek analysis was limited to partial area development using normal residential and existing channel conditions. The major portion of the projected Sand Creek basin development was assumed to occur within the Toll Gate Creek basin.

BOULDER CREEK AT BOULDER

Discharge profiles for the 500-, 100-, 50-, 25-, and 10-year flood events were developed for Boulder Creek from the west end of Boulder to the mouth of South Boulder Creek. These profiles were developed using the modeling concepts discussed on pages 54 through 59. A basin description, flood history and the hydrologic studies for Boulder Creek are discussed below. Hydrology studies for the Boulder Creek basin from South Boulder Creek to the mouth are continuing and will be available at a later date.

Basin Description. Boulder Creek is a steep mountain stream draining a portion of the eastern slope of the Rocky Mountains in Boulder County. The creek extends 22 miles eastward from the Continental Divide to the mouth of the Canyon at Boulder. After passing through Boulder it flows 18 additional miles across the high plains to enter St. Vrain Creek 5 miles east of Longmont, Colorado. The major tributaries are Fourmile Creek, which drains about 25 square miles of mountain area and empties into Boulder Creek just downstream from the mouth of Boulder Canyon; South Boulder Creek, which drains about 125 square miles of mostly mountain area and joins Boulder Creek near Valmont Street in Boulder; and Coal Creek, which drains about 80 square miles of mostly high plains area and enters Boulder Creek near the mouth. The total Boulder Creek basin is about 440 square miles at the mouth and about 155 square miles above the mouth of South Boulder Creek. Barker Reservoir, located about 12 miles upstream from Boulder, provides only incidental flood storage, and the effects of this structure on downstream peak flows diminishes rapidly with distance from the dam. The basin map is shown on plate 59.

Streamflow Records. As shown in table 4, stream gaging stations have been maintained on Boulder Creek near Orodell, Colorado since 1906, and on South Boulder Creek near Eldorado Springs since 1888, with only minor interruptions in the record. Both of these stations are located in the mountains. In addition to these two long-term stations, there is a short record (1889-1909) available from a former gaging station located in Boulder. Peak discharge estimates are available at this site for the floods of 1894, 1914 and 1969.

Flood History. Floods in the Boulder Creek basin are produced by intense rainfall during either isolated or general storm systems. In addition, there is normally an increase in flows during the mountain snowmelt period in May and June which is frequently augmented by rainfall runoff. Large floods in the basin were reported in 1864, 1876, 1894, 1914, 1923, 1938 and 1969. Descriptions of the last four floods are presented below.

- Flood of 29 May-2 June 1894. 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 3:00 a.m. on 2 June 1894 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. The mountain rainfall combined with the snowmelt runoff to produce the greatest flood known at Boulder, which came roaring down the valley during the night of 30 May 1894. Buildings, bridges and even long sections of roads and railroads were washed away. Damage was exceptionally heavy along Fourmile Creek and in Boulder. Computations made 18 years later by Metcalf and Eddy produced estimates of the peak discharge in Boulder that ranged from 9,000 cubic feet per second to 13,600 cubic feet per second.

• Flood of 1-2 June 1914. This flood was caused by rainfall on 1 June of more than 1 inch on North Boulder Creek near Silver Lake at an elevation of 10,200 feet. The flood, described as the worst since 1894, washed out numerous bridges between Colburn Mill and Boulder Falls. Several hundred feet of main line for Boulder's water system were destroyed. The peak discharge in Boulder was estimated at 5,000 cubic feet per second.

• Flood of 4 September 1938. A large storm system produced general rains over all of Eastern Colorado. The largest amounts of precipitation occurred in the mountains where over 6 inches was reported west of Eldorado Springs. Boulder reported 3.62 inches of precipitation from 31 August to 4 September with 2.32 inches falling on 2 September. Eldorado Springs, located in the South Boulder Creek basin, had 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 2 September. The resulting flood on South Boulder Creek had an estimated peak discharge of 7,390 c.f.s. at the Eldorado Springs gaging station. The peak gradually subsided as the flood moved downstream. A maximum discharge of 4,410 c.f.s. occurred near the mouth of Boulder Creek at noon on 3 September. Several buildings in Eldorado Springs were destroyed as a result of erosion around their foundations. Numerous bridges were destroyed and the South Boulder Creek valley from Eldorado Springs to Boulder Creek and down Boulder Creek to the St. Vrain Creek was described by local newspapers as being in shambles. This flood is the highest recorded flood on South Boulder Creek.

- Flood of 6-8 May 1969. This flood was also the result of long duration rainfall. Precipitation was heaviest in the mountains, part of which fell as snow. In the Boulder and South Boulder Creek basins the rainfall continued at a moderate rate for nearly 4 days. Total precipitation for the storm amounted to 7.60 inches at Boulder and 9.34 inches at the Boulder Hydroelectric Plant 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 the 7th of May on both Boulder and South Boulder Creeks. The gaging station at Orodell recorded a peak discharge of only 1,220 cubic feet per second. In Boulder, however, local inflow increased the Boulder Creek peak to an estimated 3,000 cubic feet per second. The peak discharge on South Boulder at Eldorado Springs was 1,690 cubic feet per second. Flooding below the confluence of these two streams extended over large portions of the flood plain.

Discharge-Probability Profiles. The fragmentary gaging record for Boulder Creek at Boulder was considered too short to be a reliable basis for estimating the discharge-probability at Boulder. The 67-year record for Boulder Creek at Orodell, although much longer, does not include the flows on Fourmile Creek, which, according to historical information, has been the major source of flooding in Boulder. For this reason, the discharge-probability profiles for Boulder Creek were developed using the EPA watershed model along with the rainfall, loss and runoff parameters discussed on page 56. Flood routing along Boulder Creek was accomplished using the Missouri River Division diffusion routing technique. The conveyance information for the diffusion routing was based on surveys made for the Flood Plain Information Report published by the Omaha District in 1969. Sensitivity runs were made in which model input parameters reflecting overland flow and channel roughness were varied by 50 to 100 percent. The variation in the results was only 2,000 to 3,000 cubic feet per second. The final parameter selection was based on achieving probability relationships that compared favorably with the discharge-probability curve determined from the fragmentary record for Boulder Creek at Boulder and with the regional criteria presented in Technical Manual No. 1, a manual for estimating flood characteristics of natural flow streams in Colorado, prepared by the U.S. Geological Survey for the Colorado Water Conservation Board and published in 1976. The discharge-probability curves determined by three methods are shown on plate 60 for comparison. The peak discharge-probability profile is shown on plate 61 and the 100-year hydrographs at selected locations are shown on plate 62.

KIOWA CREEK AT WIGGINS

The scope of the studies for Kiowa Creek was very preliminary and did not permit application of the detailed modeling concepts used in the Sand and Boulder Creek basins. The results of the study should therefore be treated accordingly. A brief description of the basin, its flood history and the hydrologic studies made are presented in the following paragraphs.

Basin Description. Kiowa Creek, a high plains tributary of the South Platte River, originates at the boundary between the

South Platte River and Arkansas River basins about 30 miles east of Denver. The creek flows in a northerly direction and joins the South Platte River just upstream from Weldona, Colorado. The basin is bounded by Bijou Creek on the east and Boxelder Creek on the west. Topography varies from steeply to gently rolling and channel slopes range from about 40 feet per mile in the upstream portion of the basin to about 20 feet per mile in the dowsntream portion of the basin. Vegetation in the mid to upper reaches of the basin is predominately pasture while much of the bottomland area in the downstream portion of the basin is under cultivation with a considerable amount of pump irrigation development. In addition to topographic differences, there are soil differences which are believed to have significant effects on runoff. Soils in the upper portion of the basin contain a considerable amount of clay while soils in the downstream portion are sandy in character. The drainage area of Kiowa Creek at Wiggins is 758 square miles. A map of the Kiowa Creek basin is shown on plate 63.

Flood History. Floods in the Kiowa Creek basin are caused by runoff from intense thunderstorm rainfall. Knowledge of historical floods is limited to three major events. These events are discussed below.

- Flood of 21 May 1878. No precipitation or discharge estimates are available for this flood. However, data presented in the United States Geological Survey Water Supply Paper No. 997, entitled "Floods in Colorado" indicates that a substantial flood did occur. The above publication reprinted the following article taken from the Colorado Magazine of July 1937:

"Among the unsolved mysteries in Colorado's history is the disappearance of a standard gage Kansas Pacific (now Union

Pacific) locomotive in the quicksands of Kiowa Creek . . . on the night of May 21, 1878. A sudden flood had destroyed the wooden bridge that crossed the usually dry channel a short time before a freight train was due, and owing to the bridge being the low point of a sag in the roadbed and (to) the high speed of the train, the engine and most of the cars plunged into a swirling torrent of water before the engineer realized the situation. The engineer, fireman, and brakeman went down with the engine, which was completely buried.

A few days later . . . search was begun for the missing engine. Long metallic rods were driven in the sands. In some places pits were started but soon abandoned because of the heavy underflow, and the location of the . . . locomotive appeared hopeless when it was estimated the bedrock formation was probably 50 feet below the channel of the Kiowa. (It never was recovered.)"

- Flood of 30-31 May 1935. This flood was caused by several small storm cells centered over the extreme upper reaches of the Kiowa Creek basin. Rainfall amounts up to 24 inches in a 12-hour period were reported. At the small town of Kiowa, Colorado, 15 houses were swept away and several stores were wrecked. Estimated peak discharges on Kiowa Creek for this event were 43,500 cubic feet per second at Elbert just below the junction of Kiowa and West Kiowa Creeks, 110,000 cubic feet per second at a site about 11 miles downstream from Kiowa, and 75,300 cubic feet per second near Bennett. Water in Wiggins was several feet deep.

- Flood of 17-18 June 1965. A large storm system which was centered over the Bijou Creek basin to the east extended into the upper reaches of the Kiowa Creek basin. The largest rainfall amount reported was 14 inches, most of which fell in a single

3-hour period. Peak discharge estimates for this event were 41,500 cubic feet per second at a site just upstream from West Kiowa Creek, 19,700 cubic feet per second at Kiowa, and 24,900 cubic feet per second near Bennett. Of 69 floodwater retarding structures built by the SCS in the Kiowa Creek basin, 30 were filled to capacity and in some cases emergency spillway flow depths were as high as 35 feet.

<u>Discharge Probability at Wiggins</u>. The discharge-probability curve for Kiowa Creek at Wiggins was based on the regional criteria presented in the Interim Review Report for Bijou Creek, dated October 1970, together with Snyder's unit hydrograph constants and the diffusion routing technique discussed on page 59 of this report.

The discharge-probability curve at Wiggins shown on plate 64 was computed from the following regional data.

log mean discharge = 2.12 + 0.531 (log drainage area)

standard deviation = 0.6

skew coefficient = 0

An expected probability adjustment based on average length of record of 25 years are applied to this curve. The above regional data were developed from discharge records of tributaries with relatively narrow flood plains. The Kiowa Creek basin has similar characteristics to a point about 4 miles upstream from Wiggins. At this point, however, the Kiowa Creek flood plain widens out considerably. In order to compensate for the attenuating effects of this storage, a flood routing analysis was made through this reach. An estimated 100-year flood hydrograph was developed for the upstream end of the reach using a synthetic unit hydrograph and the 100-year peak discharge from the regional-probability curve. This hydrograph is shown on plate 65. A diffusion routing model developed from surveyed (1974) sections of the flood plain was used to route this hydrograph to Wiggins. The routed 100-year flood at Wiggins was used to determine the remainder of the discharge—probability curve at Wiggins by drawing a curve parallel to the regionally developed curve. The adjusted curve at Wiggins is shown on plate 64. It should be recognized that, because of data inadequacies for streams in this area, there is considerable uncertainity associated with probability estimates in the Kiowa Creek basin. In addition, there is the possibility of a bias in the regionally developed curve because of the severe floods experienced in 1935 and 1965. Estimated error limit curves developed at Wiggins using regional parameters indicate the magnitude of statistical error potential. In addition, there is an undefineable error associated with the application of regional criteria to any basin. These uncertainities should be recognized in evaluating project studies for Kiowa Creek.

BIJOU CREEK

The hydrologic studies completed for the Interim Review Report for Bijou Creek, dated October 1970, were not updated for this report. However, since the scope of the planning studies made for Bijou Creek in this report are preliminary, the hydrology presented in the Interim Review Report was considered acceptable for current planning purposes. Pertinent information from that report are presented below.

Basin Description. Bijou Creek, a high plains tributary of the South Platte River, originates at the boundary between the South Platte River and Arkansas River basins about 35 miles east of the Rocky Mountain foothills. The creek flows in a northerly direction and joins the South Platte River just upstream from Fort Morgan. The Bijou Creek basin is bounded by the Kiowa Creek basin on the west, the Sandy Creek basin on the south, and the Badger Creek and Beaver Creek basins on the east. The total drainage area of the basin is 1,554 square miles. Topography varies from steeply to gently rolling; channel slopes range from about 40 feet per mile in the upstream portion of the basin to about 20 feet per mile in the downstream portion of the basin. The land in the upstream portion is used for grazing; vegetation is predominantly pasture grass with some forested areas located in the headwaters of East Bijou and West Bijou Creeks. In the downstream portion of the basin, most of the bottomland area is under cultivation with a considerable amount of pump irrigation development. In addition to topographic differences in the basin, there also are soil differences which are believed to have significant effects on runoff. In general, soils in the upstream portion of the basin have a considerable amount of clay while soils in the downstream portion of the basin are sandy in character. A 56 square-mile area in the downstream portion of San Arroyo Creek is classified as sand hills, and surface runoff is negligible. A map of the Bijou Creek basin is presented on plate 66.

Runoff Characteristics. Runoff characteristics of the Bijou Creek basin are typical of the high plains tributaries lying east of the Rocky Mountains in Colorado. The steep slopes in the upstream portion of the basin cause a rapid concentration of runoff. This creates flash floods with relatively short peaking times and high, sharp peaks lasting only a short time. Floods are generally described by local residents as a "wall of water". Ratios of observed peak discharges to total flood volumes are extremely high. Residents of the basin have stated that the upstream portion of the basin is the flood-producing portion of the drainage area. The range in difference of topography and soil types found in the upstream and downstream portions of the area tends to support this observation. The steeper slopes and clay-type soils of the upstream portion of the basin concentrate runoff more rapidly and have lower infiltration rates than the flatter topography and sandier soils found in the downstream portion of the area.

Streamflow. Streamflow in the Bijou Creek basin follows a pattern of long periods of zero flow interrupted occasionally by runoff from rainstorms. From 1950 to 1956, the average annual runoff from the 1,370 square mile area lying upstream from Wiggins gaging station was only 0.09 inch. The flow records from the Wiggins station are summarized in table 9. These data indicate the extreme range of flow that has been experienced in the Bijou Creek basin.

Table 9
Wiggins Gaging Station Data

| Water Year | Maximum Flows | | Minimum Flows | |
|---|---|---|---|---|
| | Date | Discharge (c.f.s.) | Date | Discharge (c.f.s.) |
| 1935 | 31 May | 280,000* | -- | - |
| 1950** | 31 Jul | 767 | most of year | 0 |
| 1951 | 3 Aug | 50,100 | most of year | 0 |
| 1952 | 22 Aug | 7,840 | most of year | 0 |
| 1953 | 30 Jul | 1,080 | most of year | 0 |
| 1954 | 30 Jul | 5,700 | most of year | 0 |
| 1955 | 28 Aug | 2,450 | most of year | 0 |
| 1956 | 31 Jul | 19,000 | most of year | 0 |
| 1965 | 18 June | 466,000* | -- | - |

* Slope area estimate
** Record begins in April

Flood History. Floods in the Bijou Creek basin have occurred as the result of runoff from high intensity rainfall over a relatively small portion of the drainage area. Records do not indicate any major flooding from snowmelt runoff. The two record flood events that have occurred in the basin are described in the following paragraphs.

- Flood of May 1935. Runoff from the storm of 30 and 31 May 1935 caused major flooding in the Bijou Creek basin. An observer on East Bijou Creek at a point 3 miles west of Deer Trail reported seeing a wall of water 10 or 15 feet high rushing toward him. The business section of Byers was inundated by flooding on West Bijou Creek, and the Union Pacific railroad bridge and embankment were washed out. The estimated peak discharge at the Wiggins gaging station was 280,000 c.f.s.

- Flood of June 1965. The unprecedented rainstorms of June 1965 caused major flooding in the Bijou Creek basin. Heavy runoff caused extensive damage at the towns of Deer Trail and Byers. In the rural areas, farms and ranches along the bottomland were severely damaged. A boy was drowned as he was checking the livestock in one of the outbuildings at his father's ranch along a Bijou Creek tributary. His father indicated that the flood approached without warning shortly after the heavy rains began. These floodwaters caused record flooding on the South Platte River which inflicted extensive damage at Fort Morgan and to agricultural lands along the river downstream to its confluence with the North Platte River. The estimated peak discharge of this flood at the Wiggins gaging station was 466,000 cubic feet per second.

Discharge Probabilities. Discharge–probability relationships were developed for several locations in the Bijou Creek basin. The curves on Bijou Creek were developed on the basis of a regional study of streams in the South Platte River basin. This study showed that drainage area was related to the mean annual flood through the following regression equation:

$$LOG\ Q = A + 0.531\ (LOG\ D.A.);$$

where LOG Q = logarithm of mean annual flood,

A = the regression constant combined with an estimate of the unexplained variance characteristic of the immediate area, (A = 2.12 in the Bijou Creek basin)

0.531 = slope of the regression curve,

LOG D.A. = logarithm of the contributing drainage area.

This regional study also indicated that the average standard deviation for high plains streams in the South Platte River basin is 0.60. The average length of record for the streams included in the study was 25 years. The computed curves were adjusted for partial duration series and expected probability. The resulting discharge–probability curves and profiles are shown on plate 67.

## BASIN MODELING STUDIES

As presented in previous discussion, basin runoff models were used in accomplishing the hydrologic studies for the South Platte River and tributary streams. Development of the various models used and the input parameters employed are presented in the following discussion.

TRIBUTARY INFLOW

The tributary inflow portion of the models was based on both synthetic unit hydrographs and EPA's Surface Water Management Model (SWMM). Synthetic unit hydrographs were used for all of the high plains tributaries downstream from Sand Creek. SWMM was used for all tributaries between Chatfield Dam and Clear Creek plus the high plains and foothills portion of the left-bank tributaries which originate in the mountains. Pertinent information concerning the tributary inflow development is presented below.

Synthetic Unit Hydrographs. Synthetic unit graph development was based on using Snyders unit graph equations derived from the June 1965 inflow hydrograph to Cherry Creek reservoir. This hydrograph is shown on plate 8 along with the derivation of a 1-hour Clarks unit graph from it. Snyders constants of $C_t = 0.51$ and 640 $C_p = 537$ were computed from this Clarks unit graph. These constants were also applied to smaller basins by assuming a 15-minute unit graph duration. Synthetic unit graphs developed for areas having or facing urban development were adjusted by reducing peaking times 50 percent and increasing peak discharges 100 percent. This adjustment was made in order to reflect the more severe runoff characteristics that are associated with urbanized areas.

SWMM. The EPA Surface Water Management Model (SWMM) is based on the collection and routing of rainfall runoff hydrographs from small sub-area components of a tributary system. An overland flow equation is used to compute runoff hydrographs from the sub-area system and these hydrographs are collected and routed through the system to the point or points of interest. A detailed description of the model is presented in an EPA publication entitled "Storm Water Management Model, Volume I - Final Report, July 1971." Several studies were made in order to become acquainted with the model parameters utilized in the program. This resulted in modifying the program logic to adapt the model to larger areas which experience overbank flow in addition to channel flow. Reconstitution of the May 1973 flood hydrograph for the uncontrolled Cherry Creek area lying downstream from Cherry Creek Dam provided practical experience in application of the model to other basins. The results of the Cherry Creek reconstitution are shown on plate 12.

Model Input Parameters. The rainfall and loss parameters used in the model studies are discussed below.

- Rainfall. A rainfall model was developed for use as needed in the South Platte River basin. The rainfall-frequency relationships were obtained from NOAA Atlas 2 for Colorado published in 1973. The NOAA values were adjusted for expected probability. The 500-year values were estimated by extrapolating on arithmetic-probability paper. The various rainfall durations presented in the NOAA publication were studied at each location to determine which duration best represented the specific condition being analyzed. In each case the 6-hour duration was selected. A 30-minute distribution of this 6-hour storm is shown in the following table 10. It was developed from a study of hourly precipitation data recorded for major storms in the South Platte River basin and refined to 30-minute values by using Civil Works Bulletin 52-8, Plate No. 11 (1952) as a guide.

Table 10
Model Rainfall Distribution

| End of Period (Minutes) | Percent of 6-Hour |
|---|---|
| 30 | 2 |
| 60 | 4 |
| 90 | 4 |
| 120 | 5 |
| 150 | 9 |
| 180 | 10 |
| 210 | 40 |
| 240 | 10 |
| 270 | 6 |
| 300 | 4 |
| 330 | 4 |
| 360 | 2 |

• Losses. Reliable information on rainfall-runoff relationships in the South Platte River basin are not readily available. This lack of knowledge is primarily due to the inability to obtain the time and areal distribution of rainfall events and the associated volumes. The reasoning used to determine the model loss rates for both the plains and the mountain areas is presented in the following paragraphs. In each case a constant loss rate was assumed to be applicable to all events regardless of their frequency. This assumption was made after comparing the slopes of model developed curves with those computed analytically from gaging records.

• Plains Losses. Infiltrometer studies made by the S.C.S. in the Cherry Creek basin showed a minimum loss rate of 0.7 inch per hour and an average loss rate of 1.07 inches per hour. This compares with an average loss rate of 0.86 inch per hour computed for the 1965 inflow into Cherry Creek Reservoir. The infiltration map prepared for the Missouri River Basin Framework Study indicated a range in infiltration rates for this area of 0.2-0.6 inch per hour which averages about 50 percent of the infiltrometer studies discussed above. On this basis, a model infiltration rate of 0.5 inch per hour was selected for use in analysing high plains tributaries.

- Mountain Losses. Infiltrometer studies on forest land, mixed forest and grassland, and grassland in the mountain areas of the South Platte River basin have been conducted over a period of years by the U.S. Forest Service and were summarized in a report by Dortignoc and Love. Their results showed average rates of 2.37 inches per hour for pine forest, 1.94 inches per hour for pine forest and grassland mixed, and 1.5 inches per hour for grassland. Using the same factor of 50 percent applied to the infiltrometer studies for the plains area resulted in a model infiltration rate of 1.00 inch per hour in mountain areas.

- Urbanized Losses. The change in loss rates in urbanized areas were accounted for by assuming that the area covered by roads, driveways, buildings, and parking lots were impervious and would not infiltrate rainfall application. The amount of impervious area allocated for each type of land use were taken from an Urban Storm Drainage Manual prepared for the Denver Regional Council of Government by Wright-McLaughlin in 1969. The values used are shown in table 11.

Table 11
Land Use Vs. Percent of Impervious Area

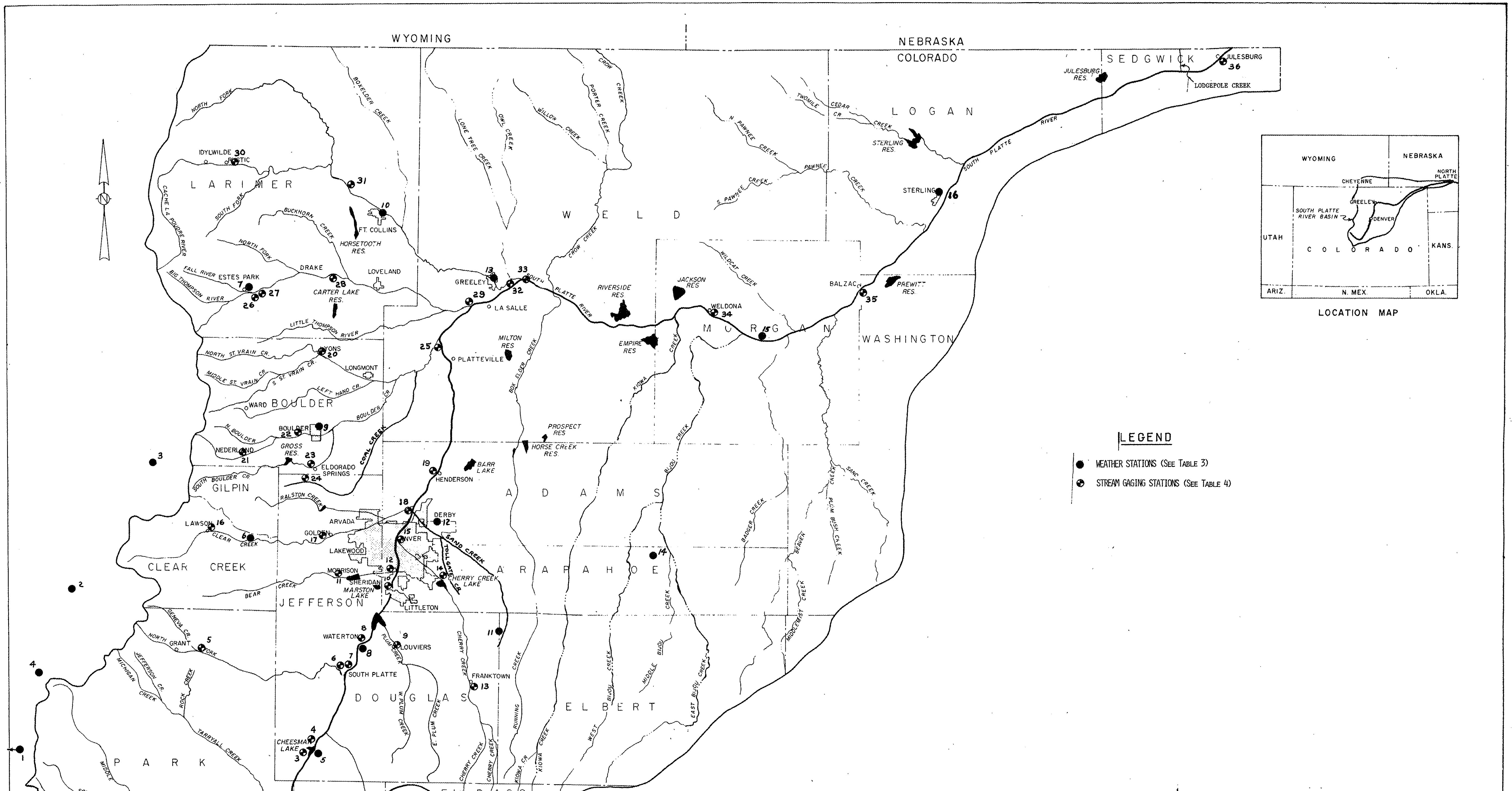
| Land Use | Percent Impervious |
|---|---|
| Industrial | 95 |
| Dense Residential | 52 |
| Normal Residential | 40 |
| Large Lot Residential | 30 |
| Open Areas | 5 |

FLOOD ROUTING

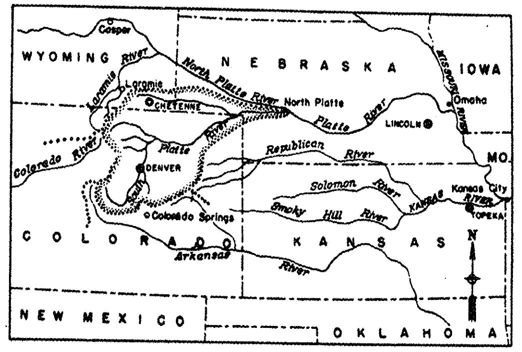
The flood routing portion of the South Platte River model was developed using the Missouri River Division diffusion routing technique. This technique is based on the solution of two finite difference equations that represent the continuity of flow and the flow friction along any given stream reach. The computational procedure requires a stage-conveyance relationship and a stage-area flooded relationship for each selected channel and flood plain cross section.

MODEL VERIFICATION

The flood routing portion of the South Platte model, and to a lesser extent the inflow portion, were tested by routing the June 1965 and May 1973 flood events between South Platte River gaging stations where inflow was gaged or could be estimated with acceptable accuracy. Ungaged inflow hydrographs were estimated using the inflow portion of the South Platte model described on page 55. Other factors affecting the flow between gaging stations, such as water trapped in the overbank area and withdrawals for irrigation, were not accounted for in the flood routing procedure. This resulted in some of the reconstituted hydrographs having more volume than the actual event. The actual and reconstituted hydrographs developed for the 1965 and 1973 floods are shown on plates 9 to 11 and 13 to 17.

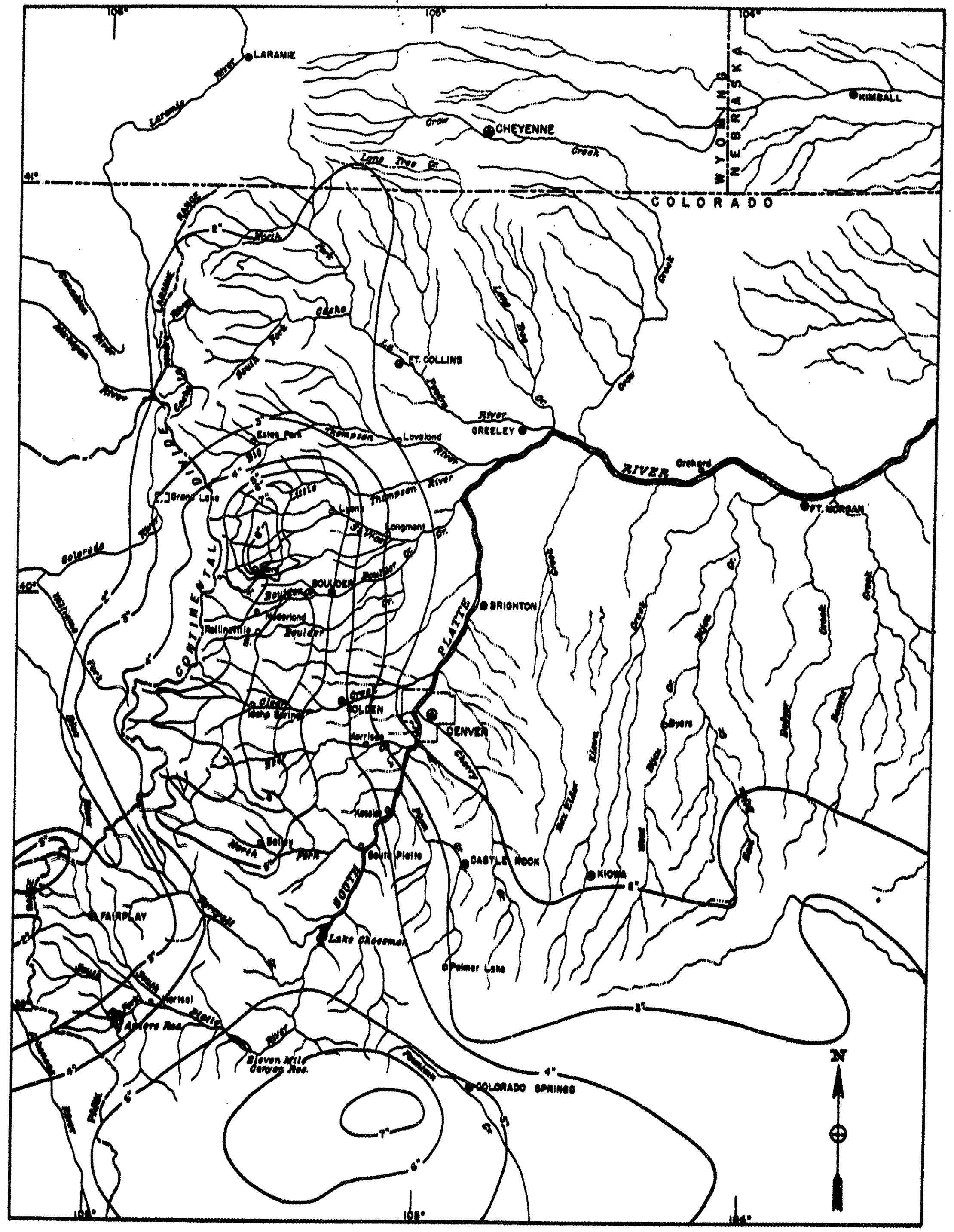



METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES

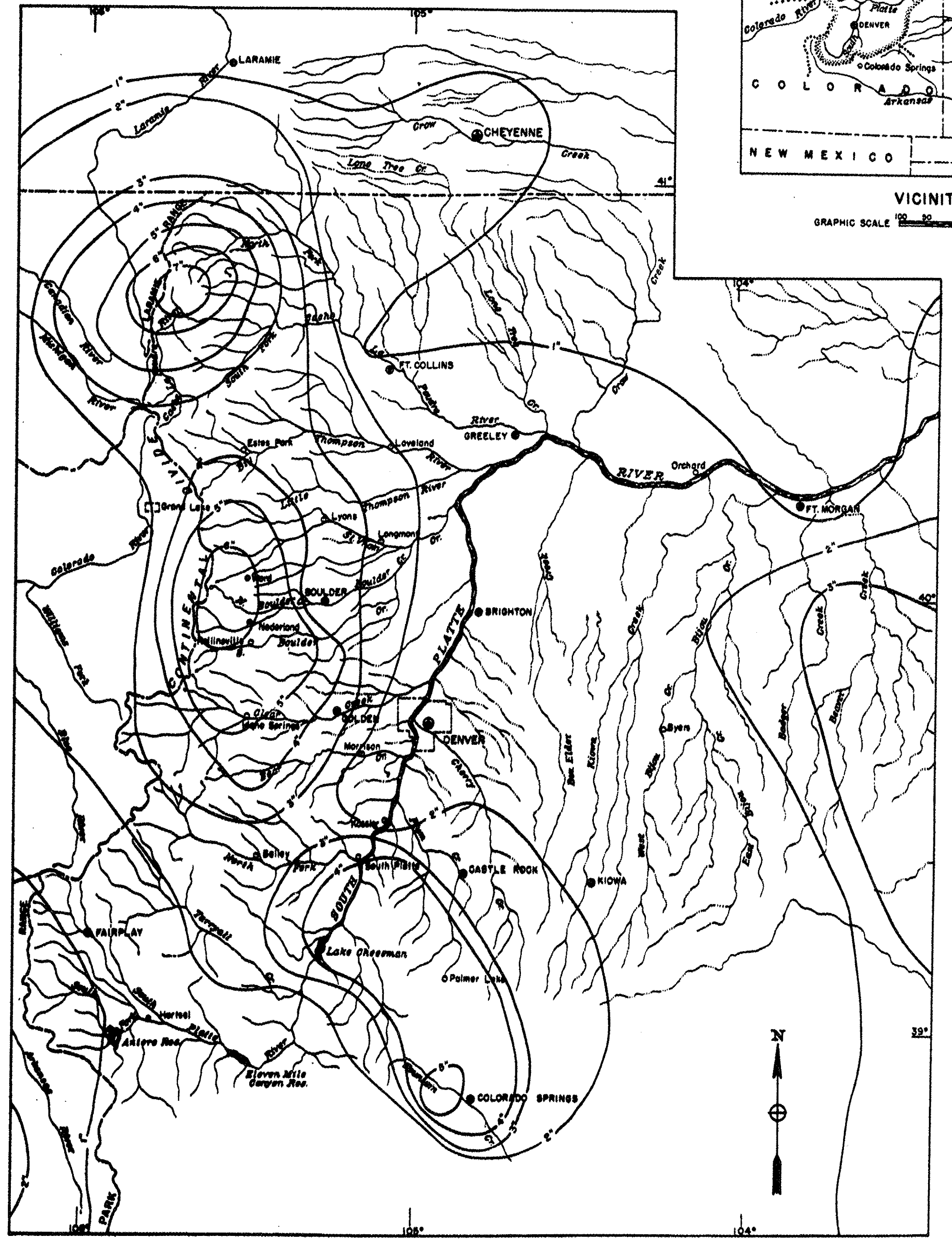



VICINITY MAP

GRAPHIC SCALE 100 50 0 50 100 MILES




MAY-JUNE 1894 STORM
96 HOURS ENDING 3 A.M. JUNE 2, 1894

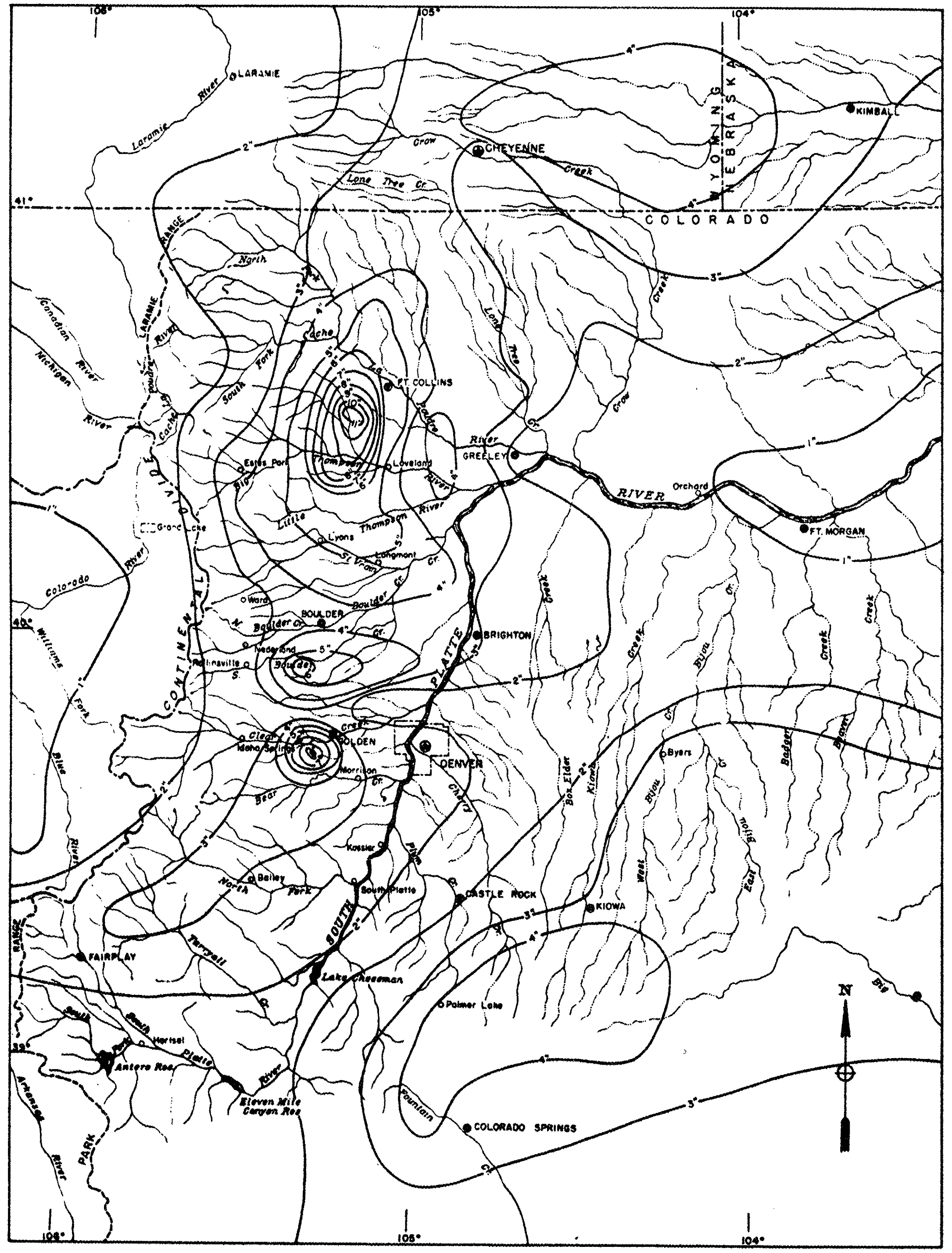



APRIL 1921 STORM
43 HOURS ENDING 6 A.M. APRIL 16, 1921

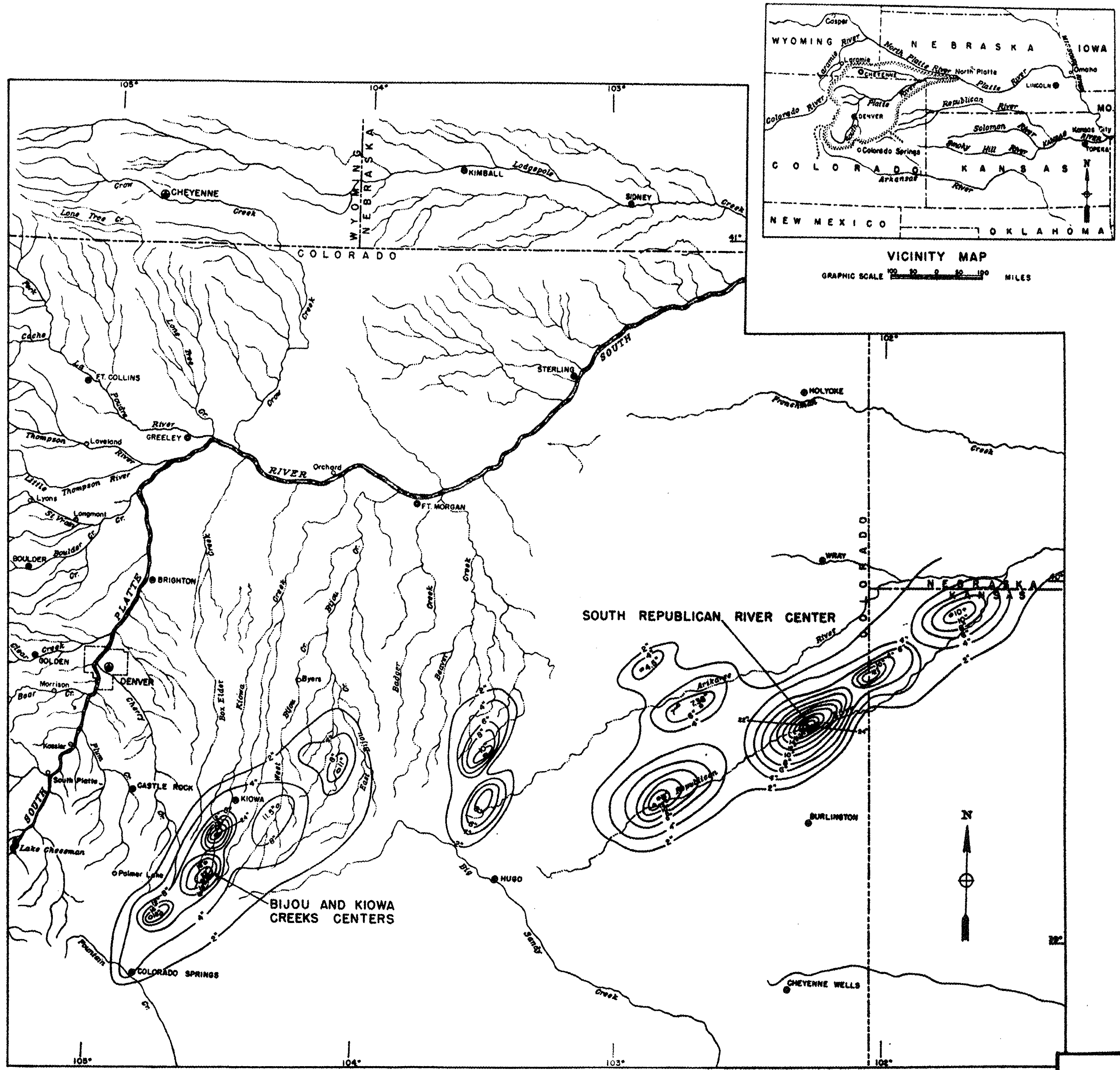
METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

ISOHYETAL MAPS FOR TOTAL STORMS
OF MAY-JUNE 1894 AND APRIL 1921

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




AUG.- SEPT. 1938 STORM
120 HOURS ENDING 10 A.M. SEPT. 4, 1938




VICINITY MAP

MAY 1935 STORM
BIJOU & KIOWA CENTERS
12 HOURS ENDING 6 P.M. MAY 30, 1935
SOUTH REPUBLICAN RIVER CENTER
12 HOURS ENDING 3 A.M. MAY 31, 1935

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

ISOHYETAL MAPS FOR TOTAL STORMS
OF MAY 1935 AND AUG-SEP 1938

U.S. ARMY ENGINEER DISTRICT OMAHA
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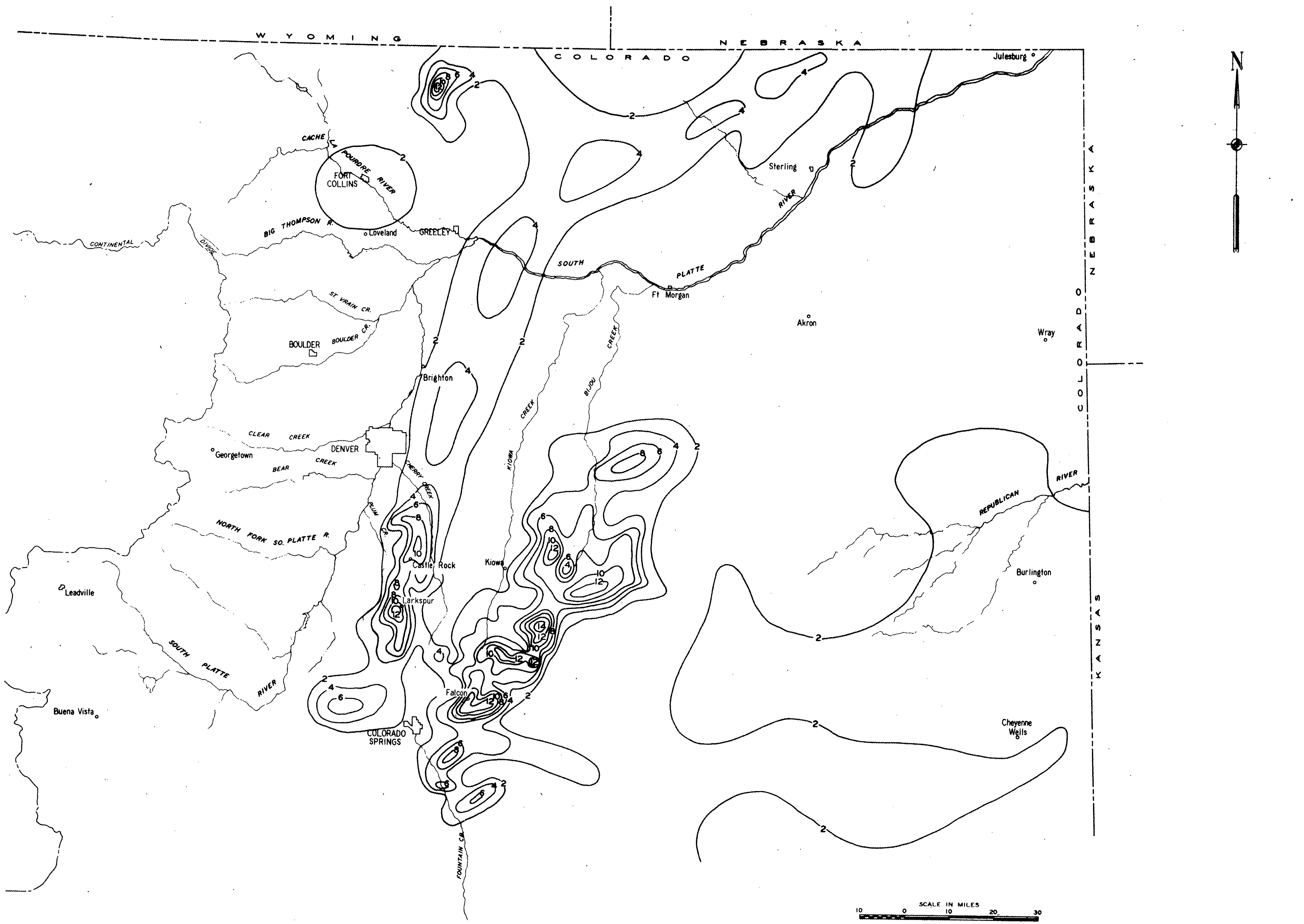
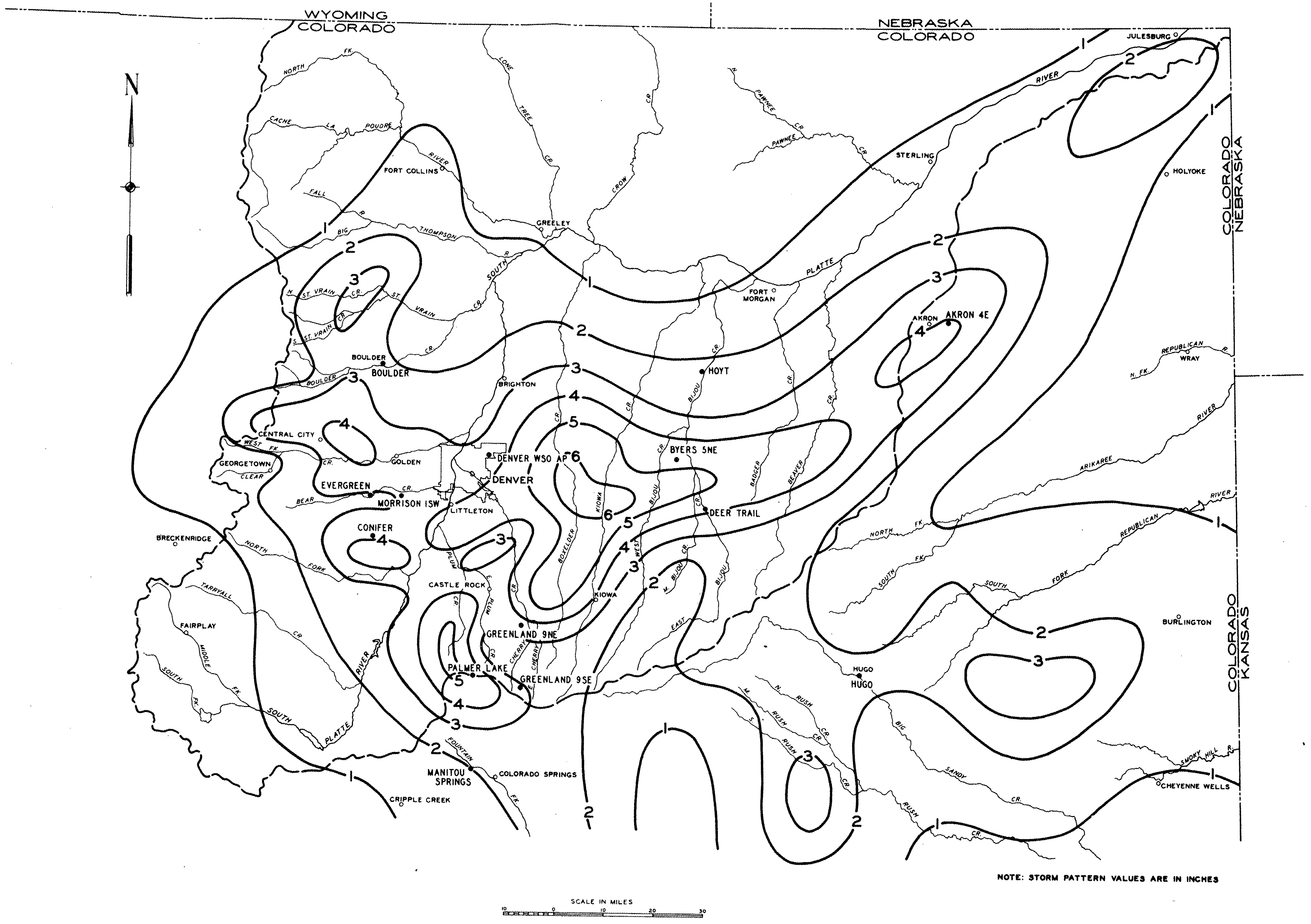
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

ISOHYETAL MAP FOR STORM
15-17 JUNE 1965

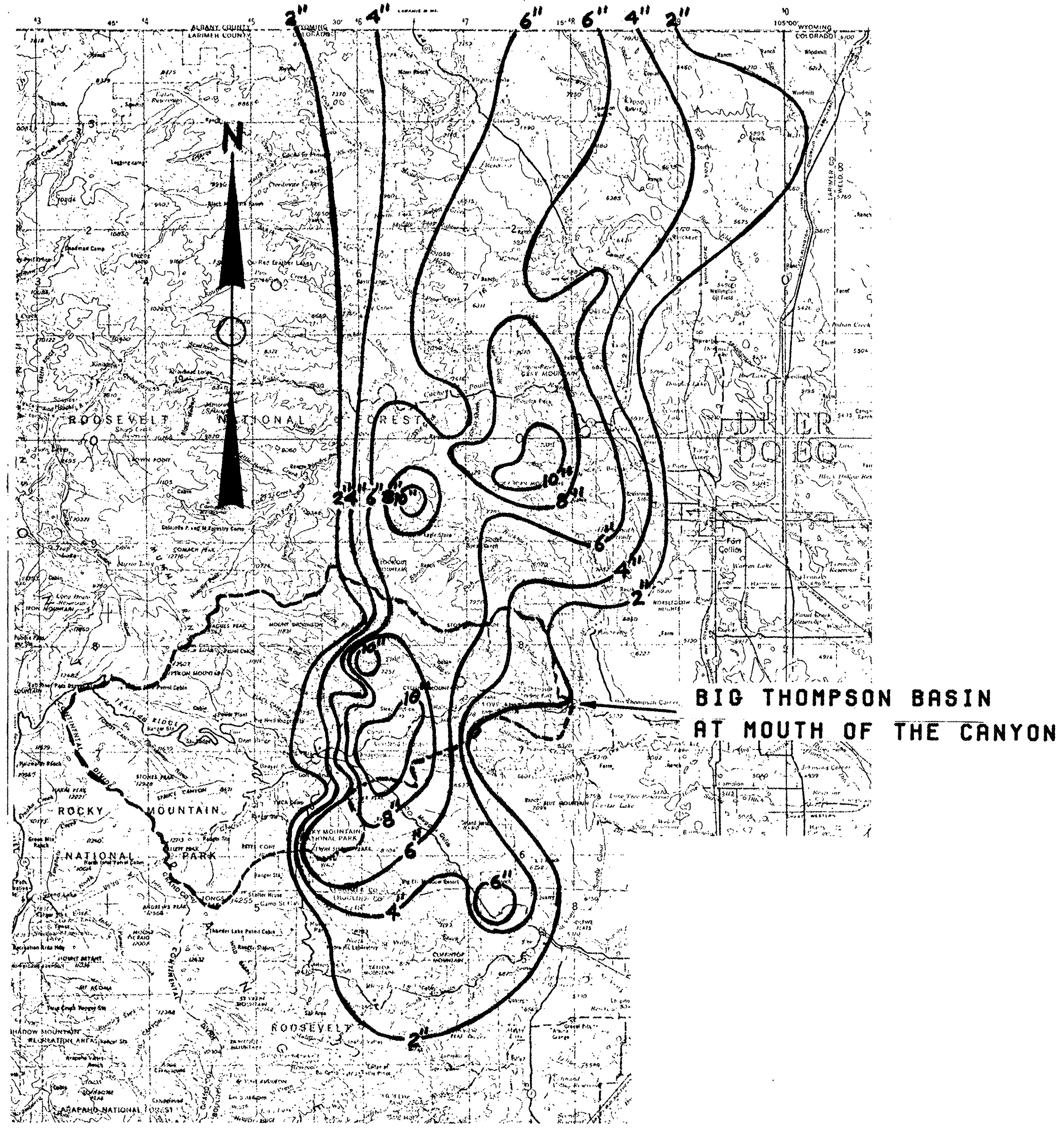
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

ISOHYETAL MAP FOR STORM
5-6 MAY 1973

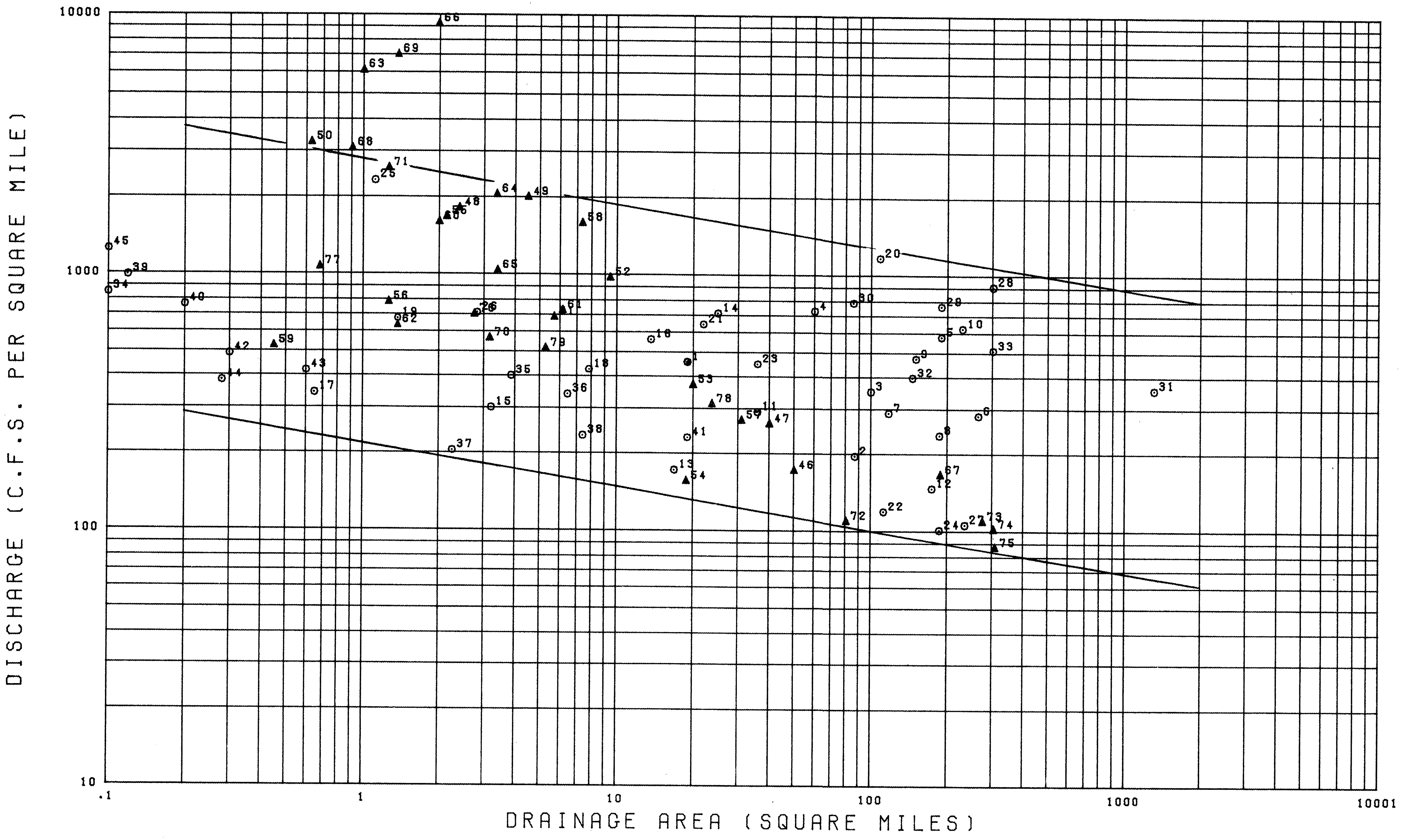
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

ISOHYETAL MAP FOR STORM
OF JULY 1976

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




## LEGEND

⊙ PLAINS TRIBUTARIES

▲ MOUNTAIN TRIBUTARIES

NOTE: SEE TABLE 5 FOR TRIBUTARY DETAILS

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER TRIBUTARIES
MAXIMUM FLOOD PEAKS

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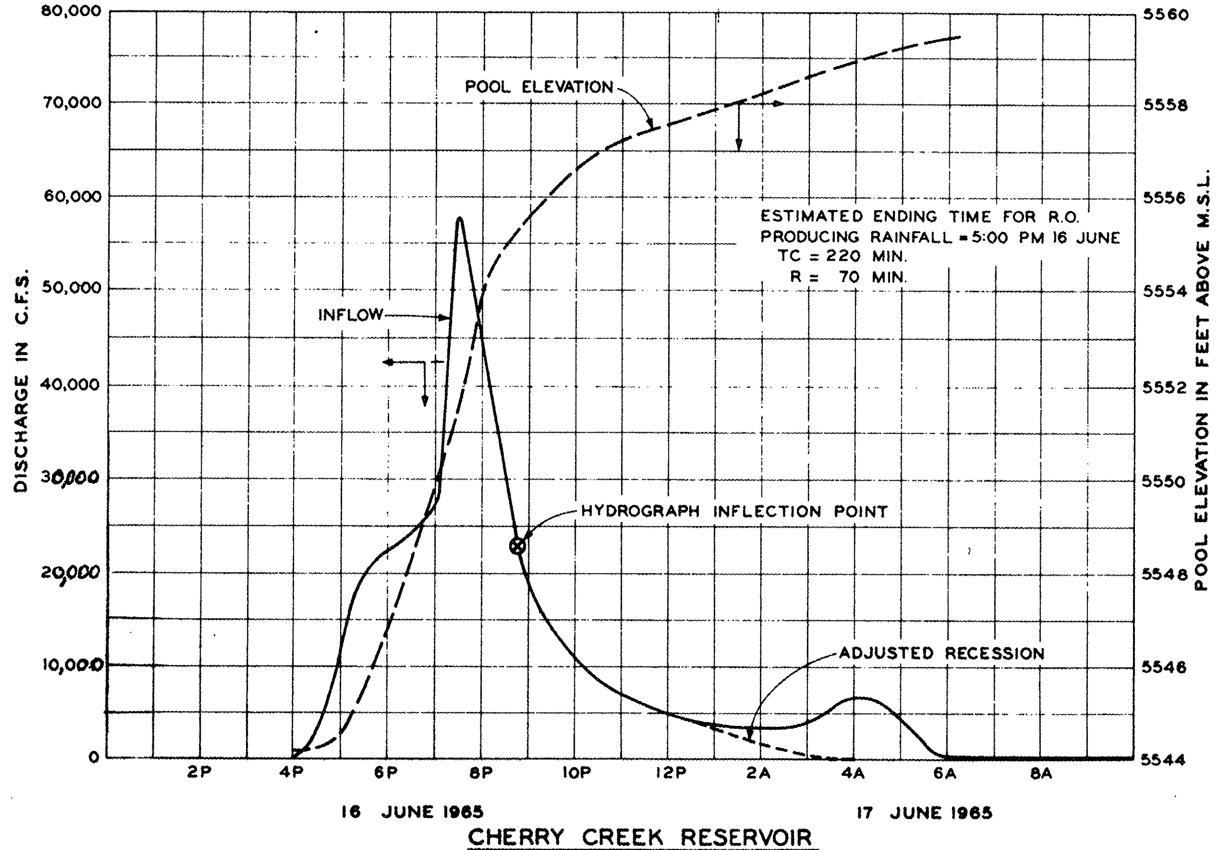
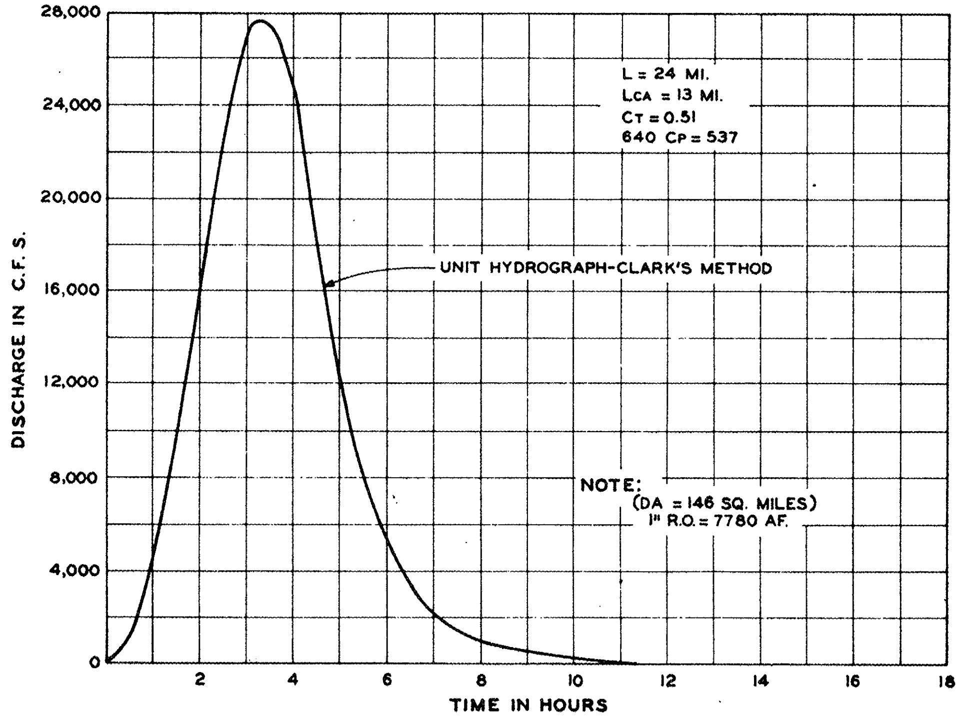



**CHERRY CREEK RESERVOIR**

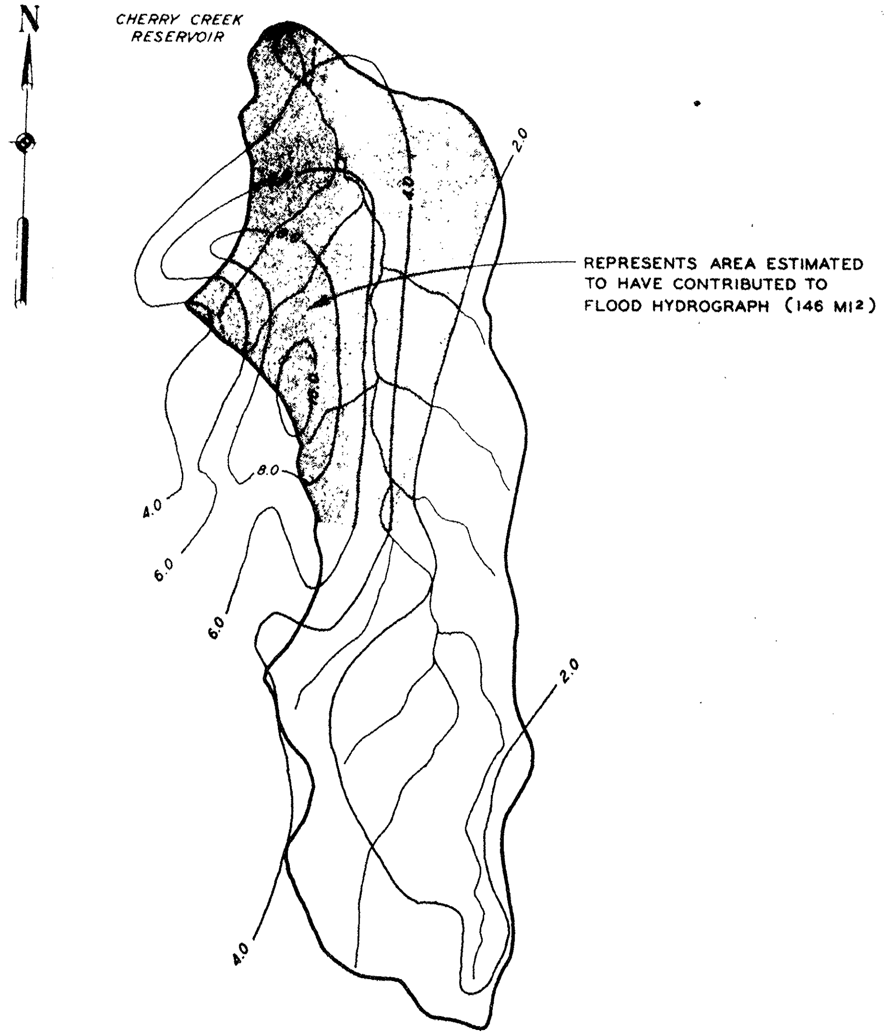
**INFLOW HYDROGRAPH**




**ONE HOUR UNIT HYDROGRAPH**

**CHERRY CREEK AT CHERRY CREEK RESERVOIR**

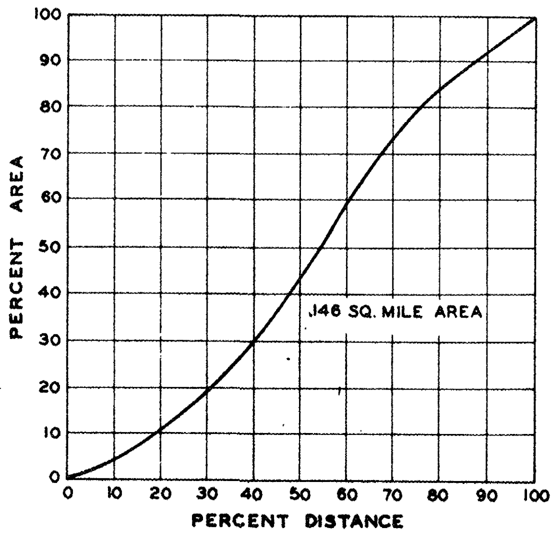
**FROM JUNE 1965 FLOOD**




**ISOHYETAL PATTERN**

**CHERRY CREEK BASIN**

**16 JUNE 1965 STORM**




**TIME AREA CURVE**

**CHERRY CREEK**

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1965 FLOOD ON CHERRY CREEK
AND UNIT HYDROGRAPH DERIVATION

U.S. ARMY ENGINEER DISTRICT OMAHA
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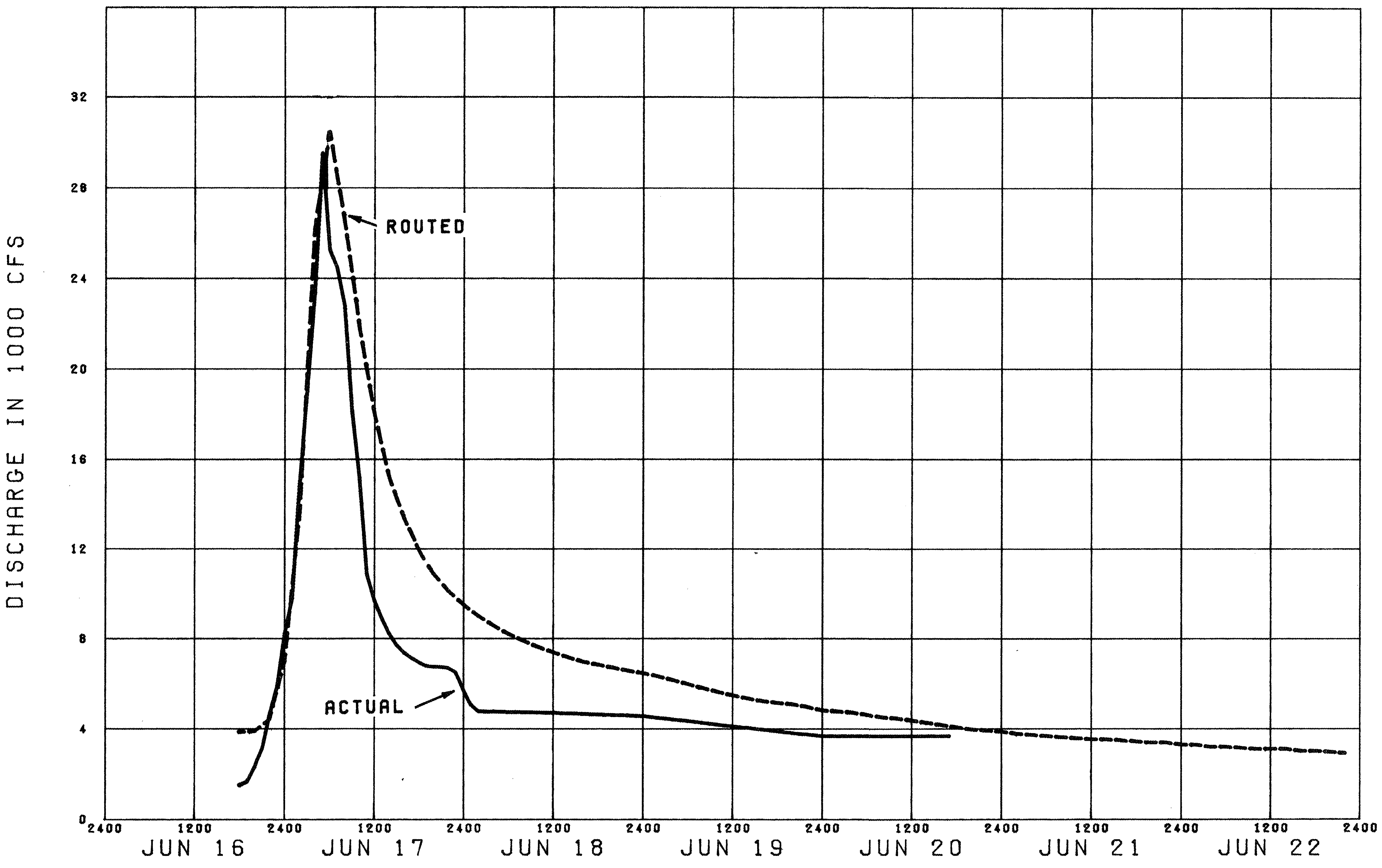


SOUTH PLATTE RIVER 1965 FLOOD AT HENDERSON

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1965 FLOOD AT HENDERSON GAGE
ACTUAL AND ROUTED

U.S. ARMY ENGINEER DISTRICT OMAHA
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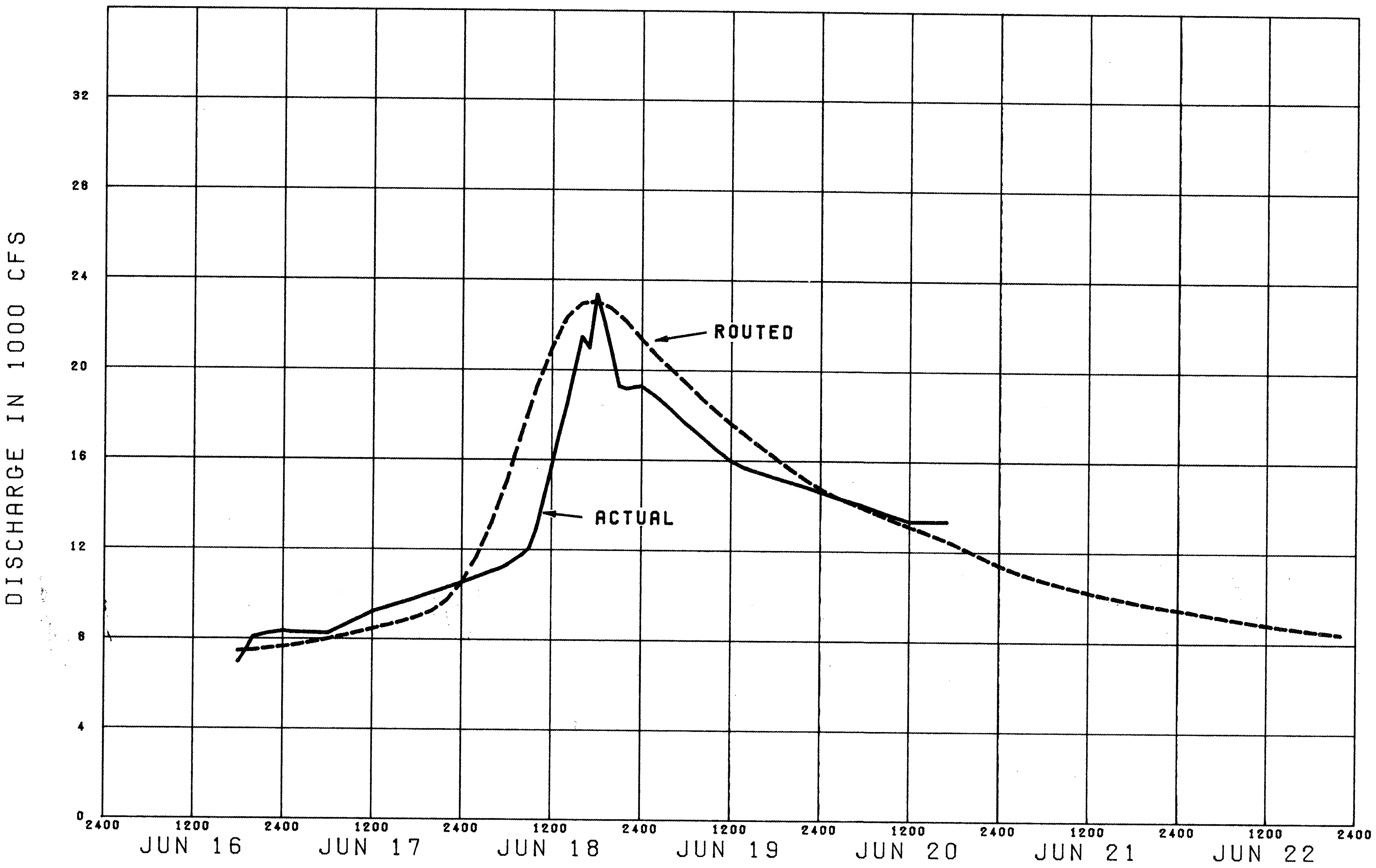
SEP. 1977




SOUTH PLATTE RIVER 1965 FLOOD AT KERSEY

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1965 FLOOD AT KERSEY GAGE
ACTUAL AND ROUTED

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
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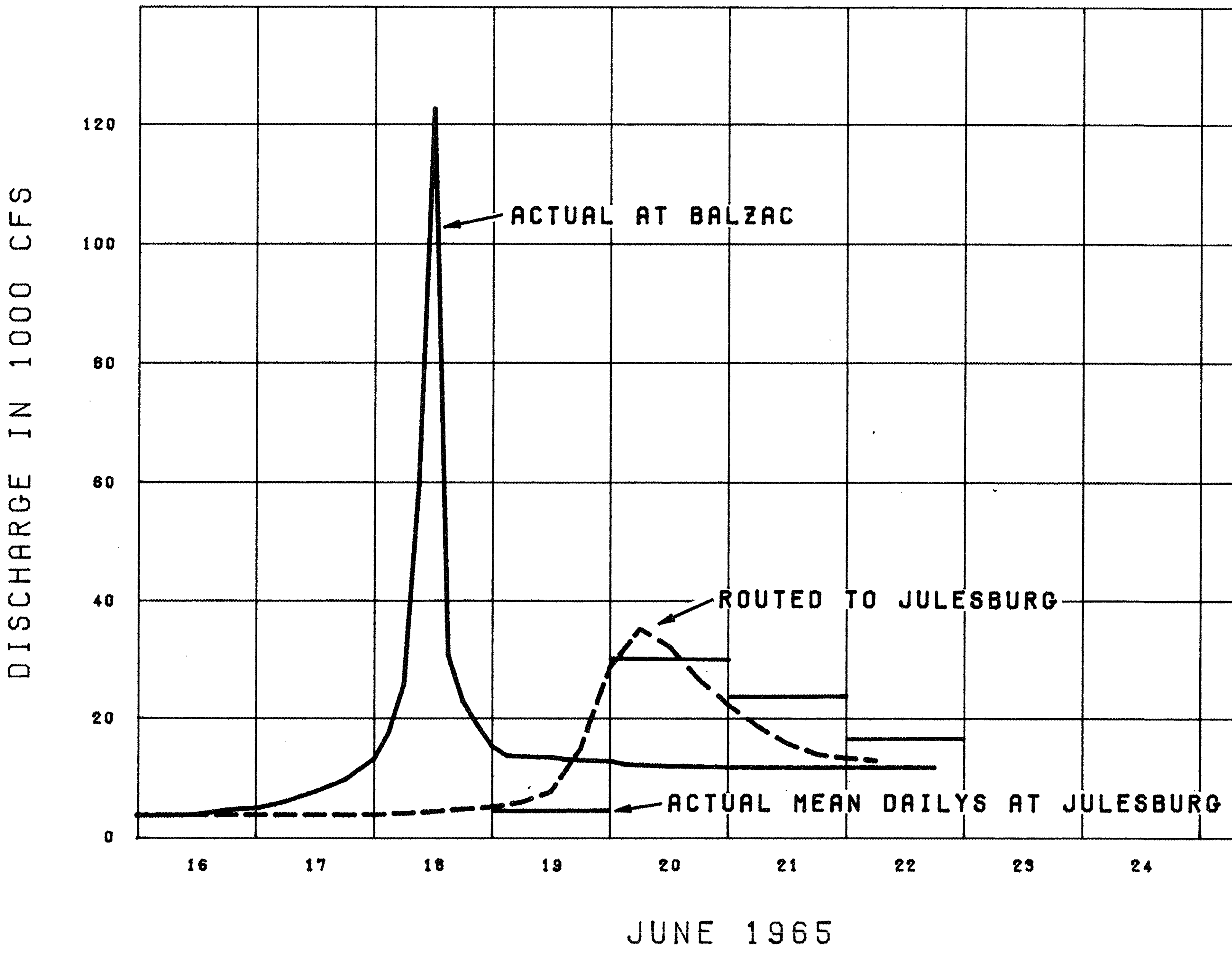


METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1965 FLOOD AT BALZAC GAGE
ROUTED TO JULESBURG GAGE

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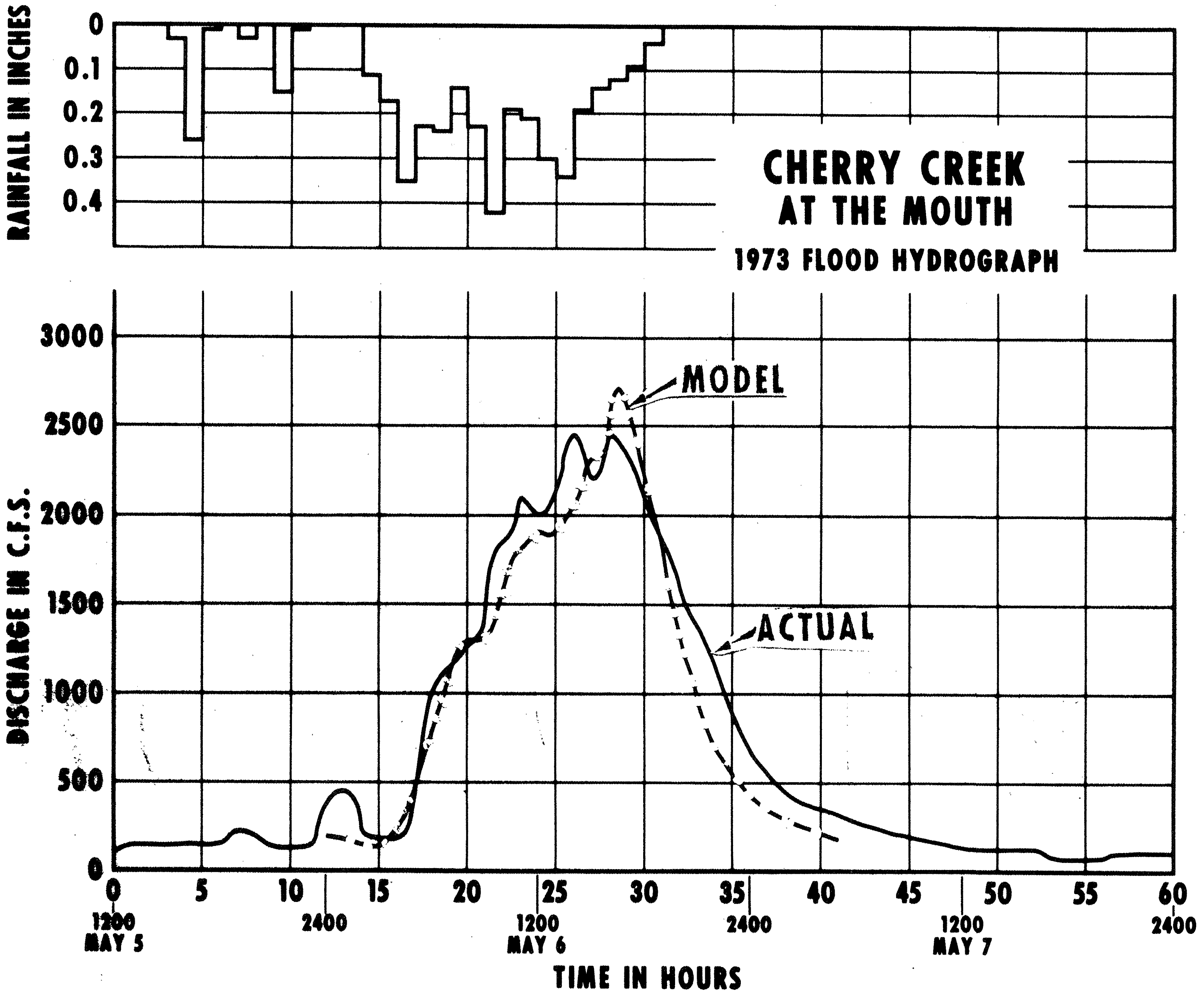
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1973 FLOOD AT CHERRY CREEK GAGE
ACTUAL AND MODEL RECONSTITUTION

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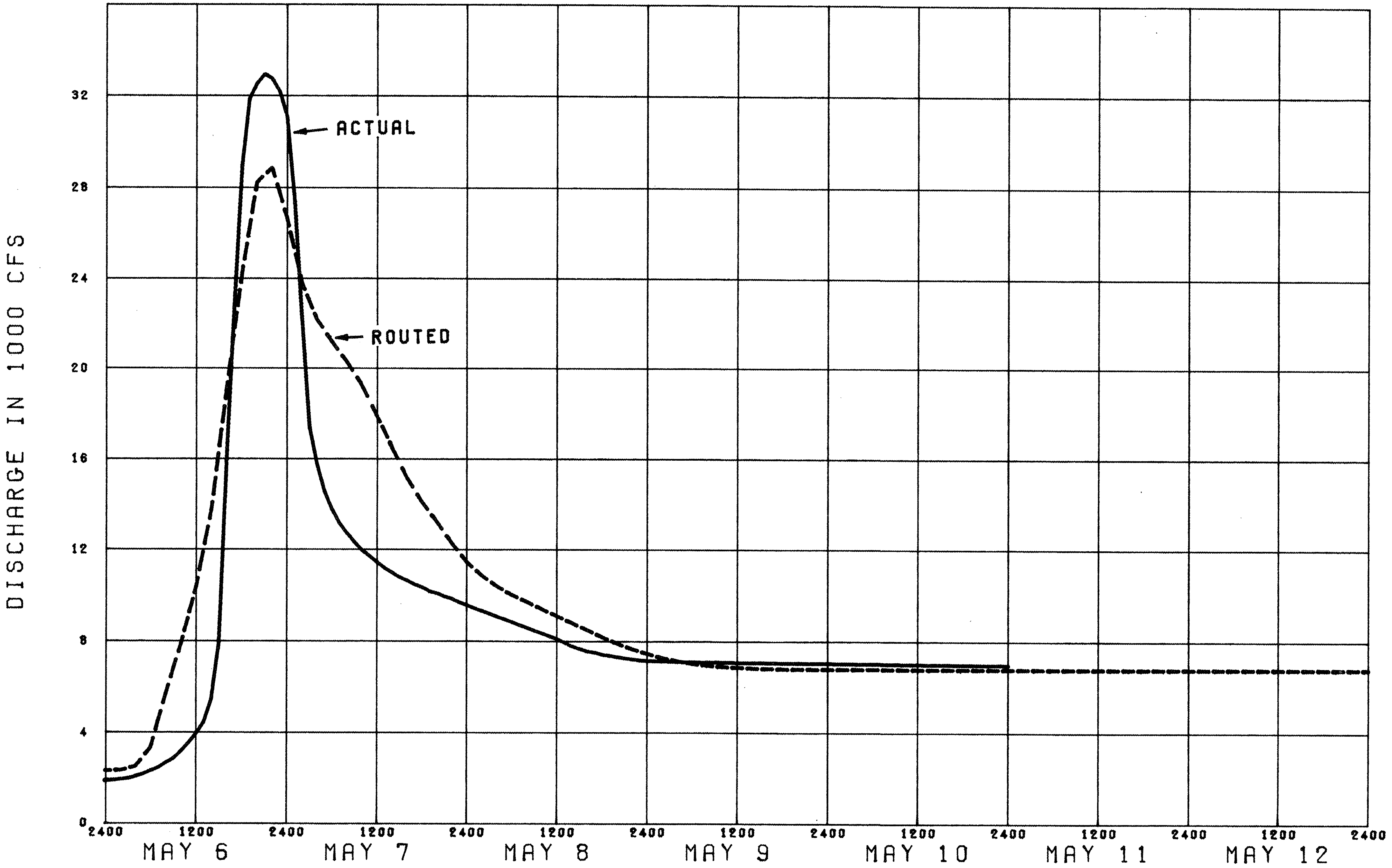
SEP. 1977




SOUTH PLATTE RIVER 1973 FLOOD AT HENDERSON

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1973 FLOOD AT HENDERSON GAGE
ACTUAL AND ROUTED

U.S. ARMY ENGINEER DISTRICT OMAHA
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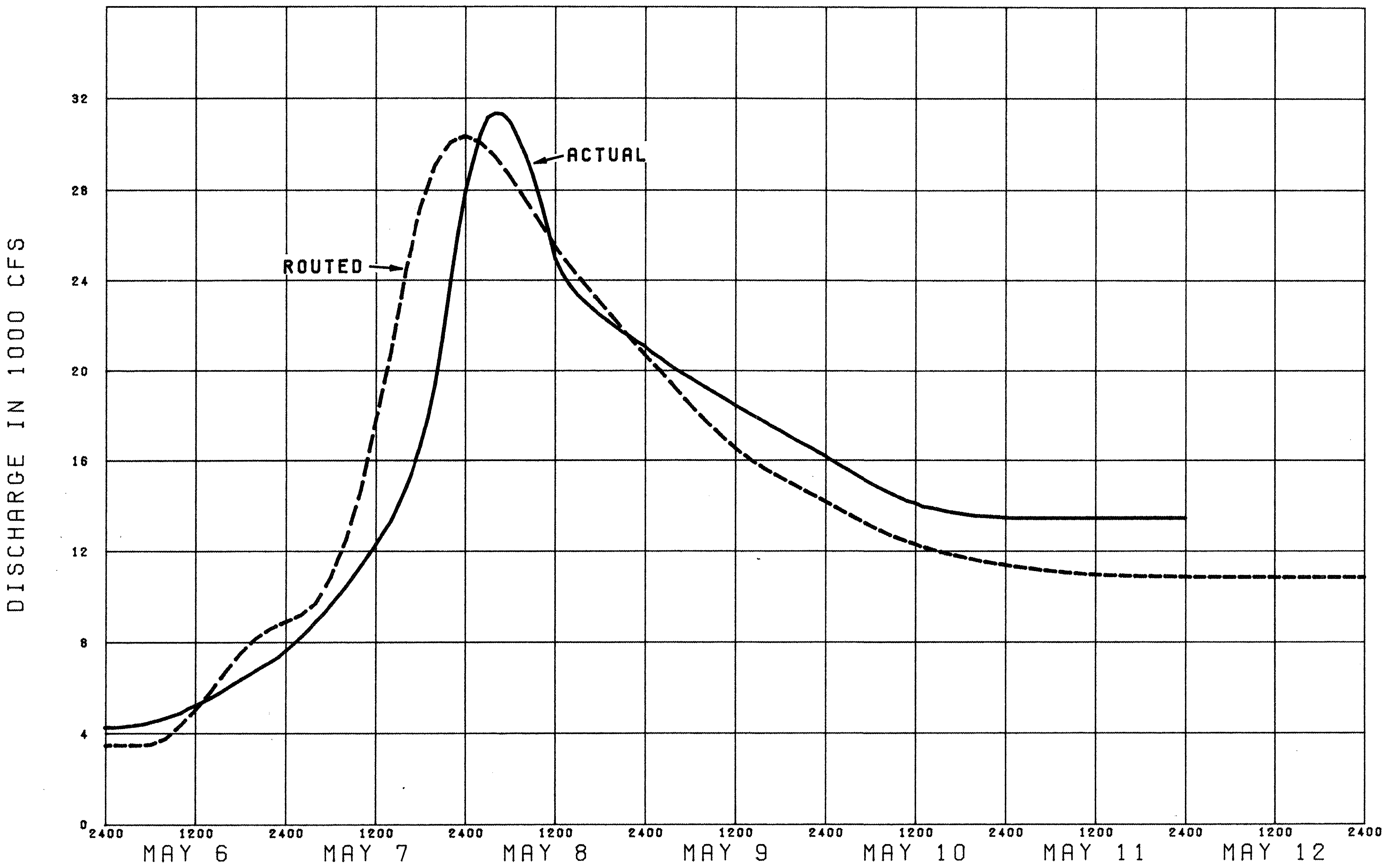
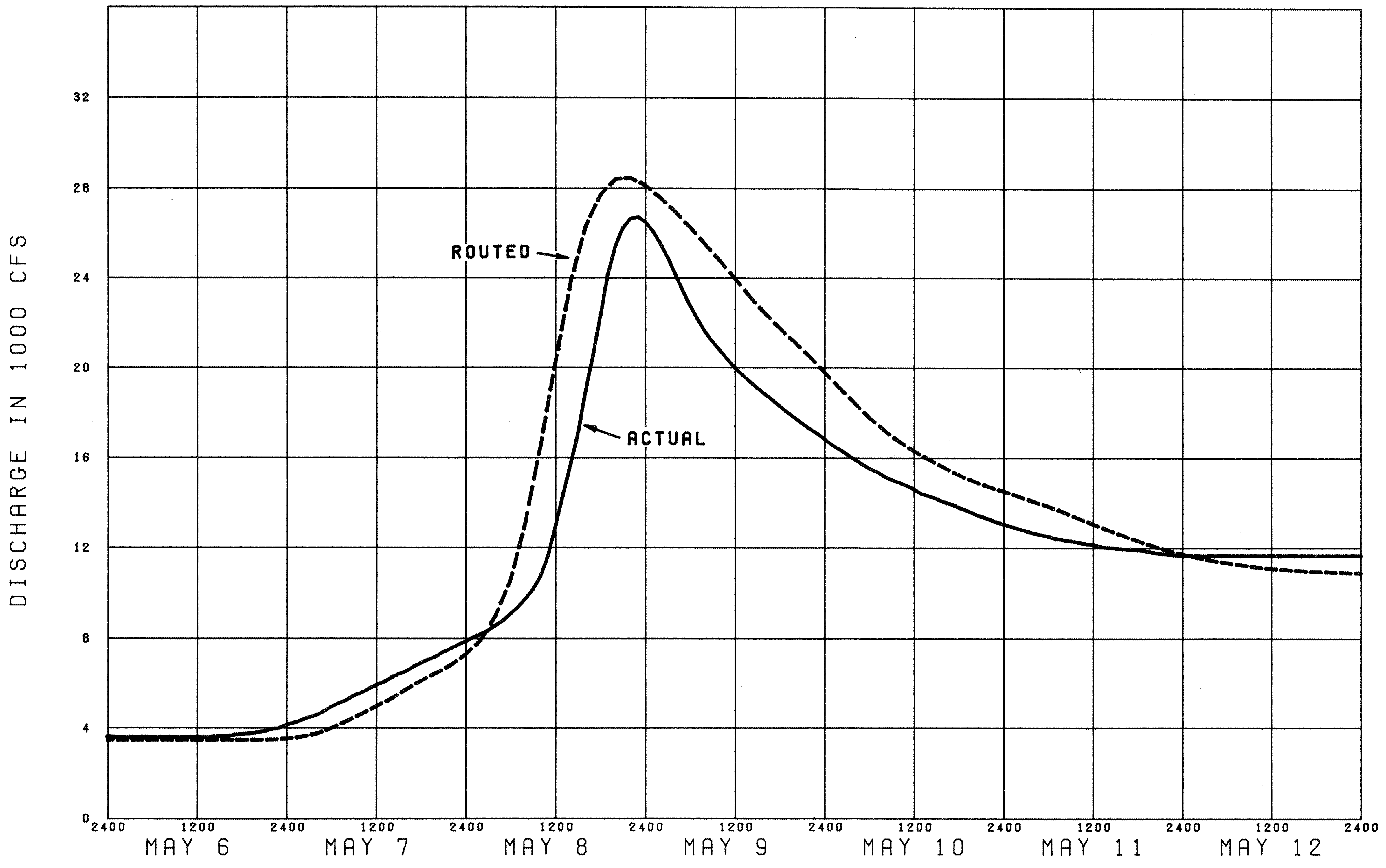



SOUTH PLATTE RIVER 1973 FLOOD AT KERSEY

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1973 FLOOD AT KERSEY GAGE
ACTUAL AND ROUTED

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977

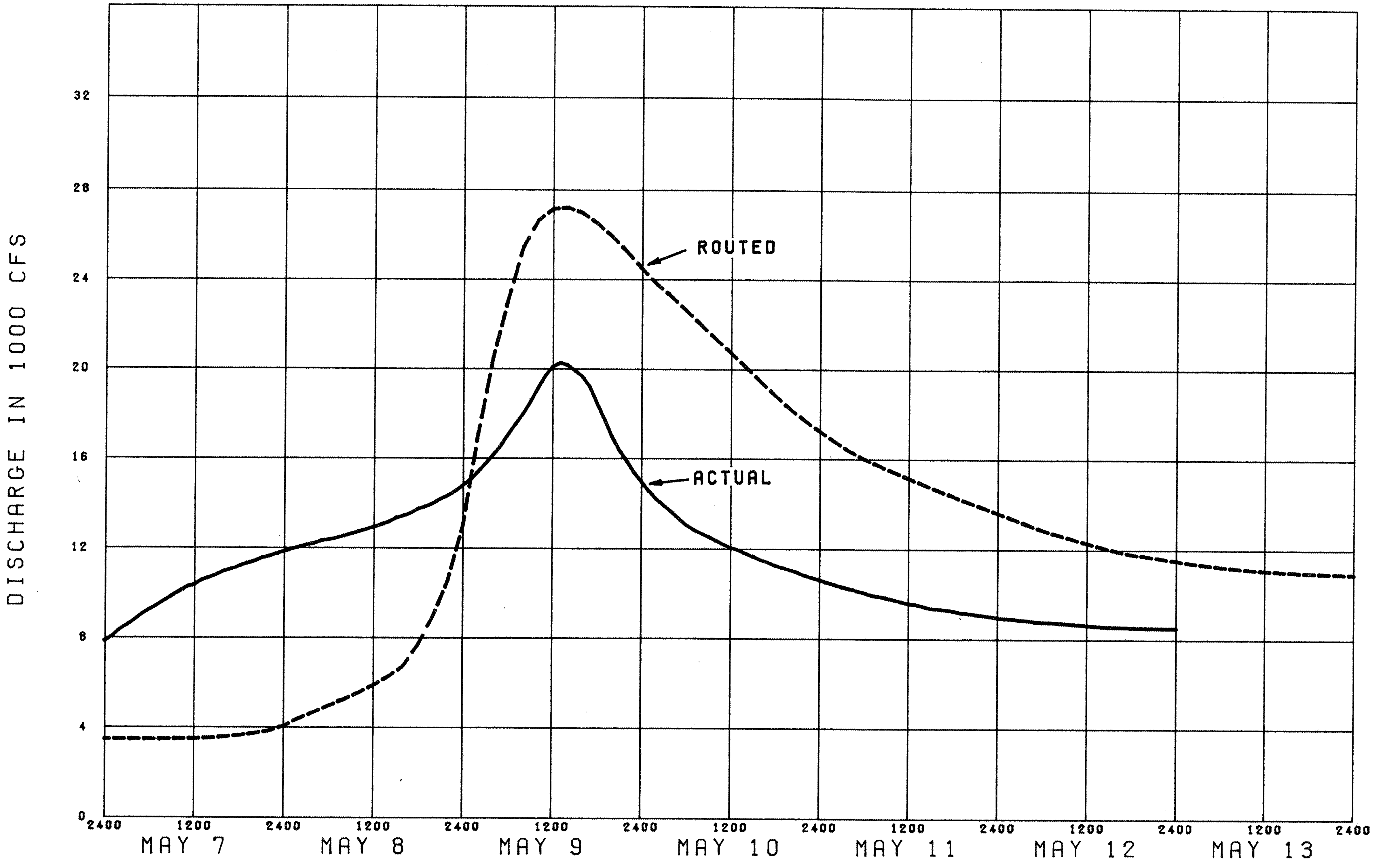



SOUTH PLATTE RIVER 1973 FLOOD AT WELDONA

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1973 FLOOD AT WELDONA GAGE
ACTUAL AND ROUTED

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




SOUTH PLATTE RIVER 1973 FLOOD AT BALZAC

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1973 FLOOD AT BALZAC GAGE
ACTUAL AND ROUTED

U.S. ARMY ENGINEER DISTRICT OMAHA
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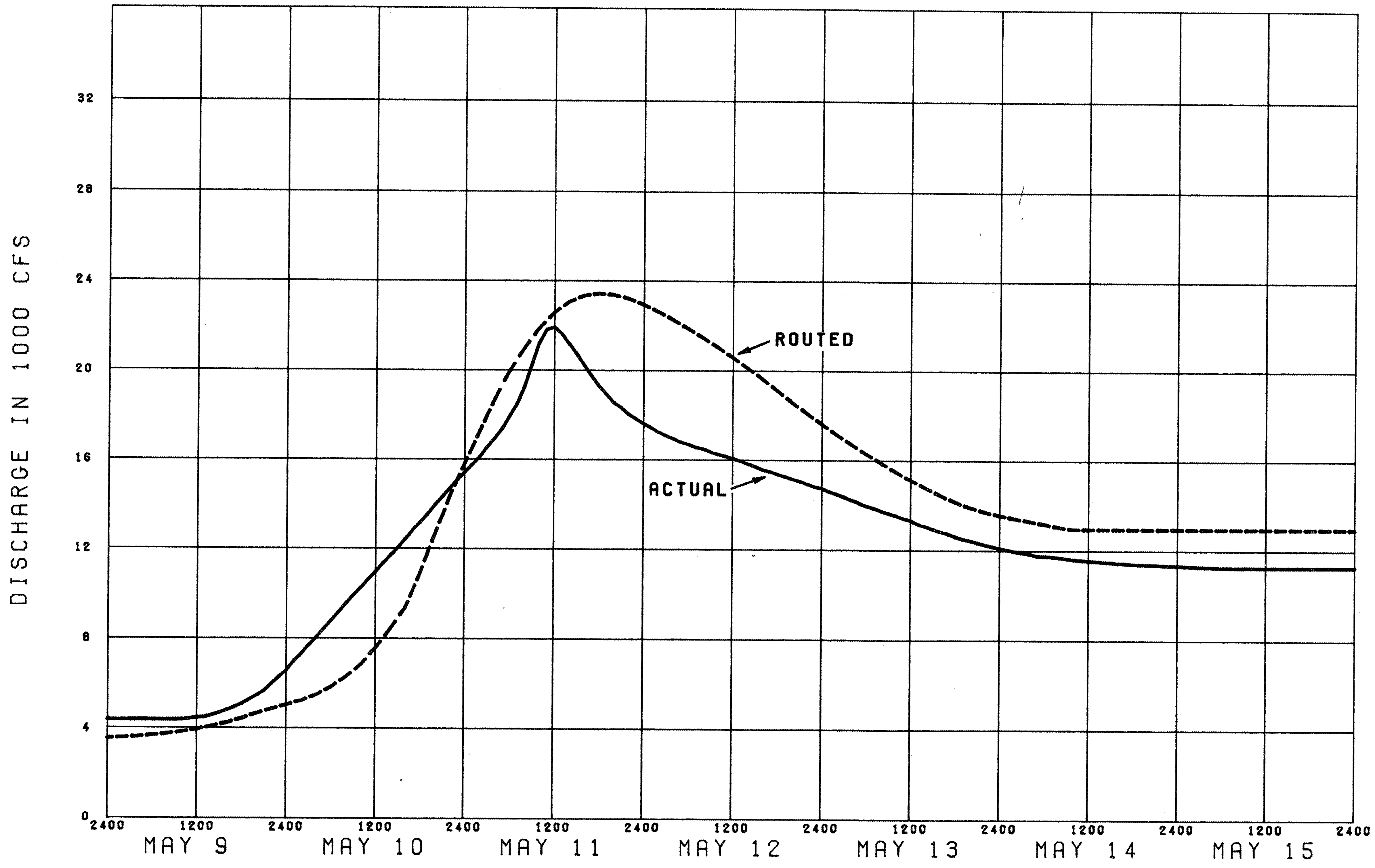
SEP. 1977

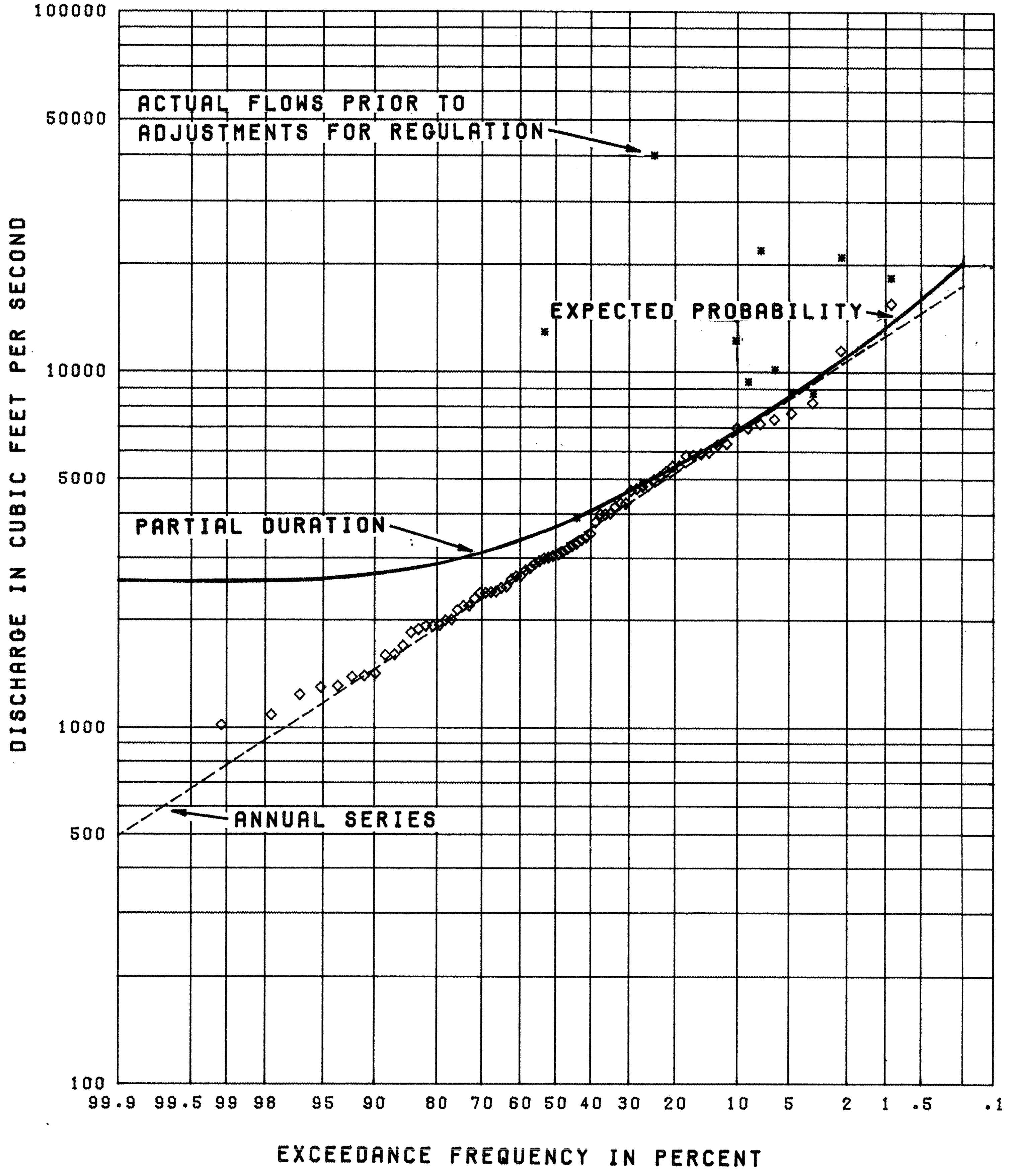



SOUTH PLATTE RIVER 1973 FLOOD AT JULESBURG

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

1973 FLOOD AT JULESBURG GAGE
ACTUAL AND ROUTED

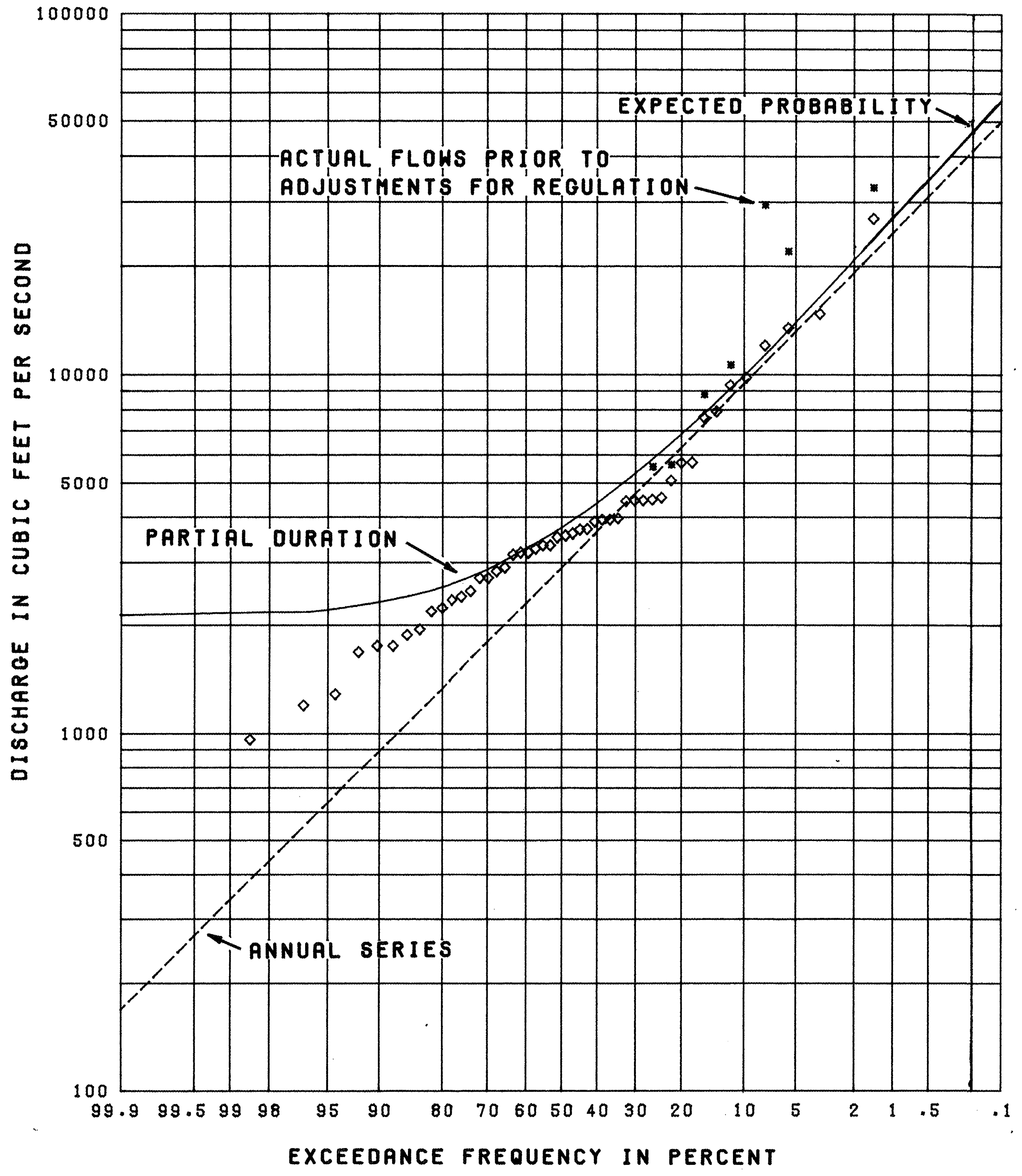
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

DISCHARGE PROBABILITY AT
DENVER GAGE

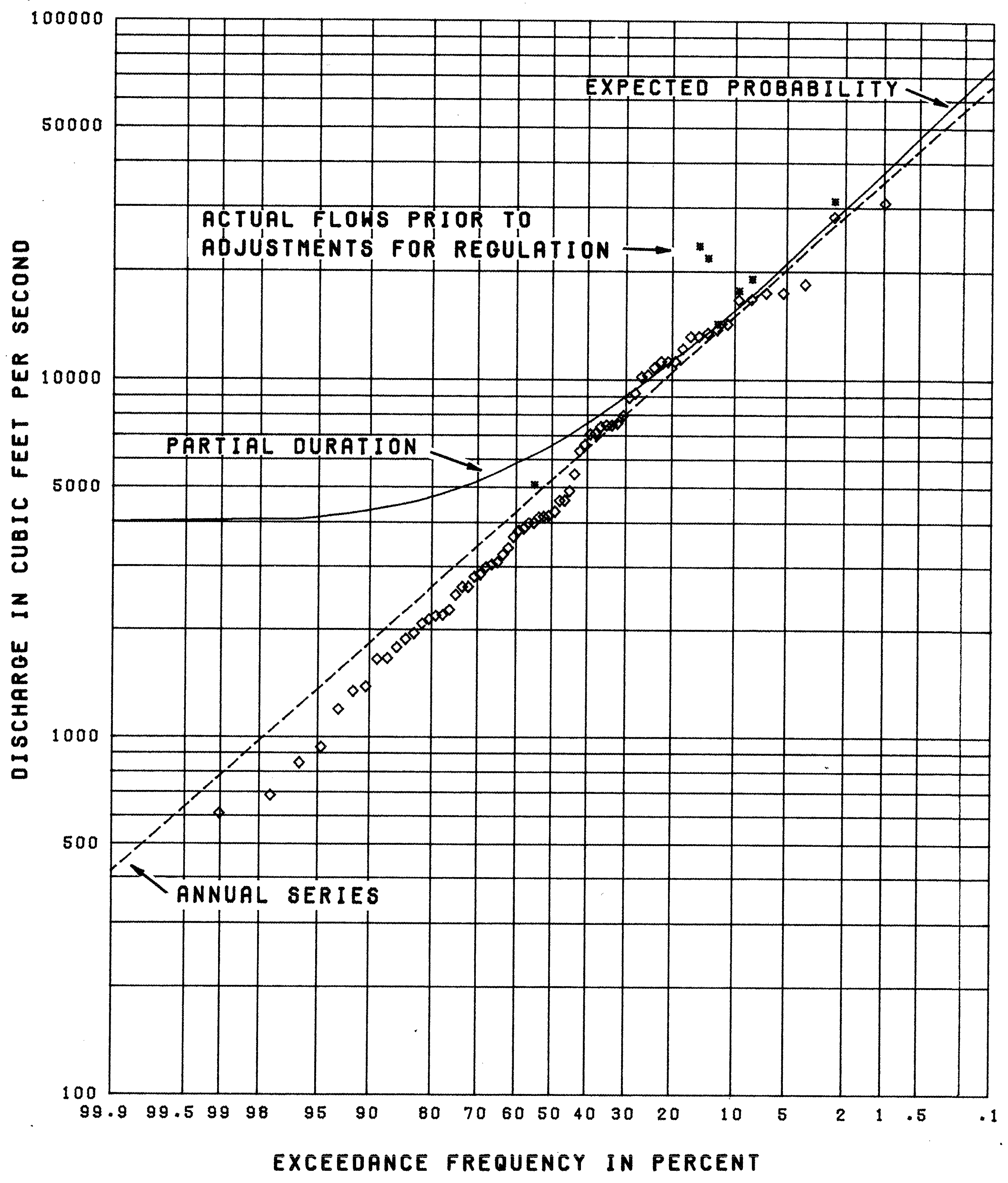
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

DISCHARGE PROBABILITY AT
HENDERSON GAGE

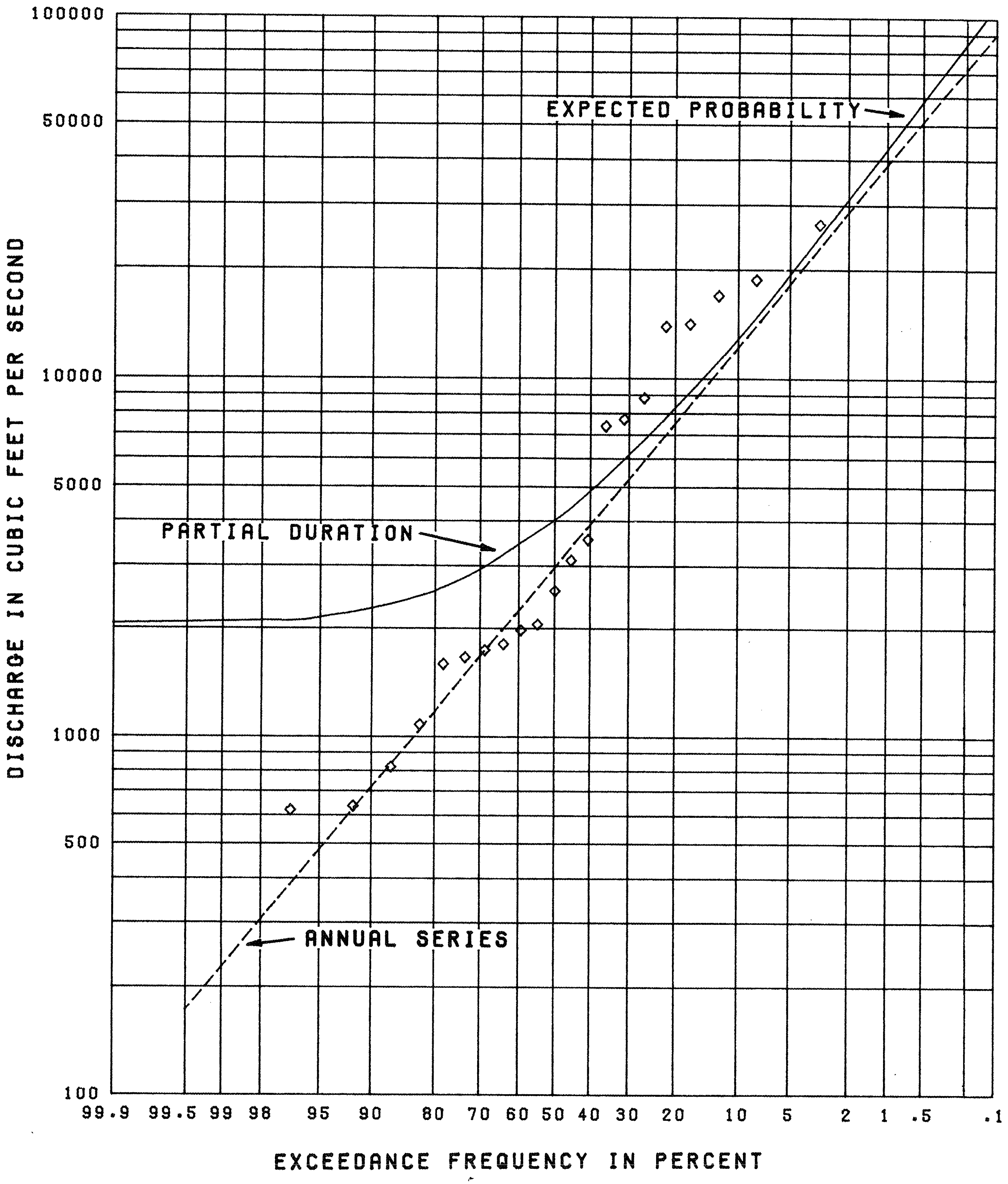
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

DISCHARGE PROBABILITY AT
KERSEY GAGE

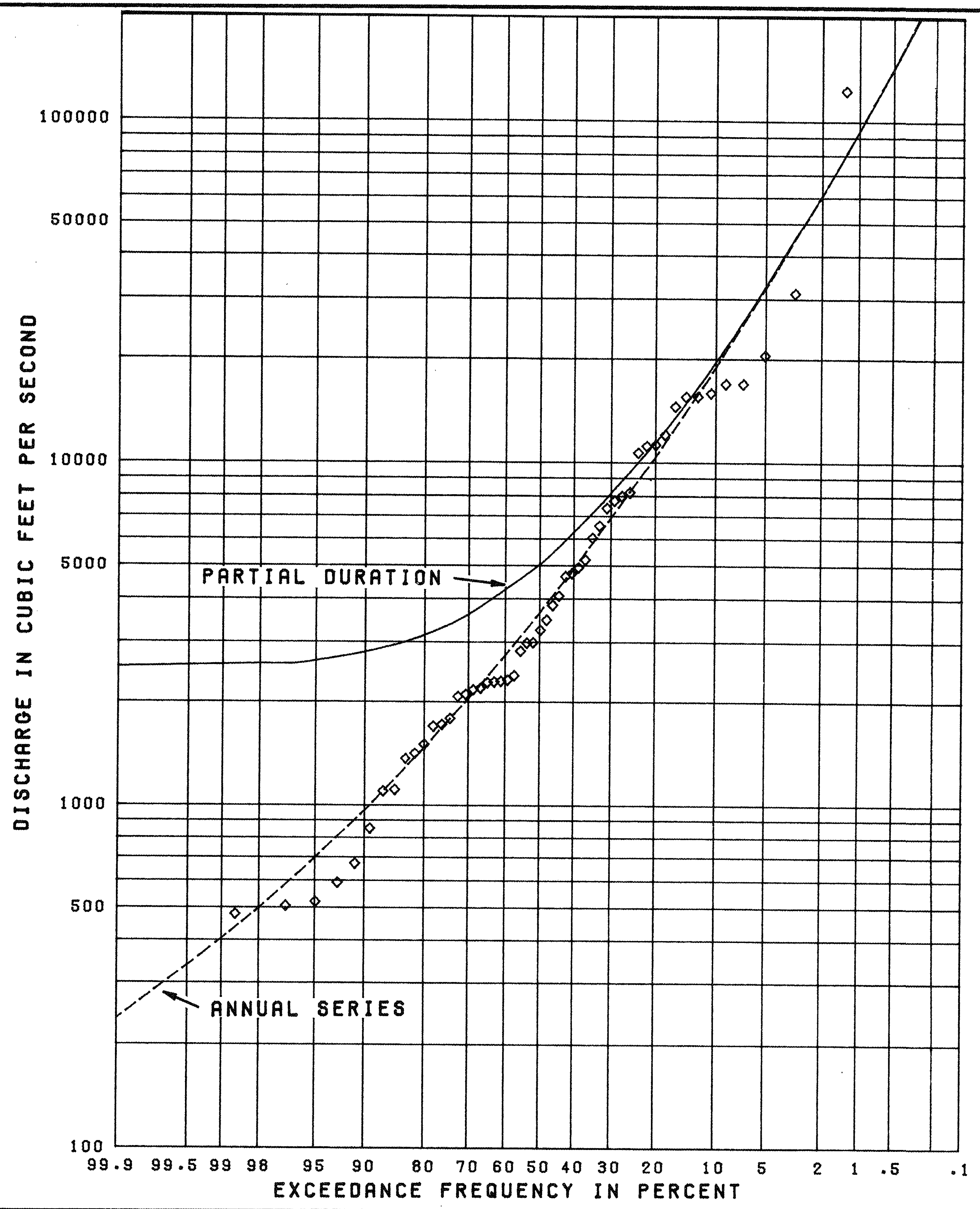
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

DISCHARGE PROBABILITY AT
WELDONA GAGE

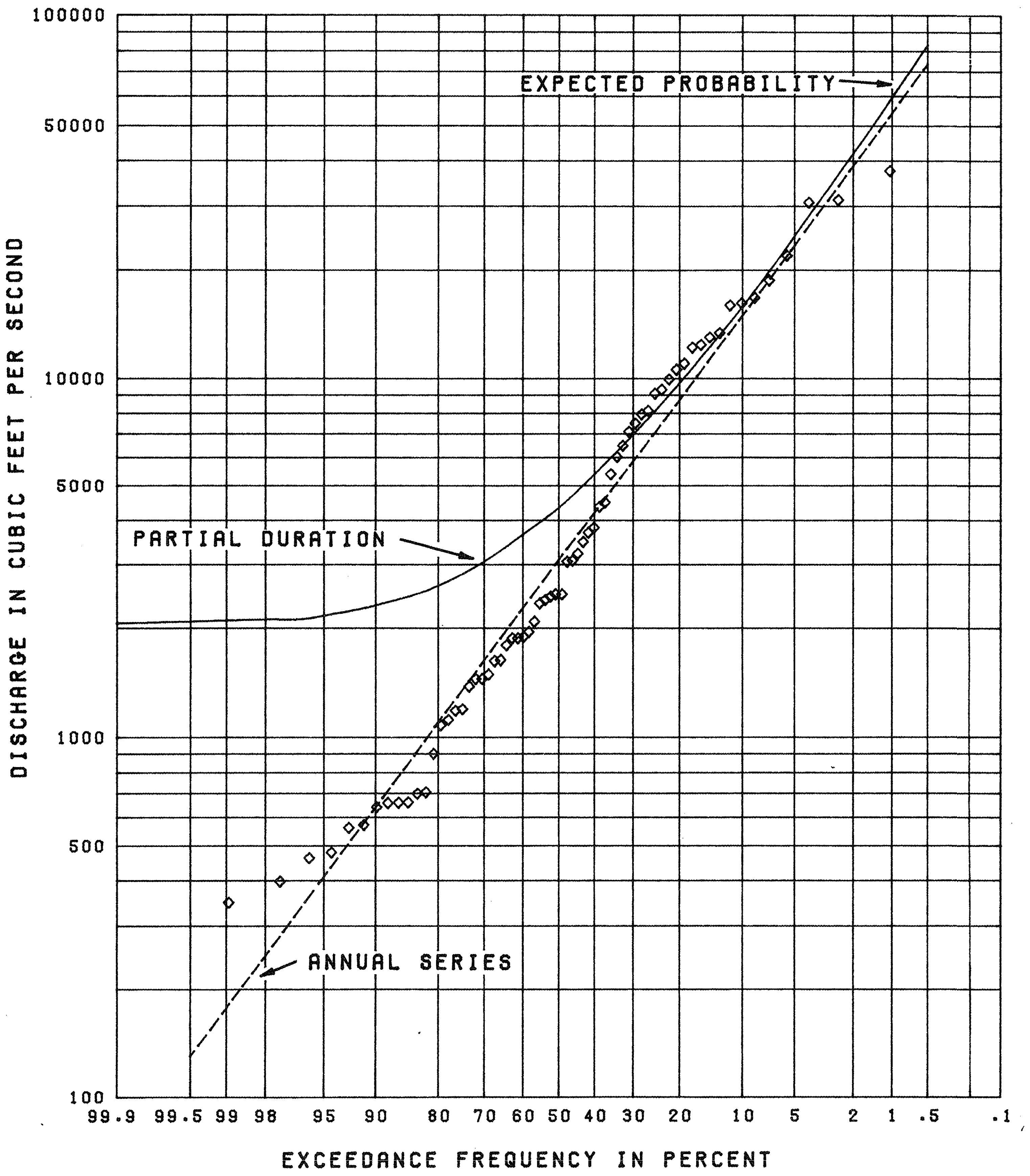
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

DISCHARGE PROBABILITY AT
BALZAC GAGE

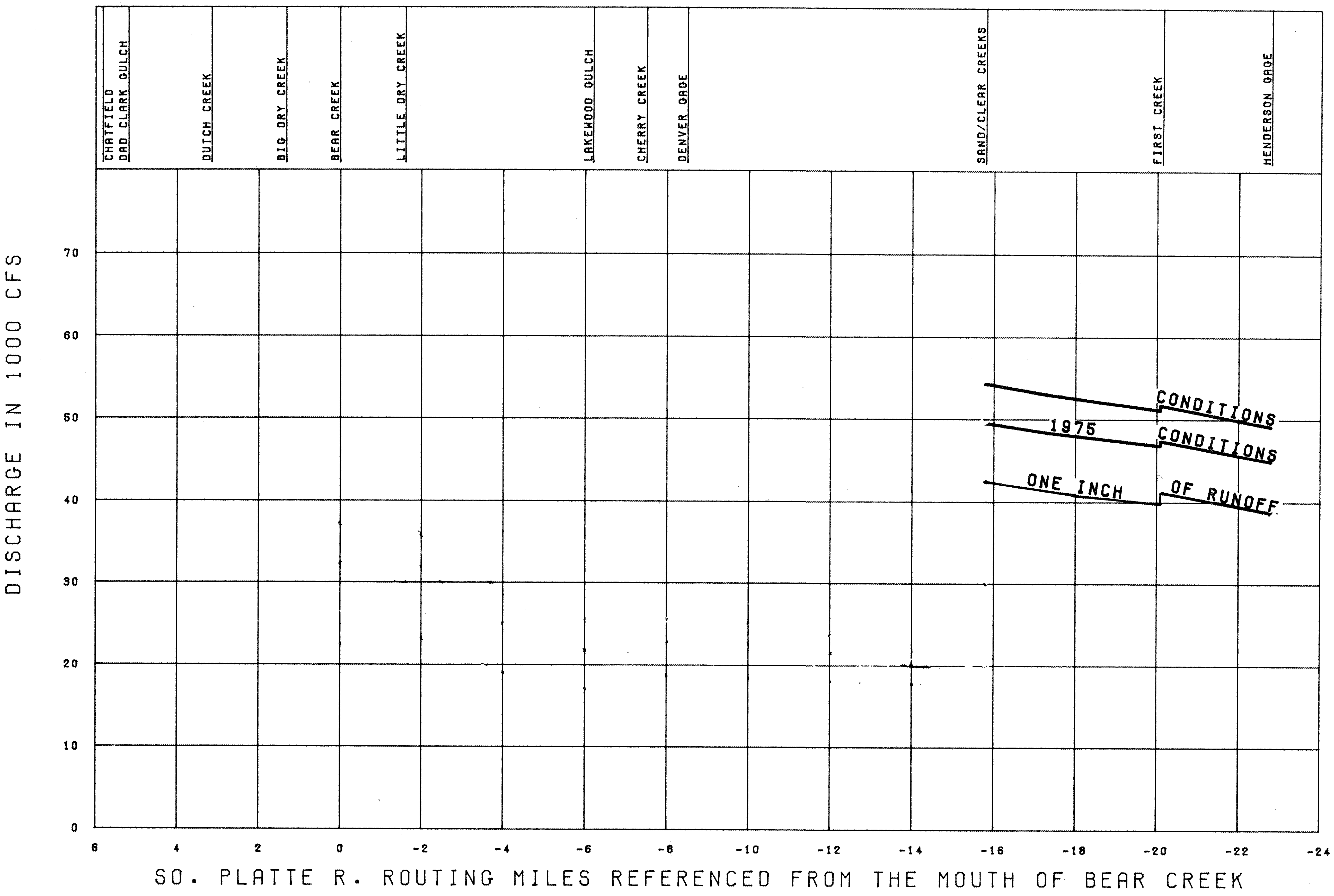
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

DISCHARGE PROBABILITY AT
JULESBURG GAGE

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
ONE INCH OF RUNOFF,
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
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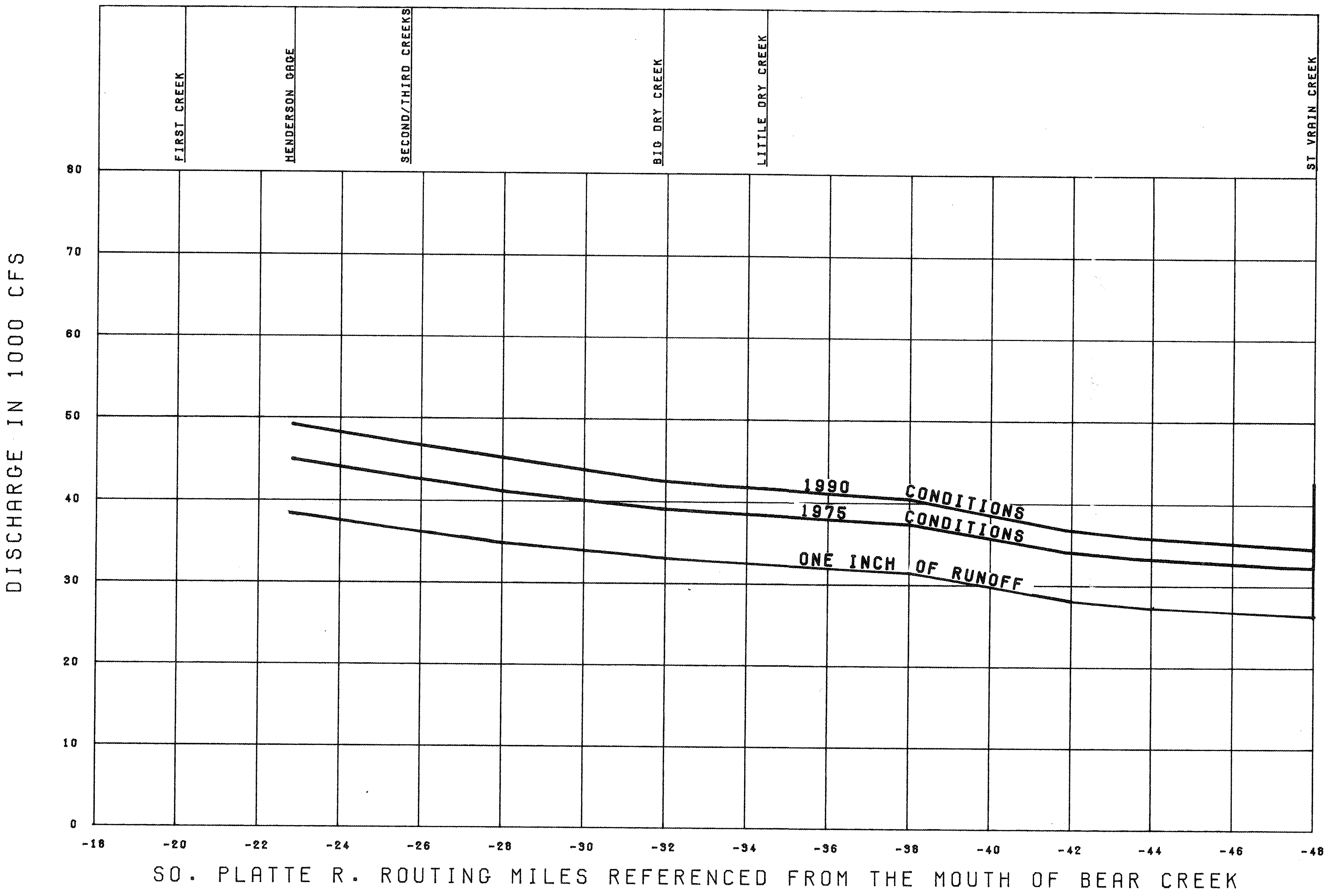


METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
ONE INCH OF RUNOFF.
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
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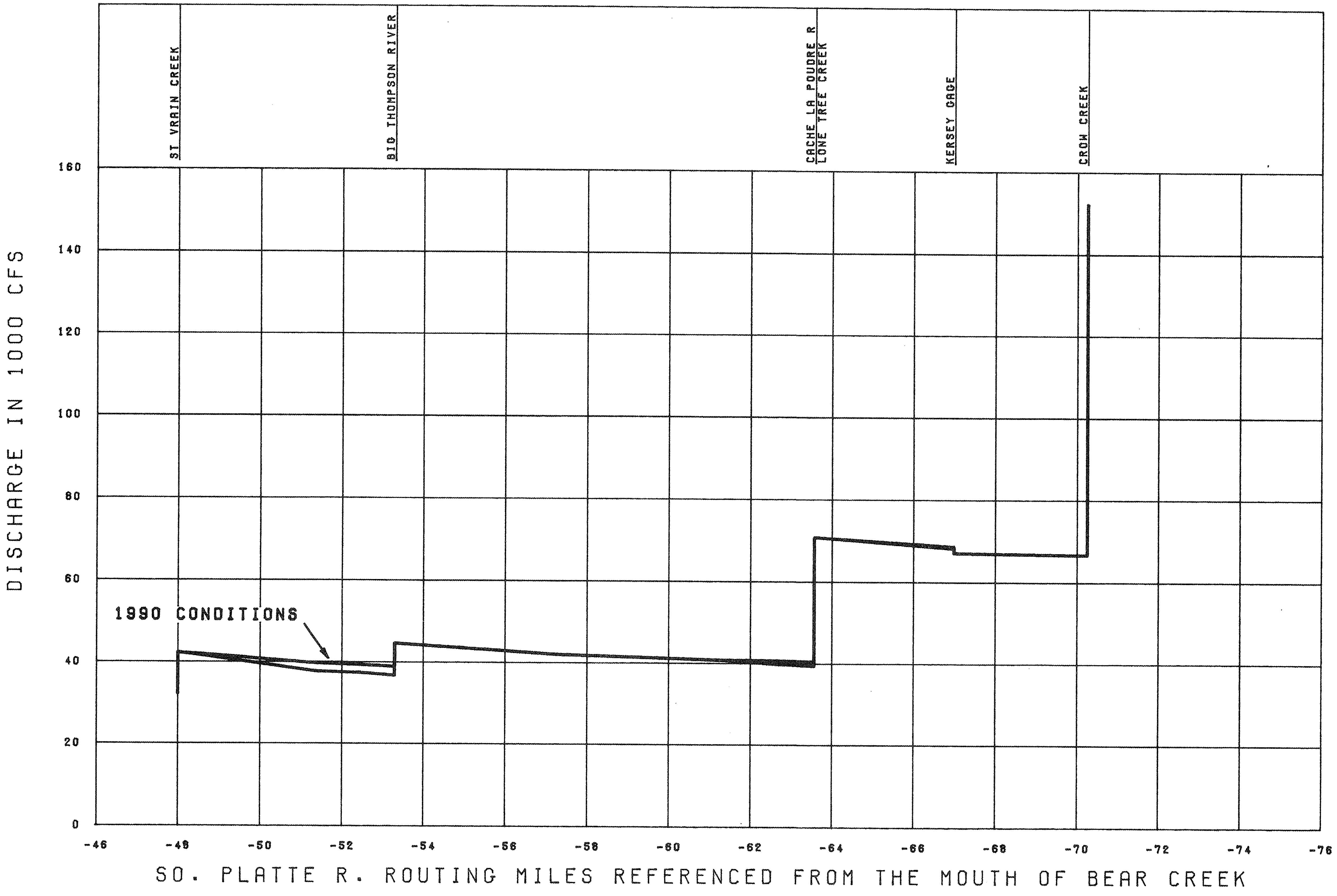
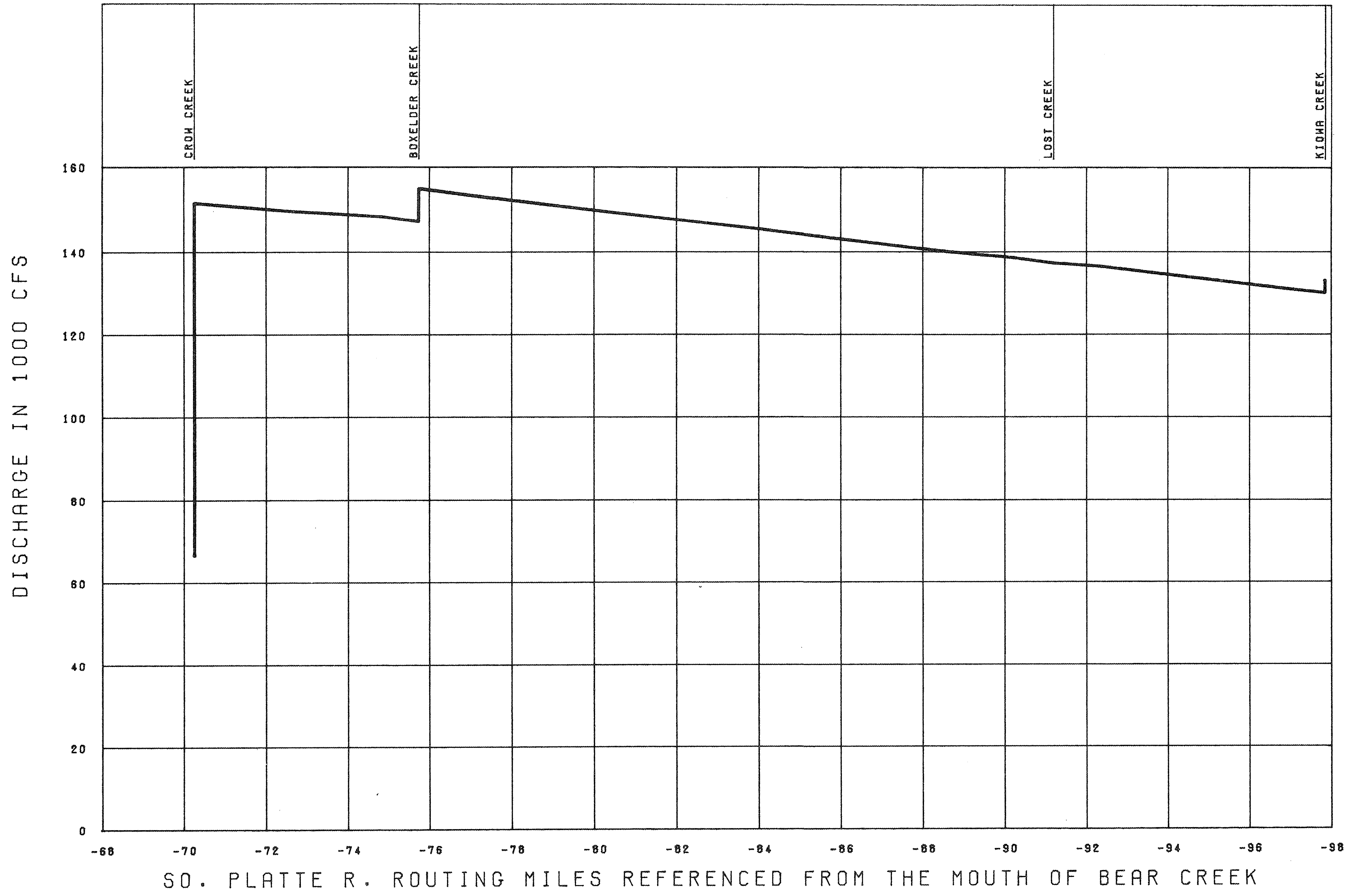



METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
ONE INCH OF RUNOFF,
1975 AND 1990 CONDITIONS

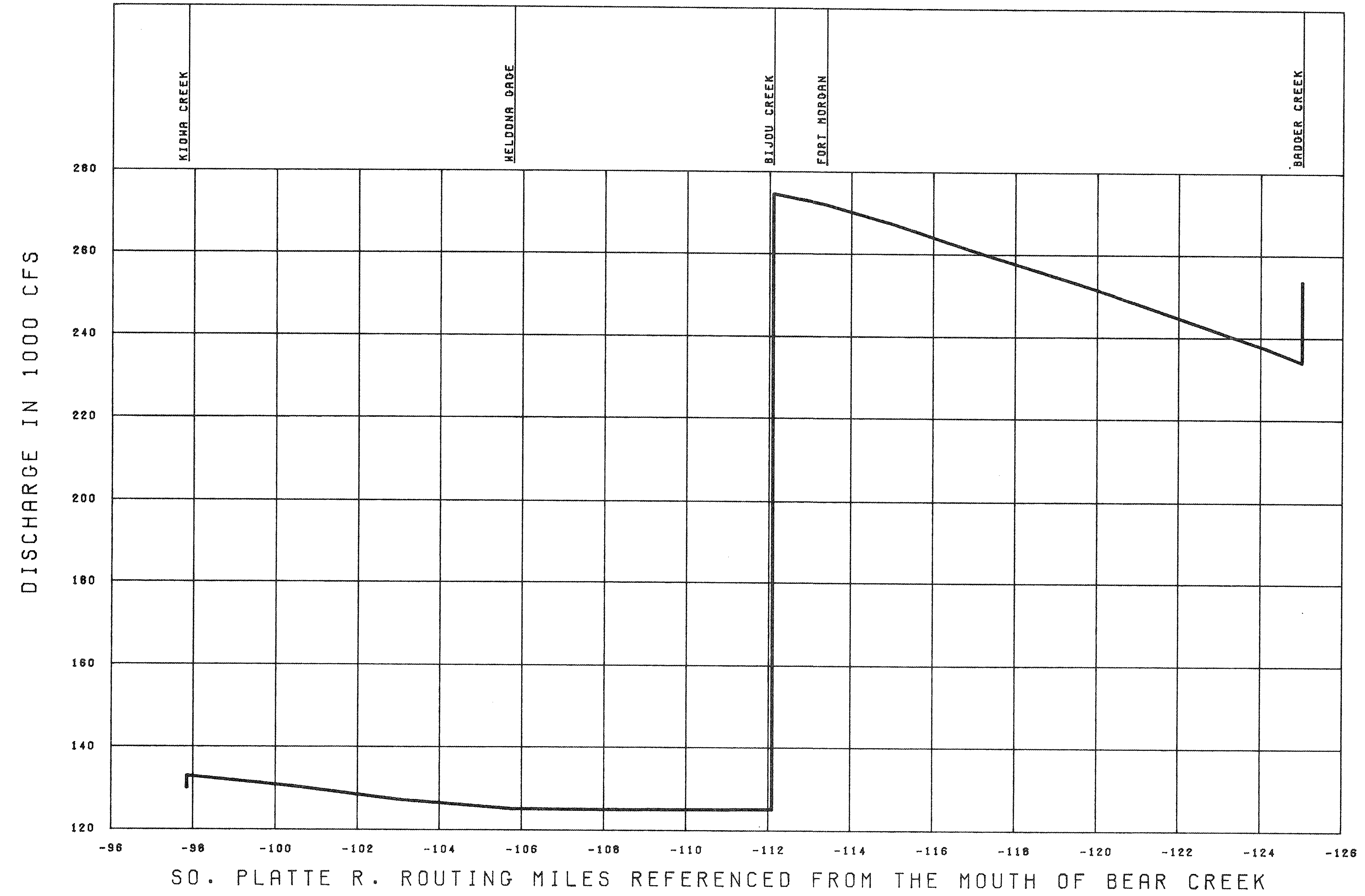
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
ONE INCH OF RUNOFF,
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
ONE INCH OF RUNOFF.
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
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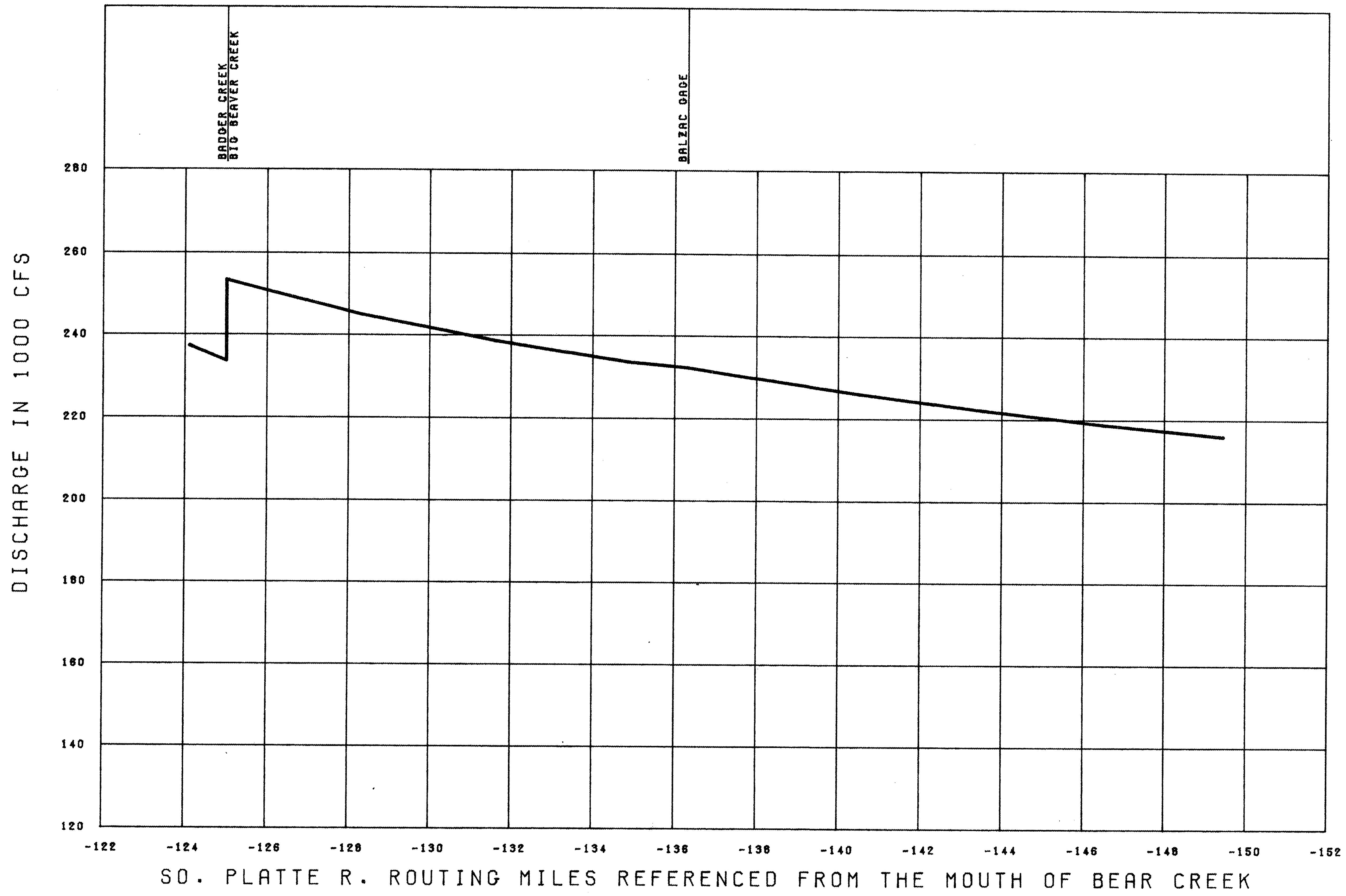
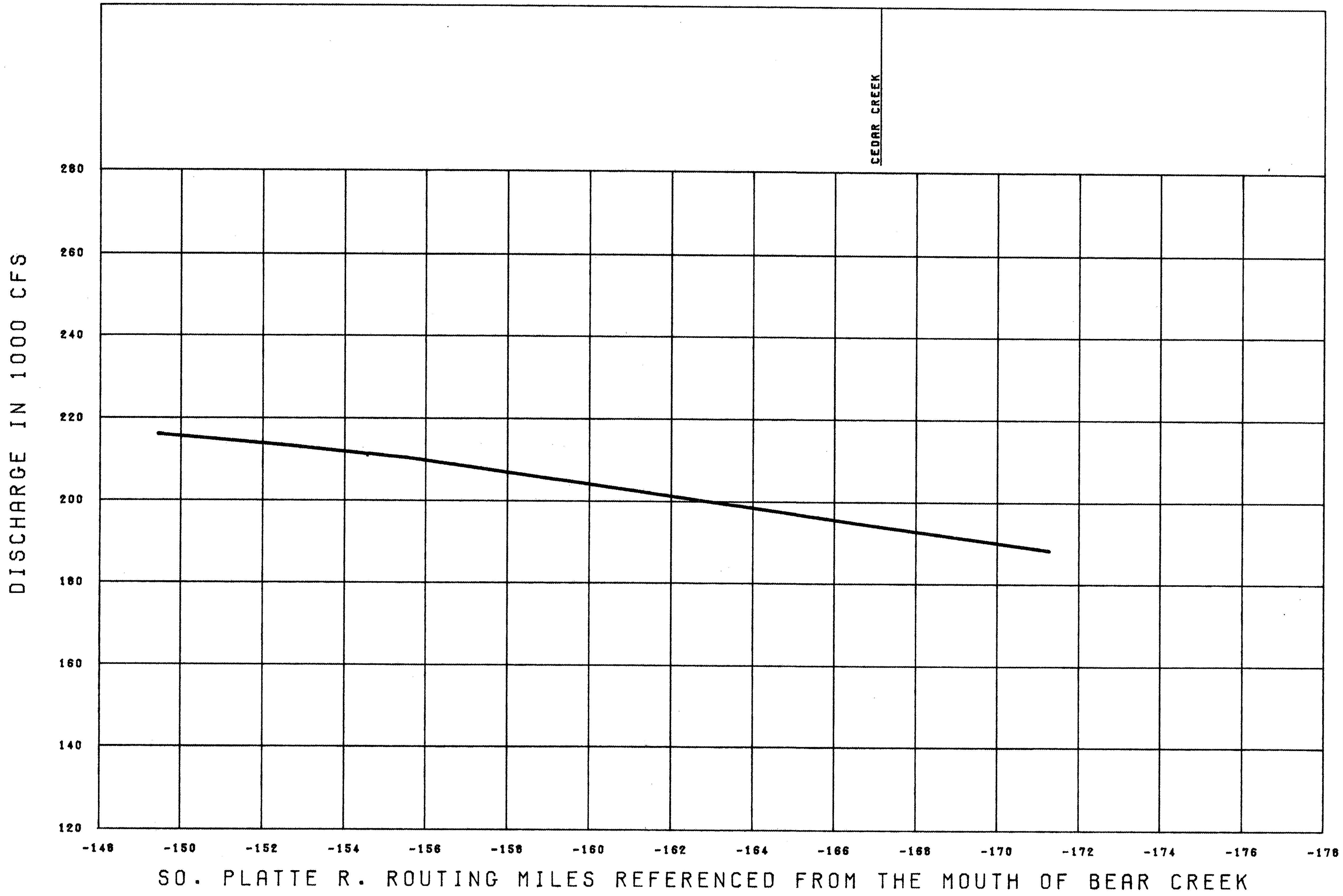
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
ONE INCH OF RUNOFF,
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
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1975 AND 1990 CONDITIONS

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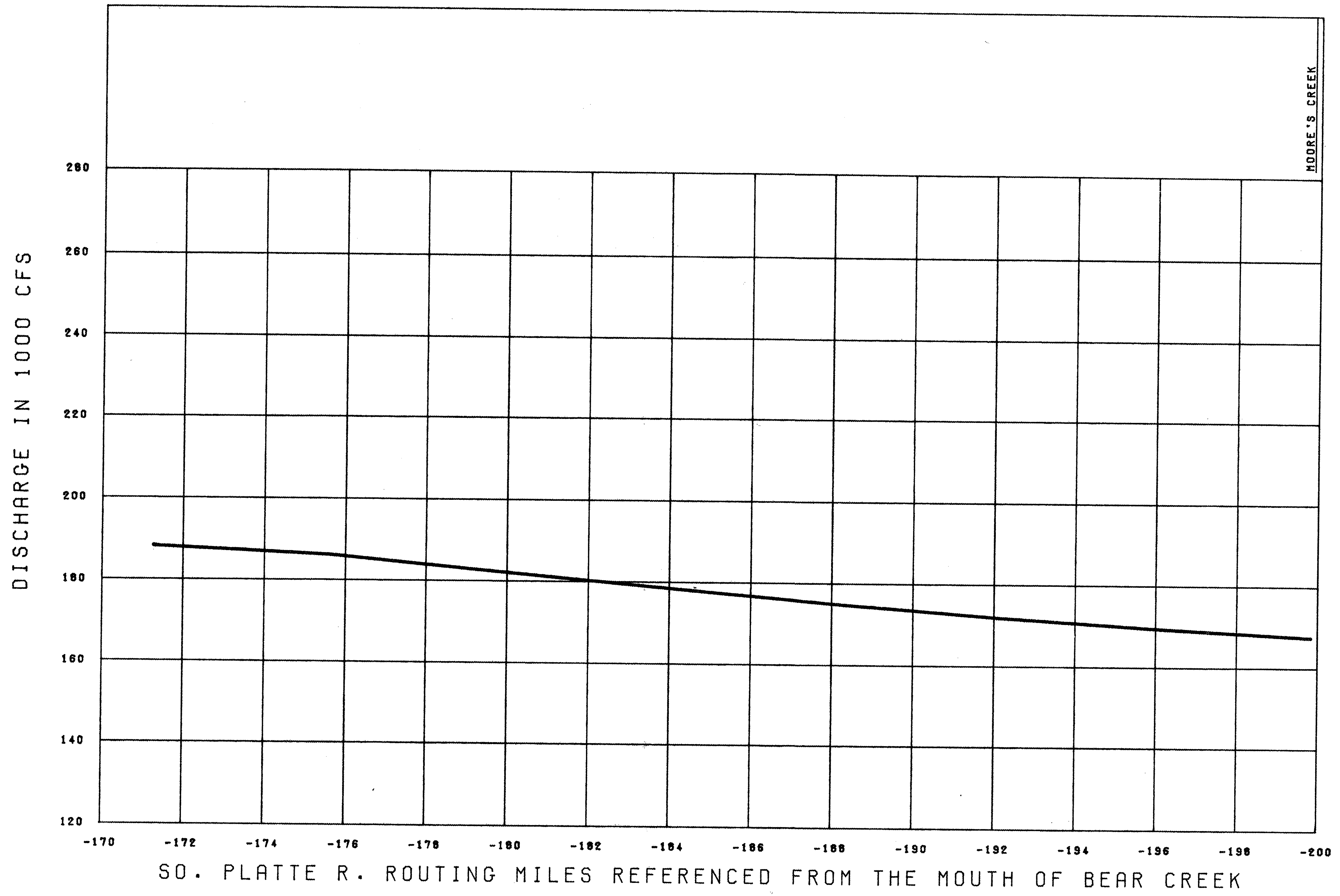
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
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1975 AND 1990 CONDITIONS

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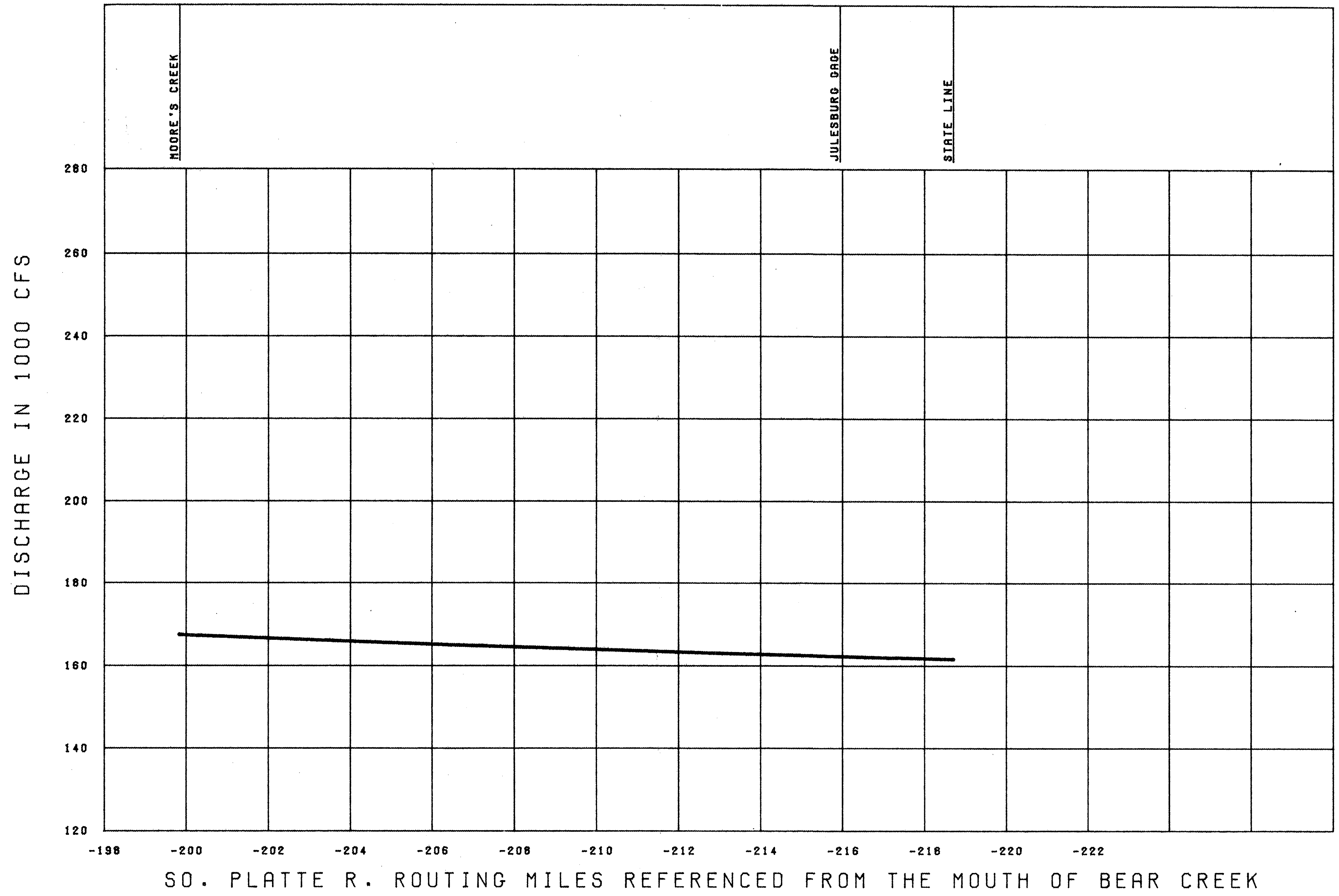


METROPOLITAN DENVER AND
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COLORADO, WYOMING AND NEBRASKA

MODEL DISCHARGE PROFILES
ONE INCH OF RUNOFF.
1975 AND 1990 CONDITIONS

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CORPS OF ENGINEERS OMAHA, NEBRASKA
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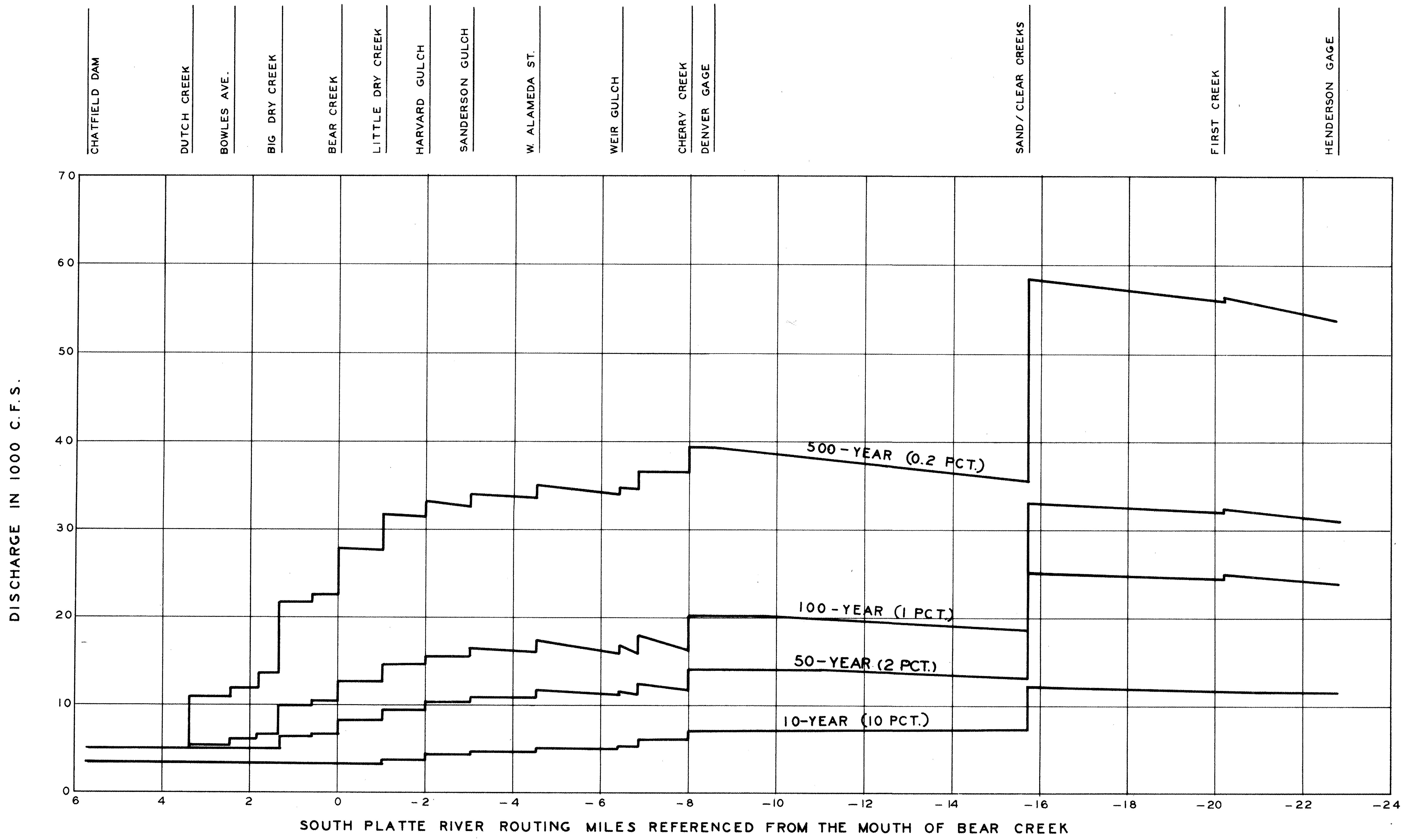



NOTE:

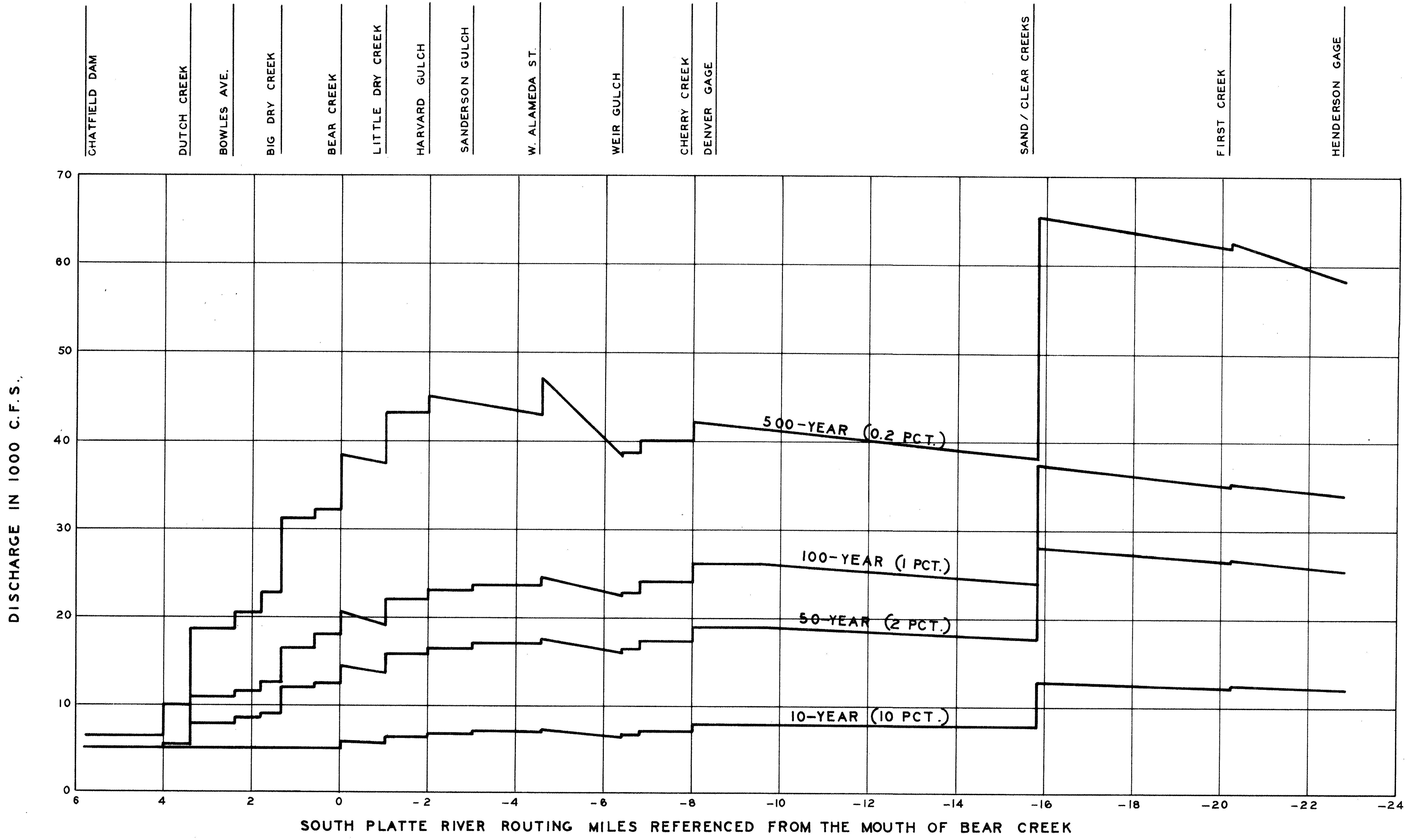
From Chatfield Dam to the mouth of Sand Creek the profiles represent development existing in the early part of 1979.

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO WYOMING AND NEBRASKA

DISCHARGE PROFILES
1975 CONDITIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

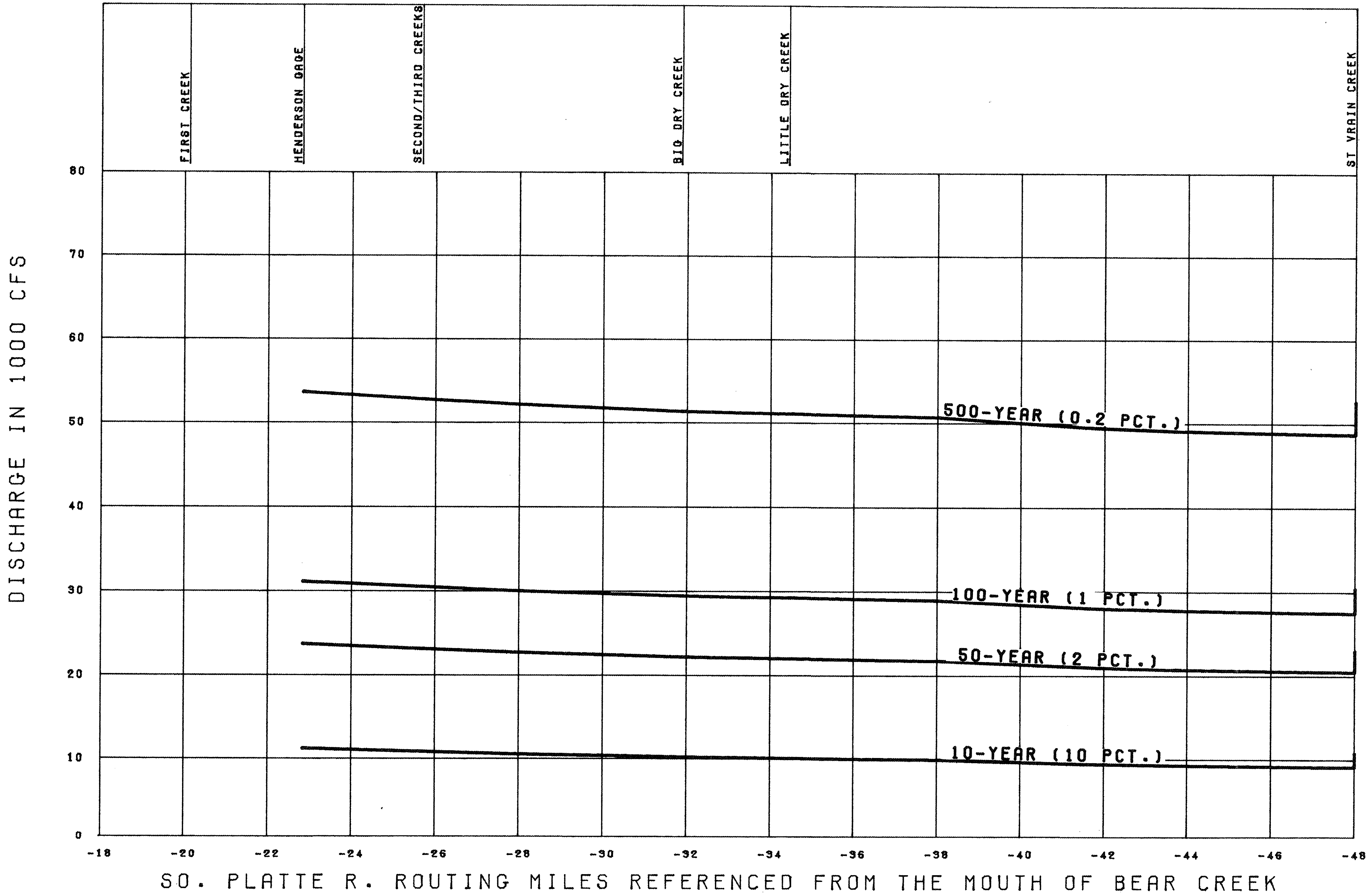
OCT. 1979




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO WYOMING AND NEBRASKA

**DISCHARGE PROFILES FULLY URBANIZED WITH IMPROVED CHANNEL 1990 CONDITIONS**

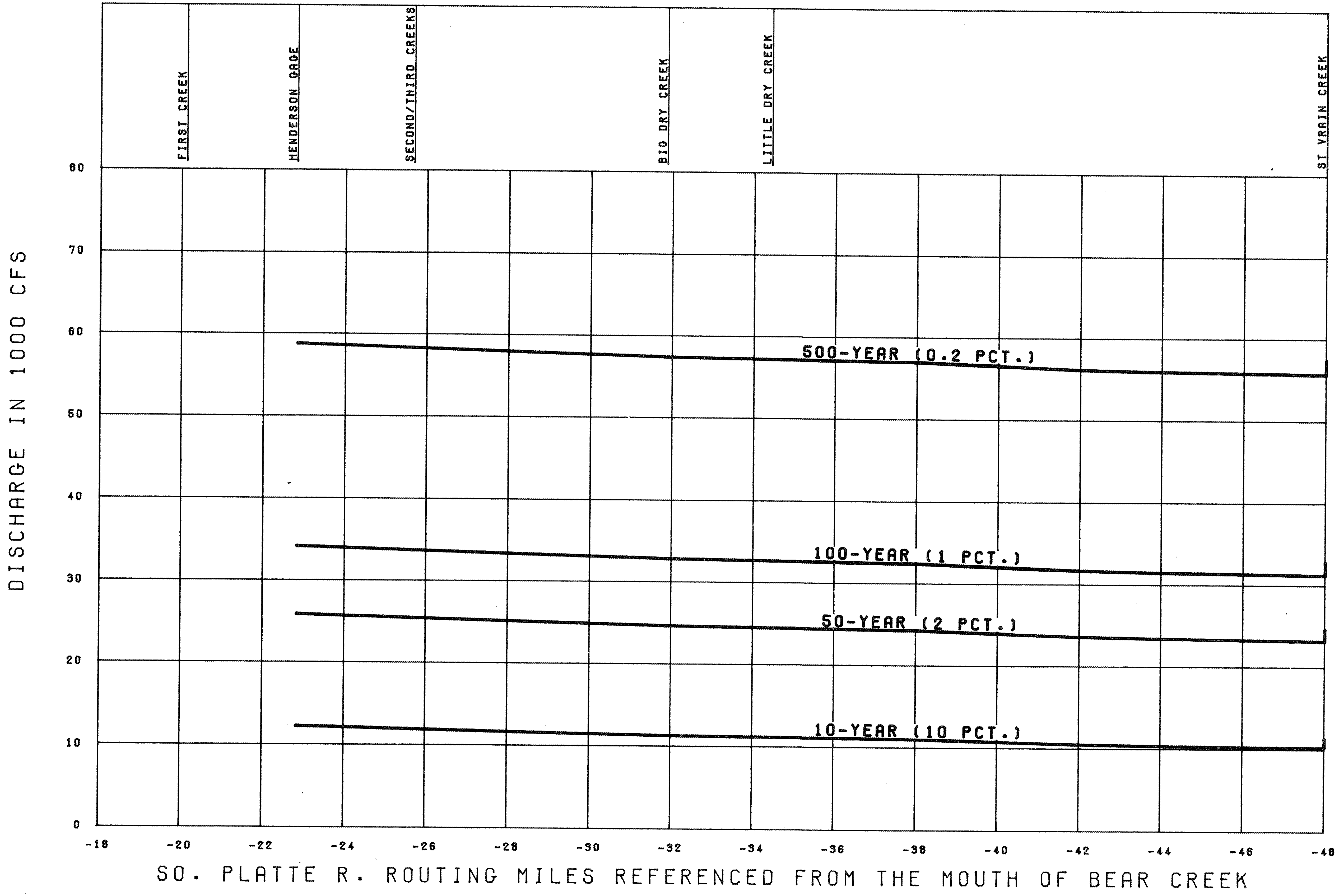
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCT. 1979




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 CONDITIONS

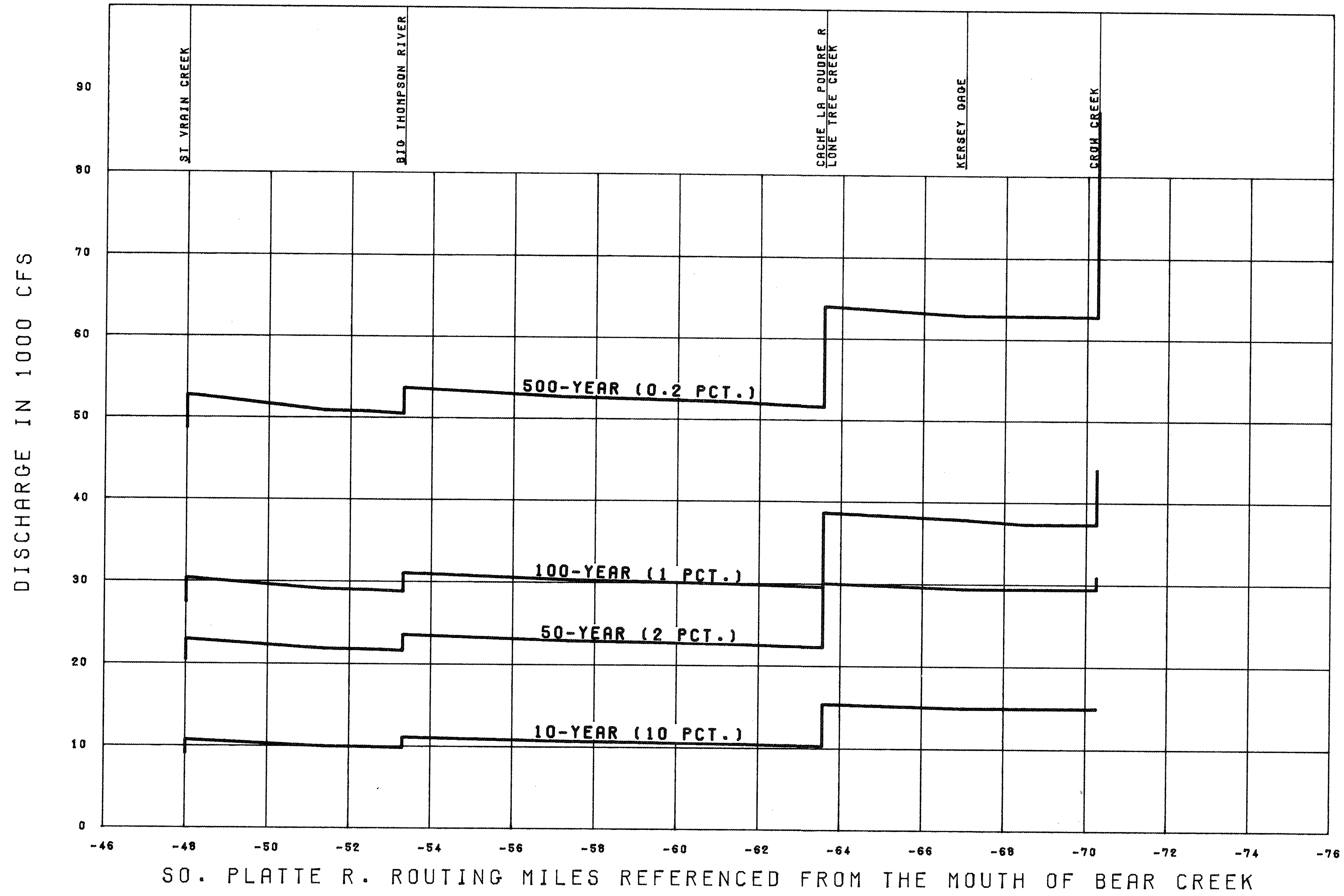
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1990 CONDITIONS

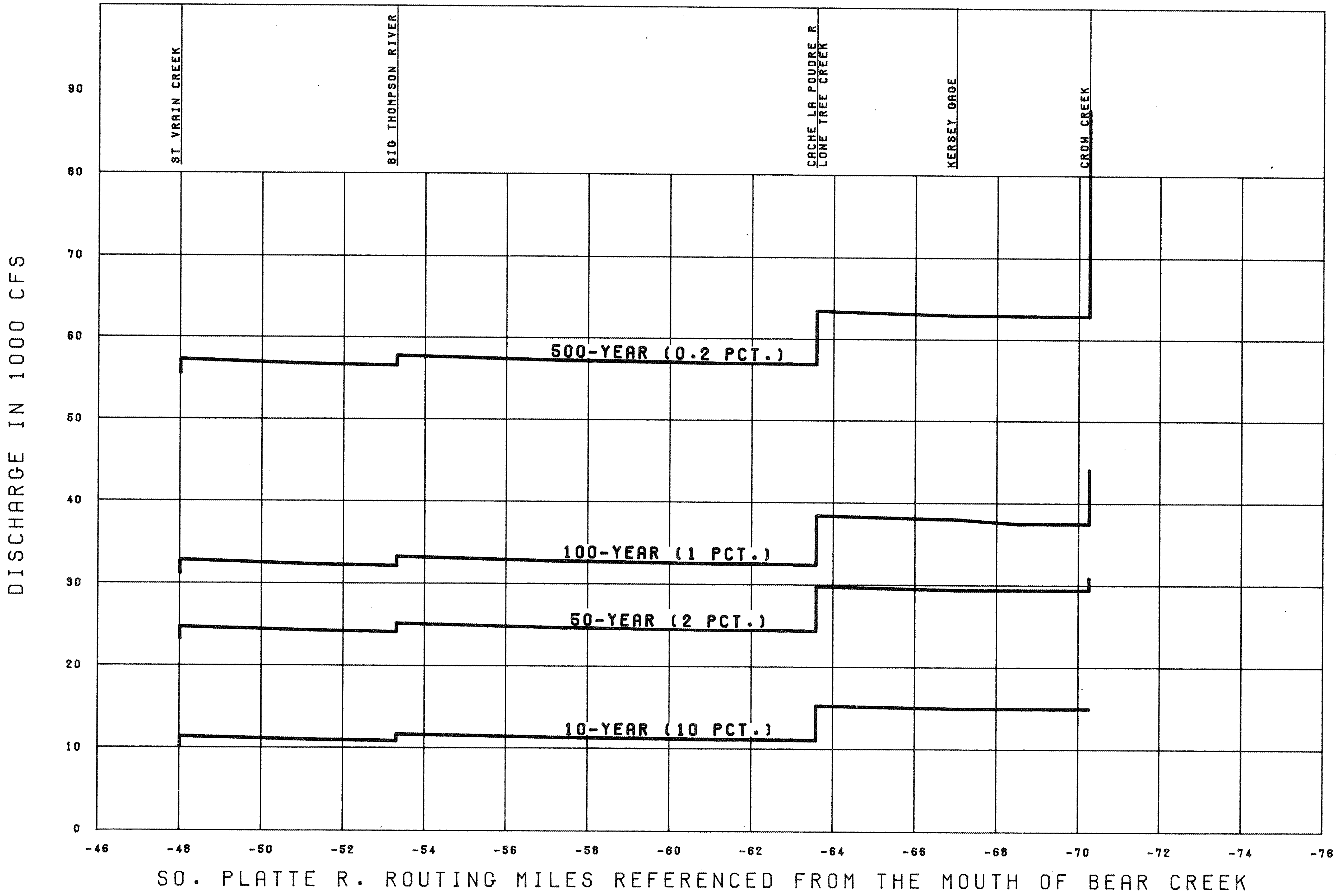
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
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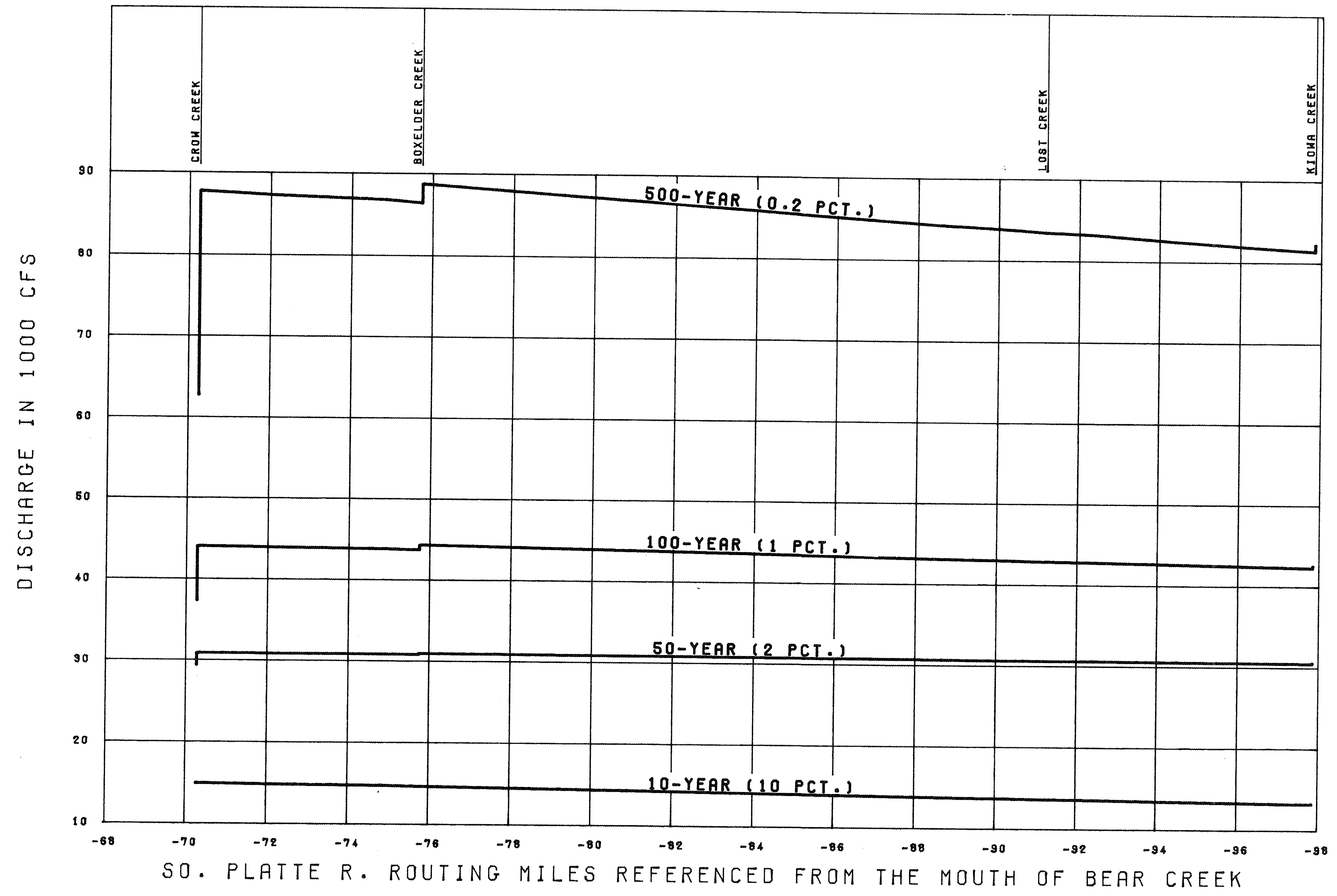
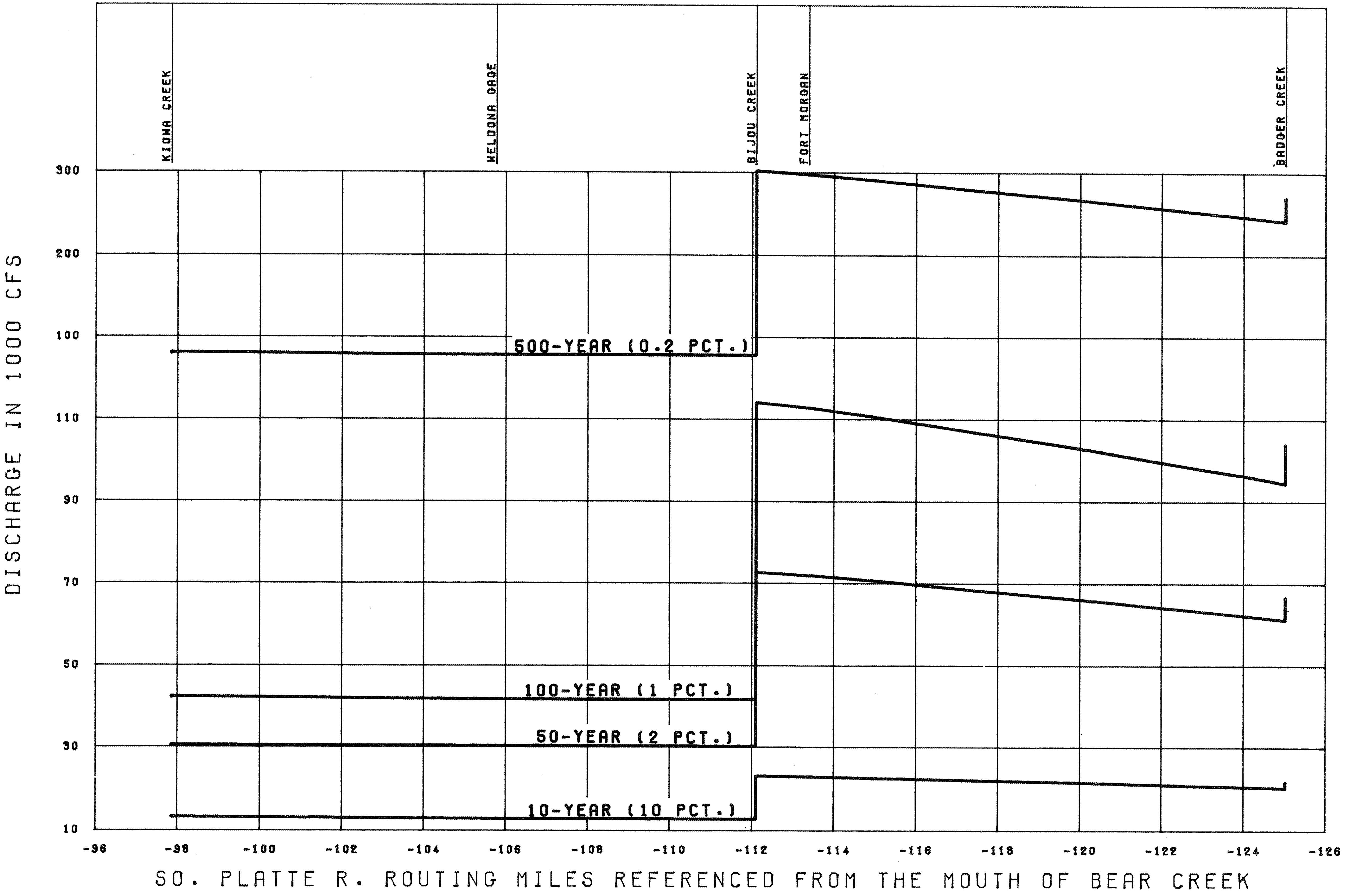
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 AND 1990 CONDITIONS

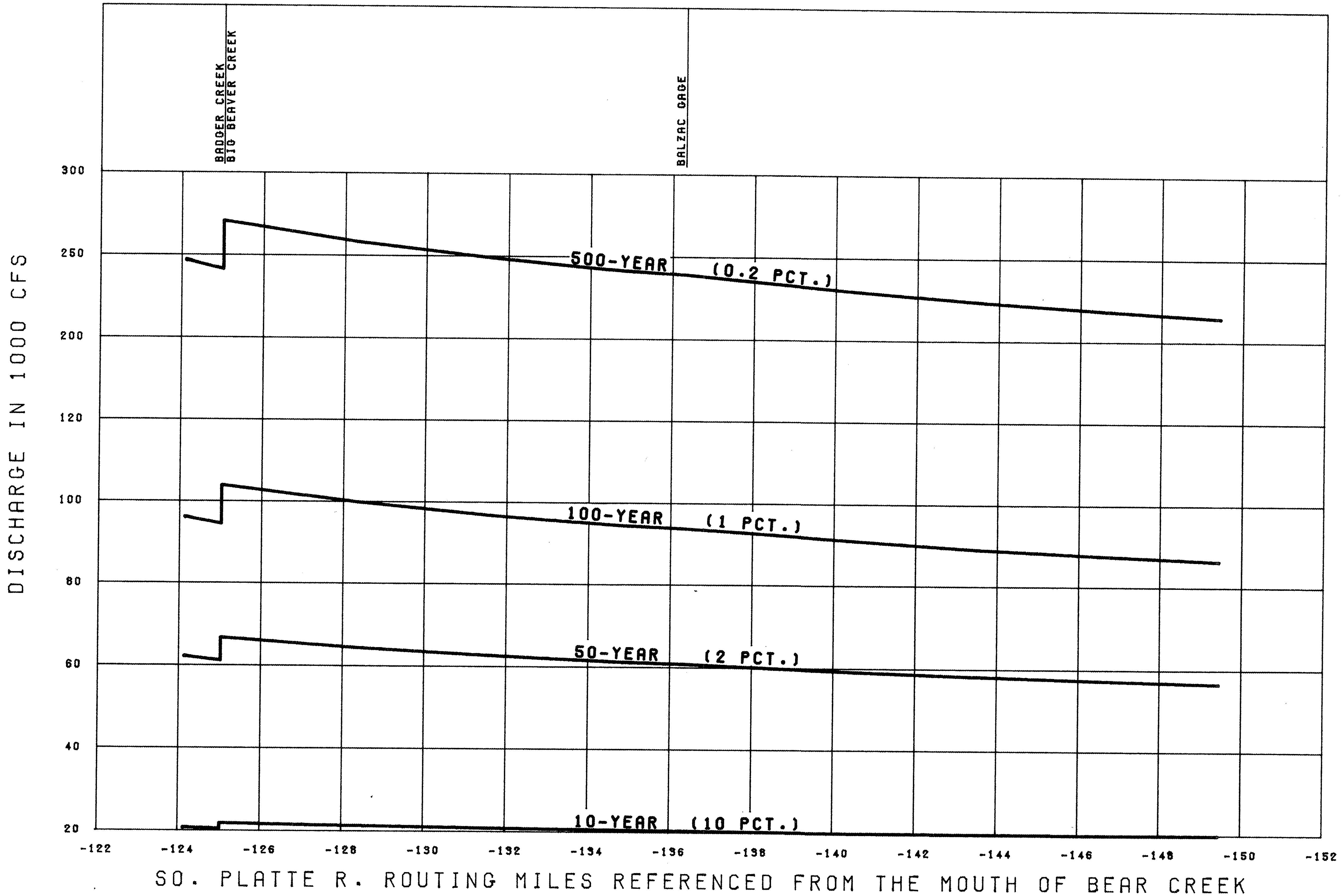
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 AND 1990 CONDITIONS

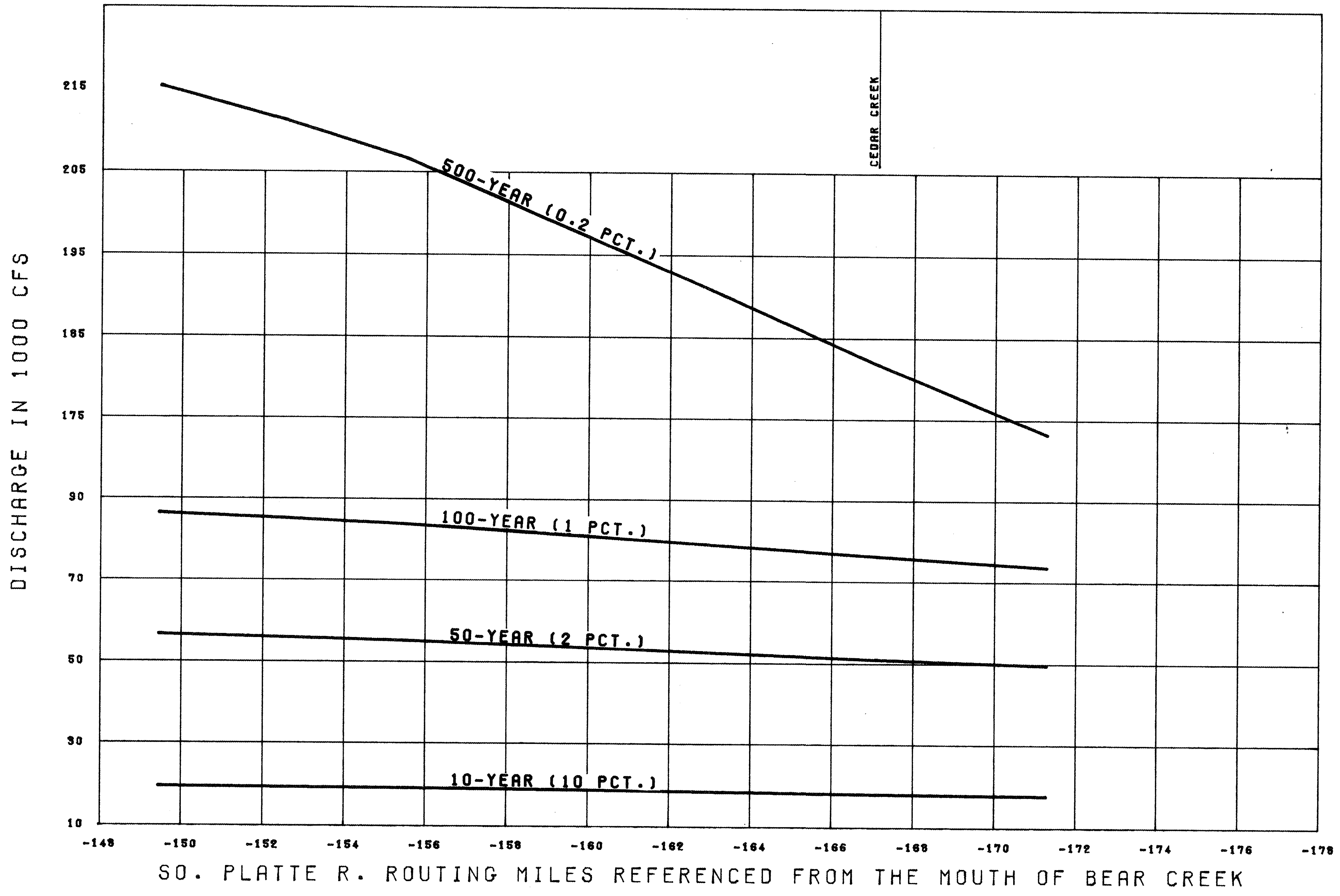
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND SOUTH PLATTE RIVER AND TRIBUTARIES COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
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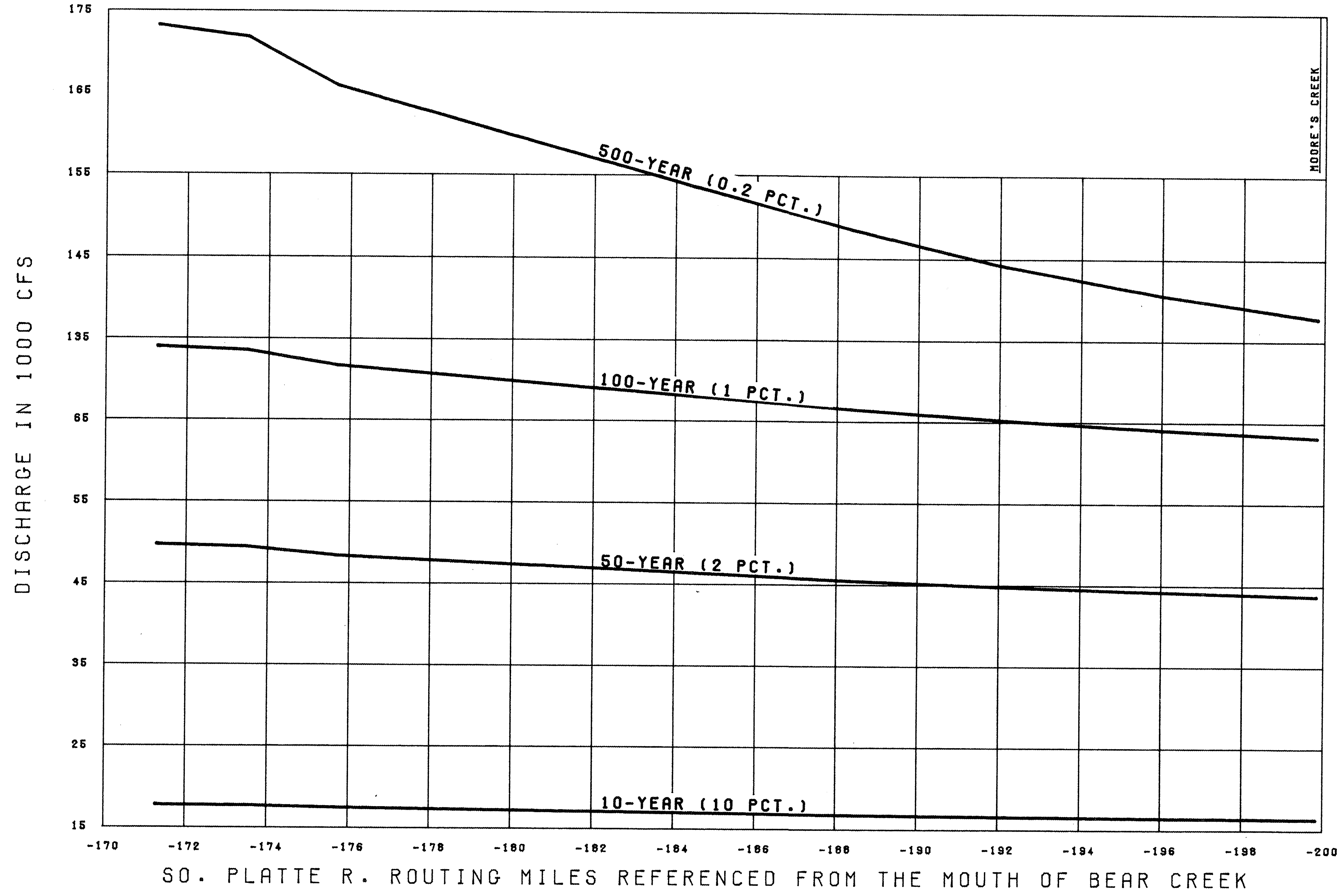
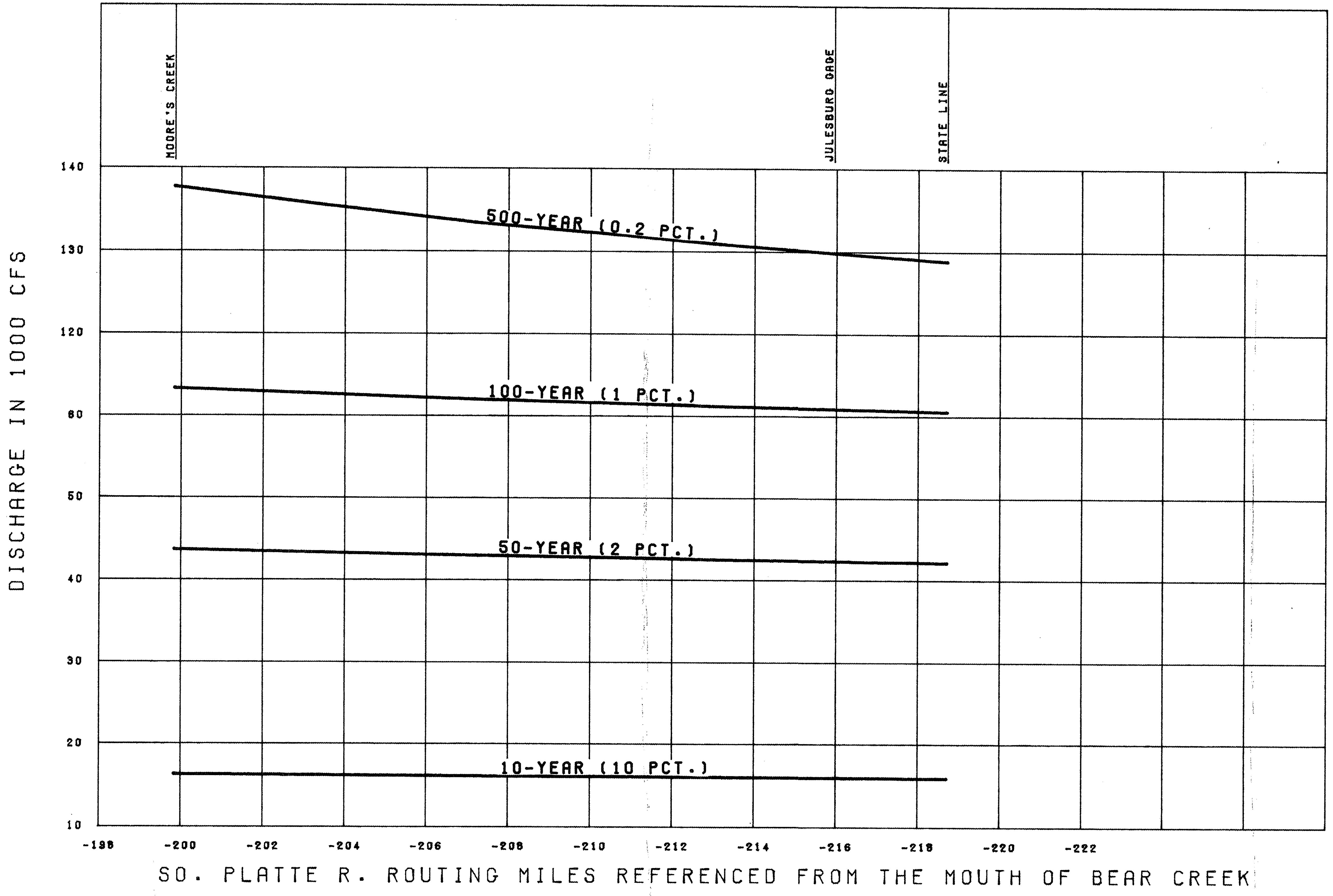
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 AND 1990 CONDITIONS

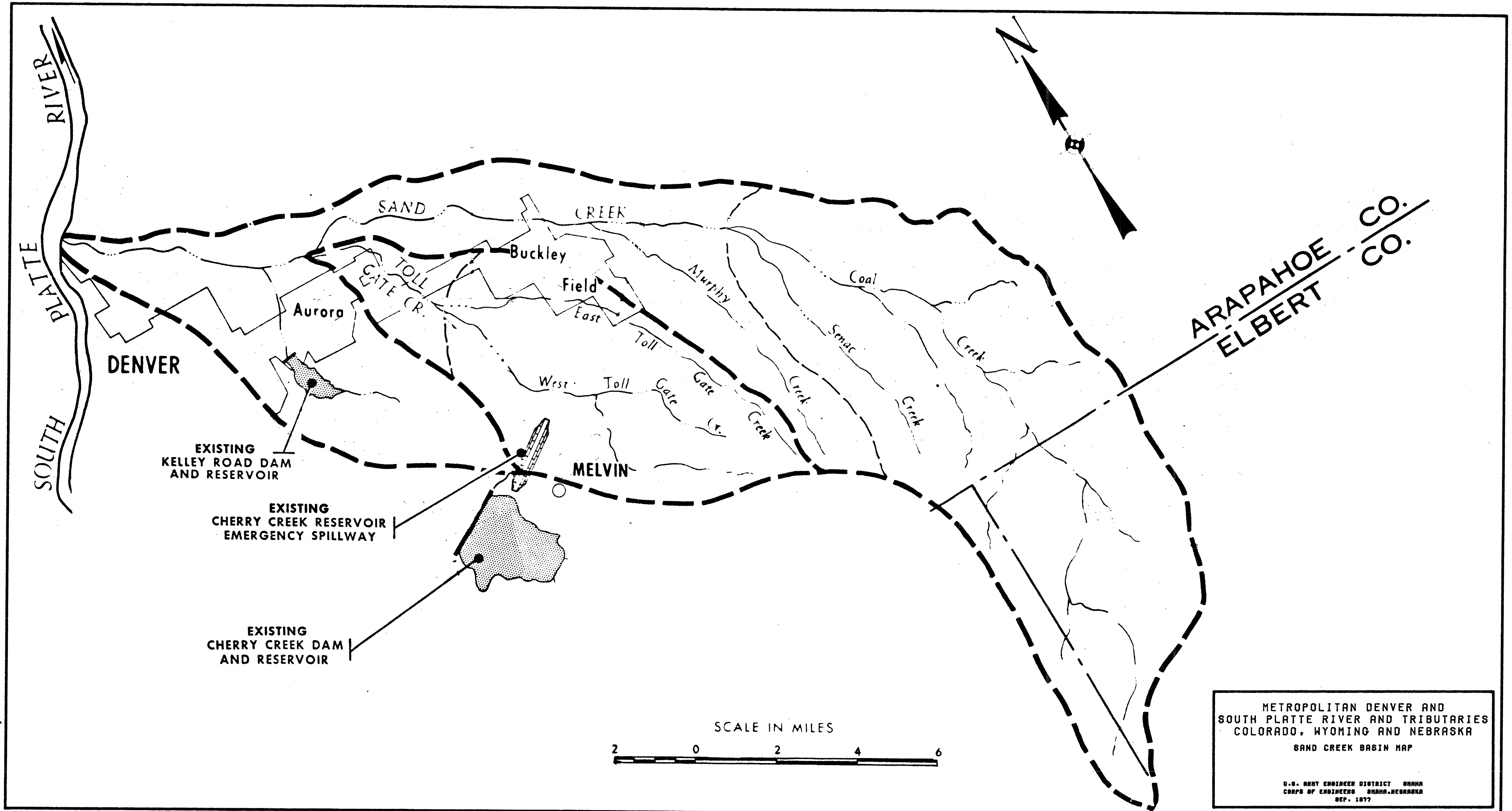
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977

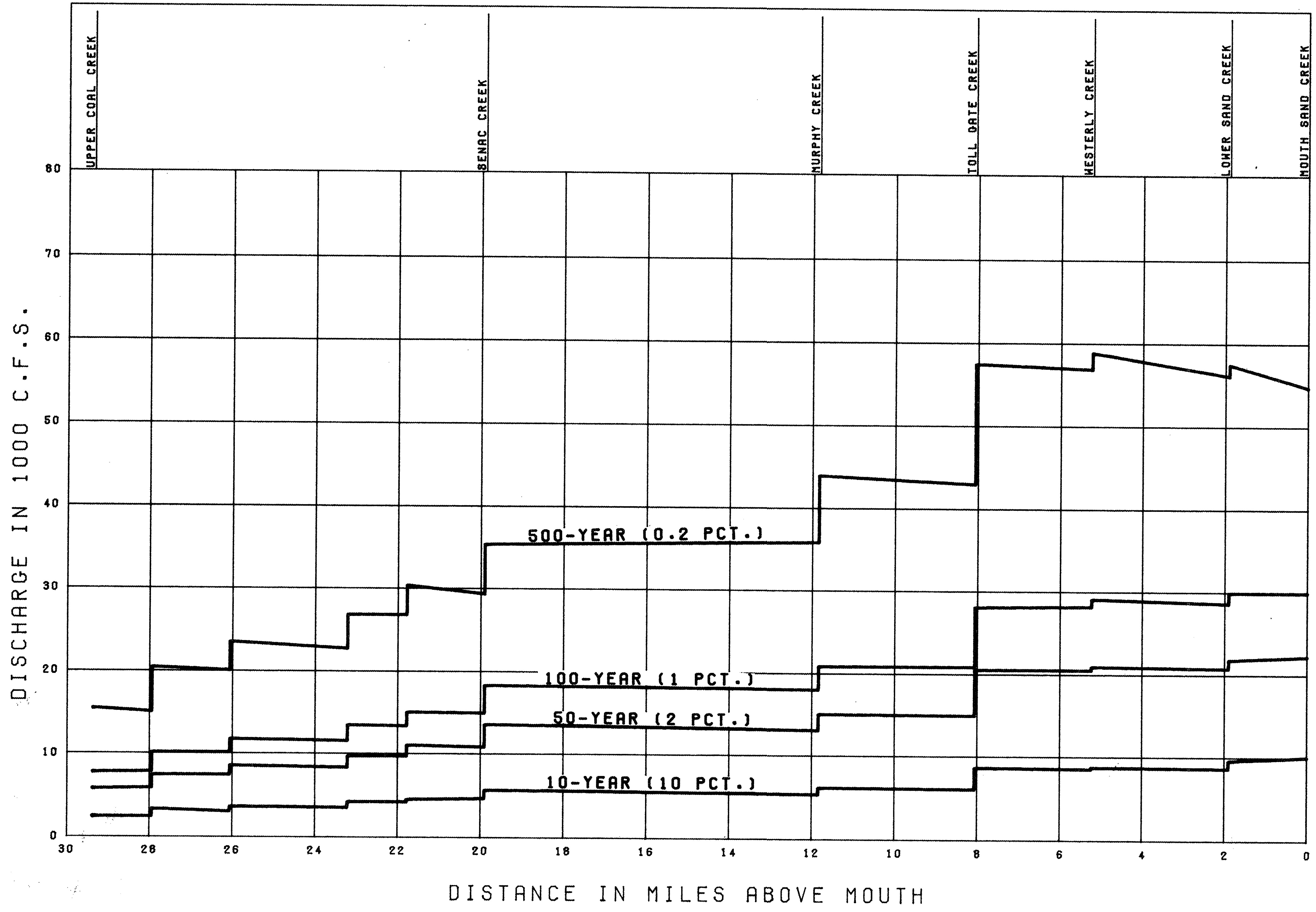



METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SOUTH PLATTE RIVER
DISCHARGE PROBABILITY PROFILES
1975 AND 1990 CONDITIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977

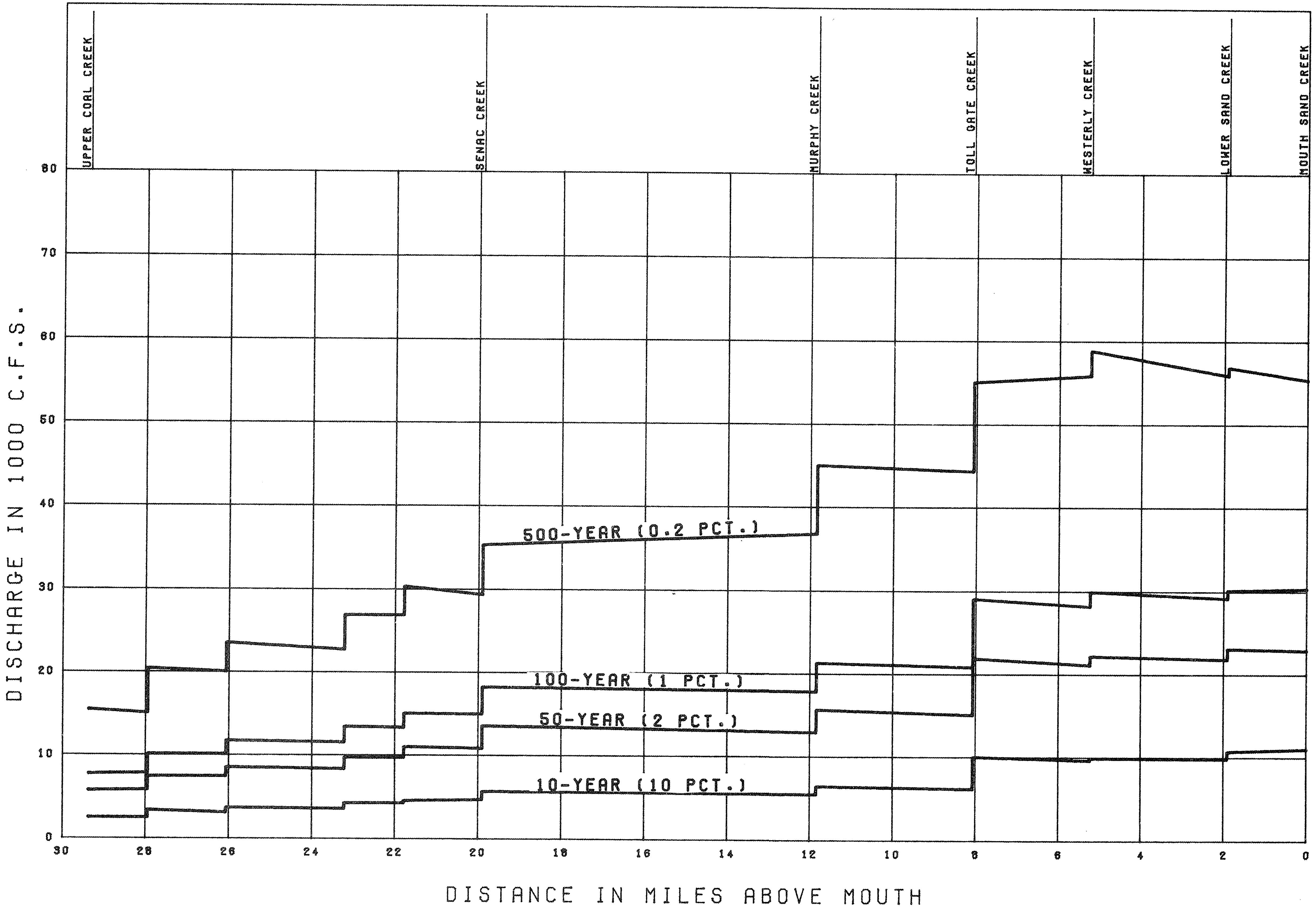

N
SOUTH PLATTE RIVER
SAND CREEK
Buckley Field
TOLL GATE CR.
Aurora
DENVER
East Toll Gate Creek
West Toll Gate Cr.
Murphy Creek
Senac Creek
Coal Creek
MELVIN
ARAPAHOE CO.
ELBERT CO.
EXISTING KELLEY ROAD DAM AND RESERVOIR
EXISTING CHERRY CREEK RESERVOIR EMERGENCY SPILLWAY
EXISTING CHERRY CREEK DAM AND RESERVOIR
SCALE IN MILES
2 0 2 4 6
METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA
SAND CREEK BASIN MAP
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SAND CREEK
DISCHARGE PROBABILITY PROFILES
1975 CONDITIONS

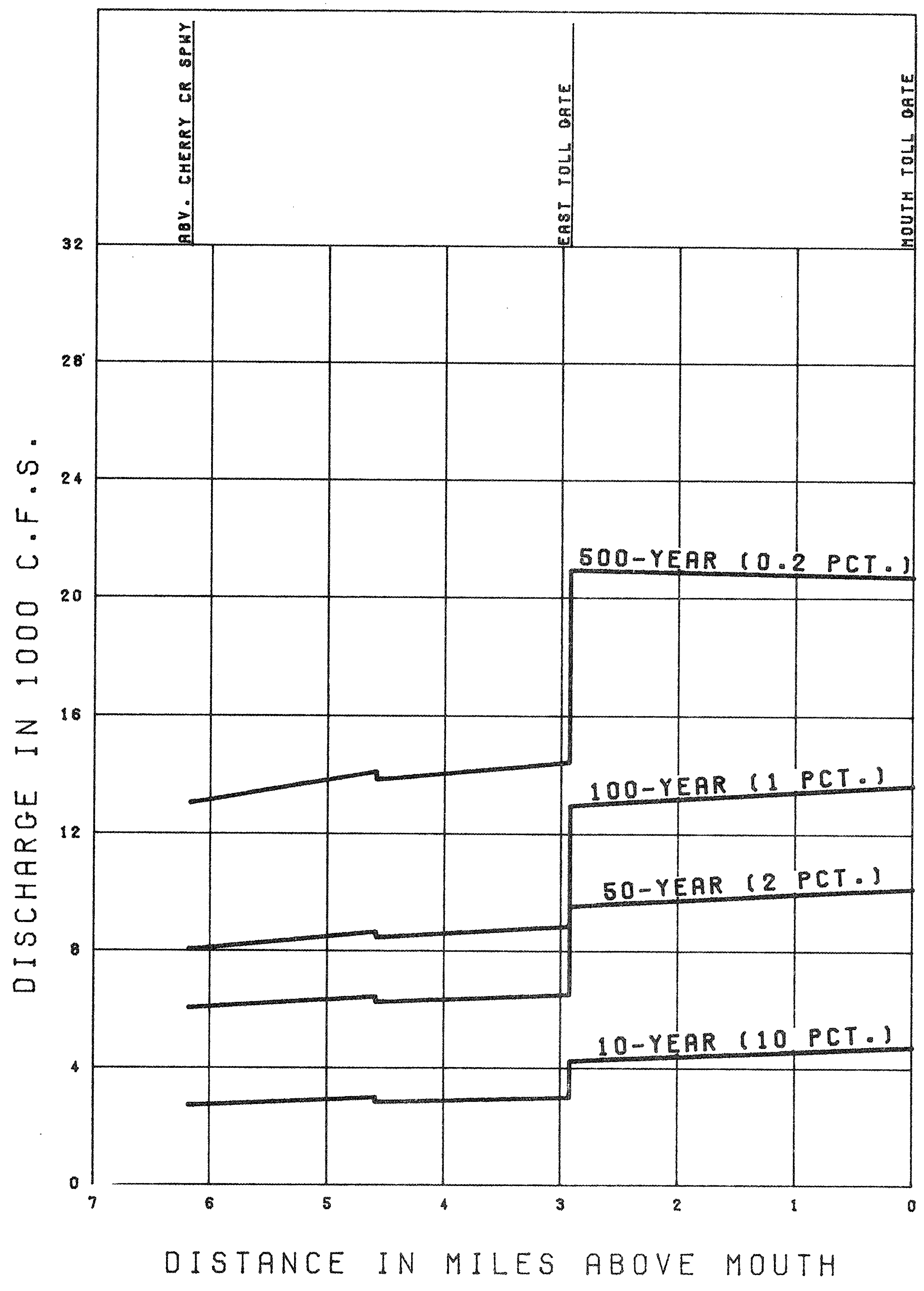
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SAND CREEK
DISCHARGE PROBABILITY PROFILES
1990 CONDITIONS

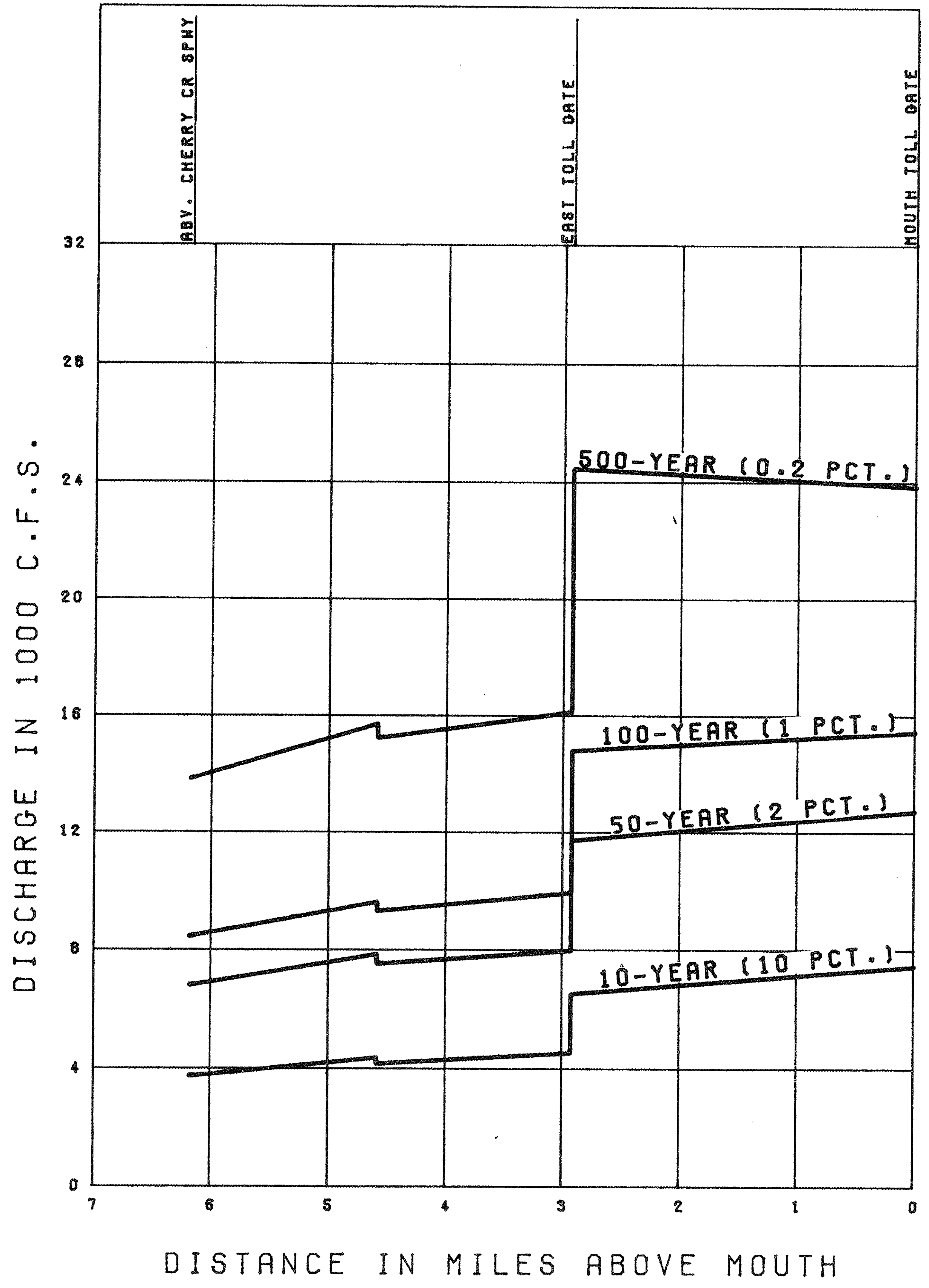
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

WEST TOLL GATE CREEK
DISCHARGE PROBABILITY PROFILES
1975 CONDITIONS

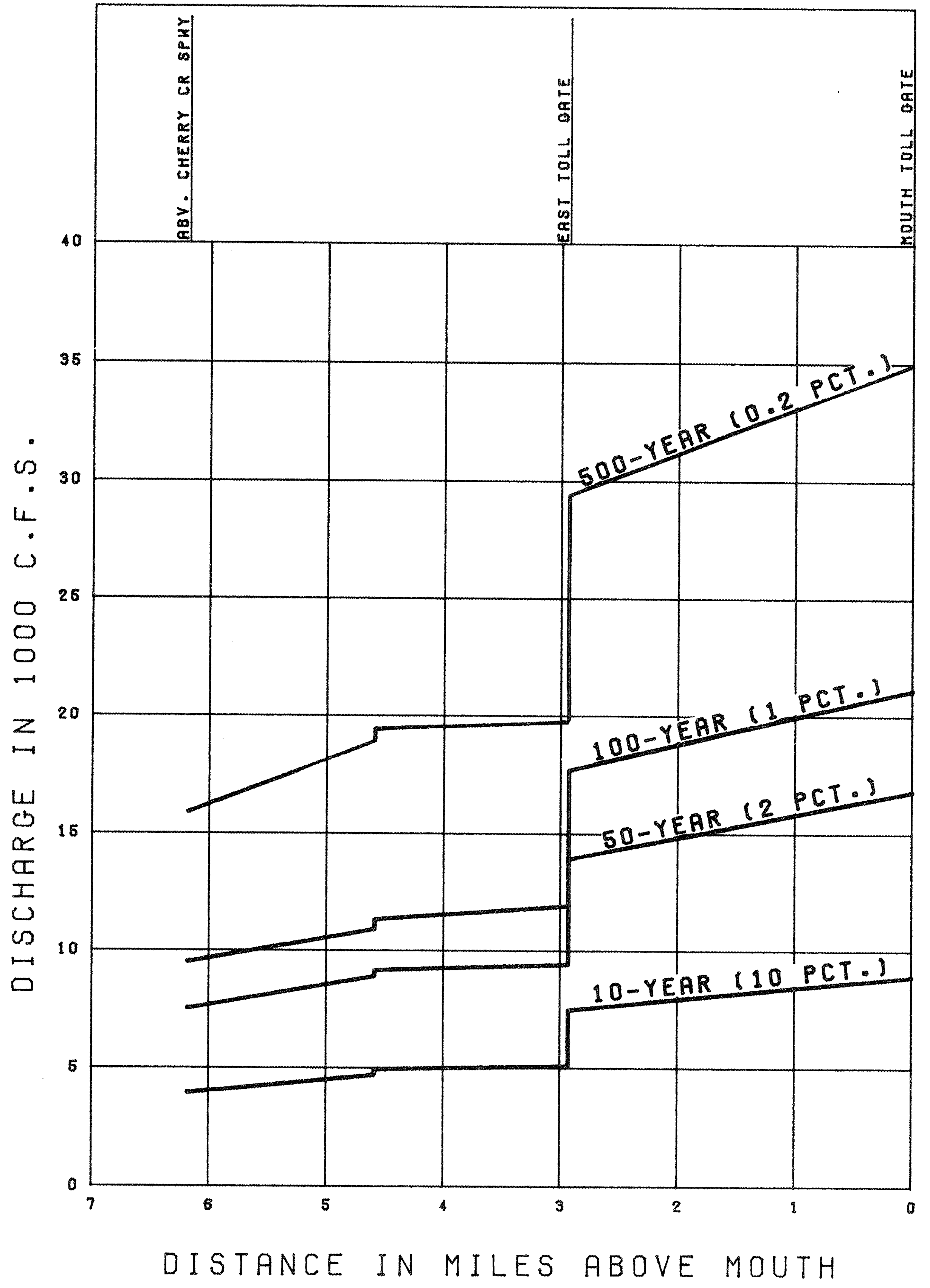
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

WEST TOLL GATE CREEK DISCHARGE PROBABILITY
PROFILES - 1990 LARGE LOT RESIDENTIAL
WITH UNIMPROVED CHANNEL

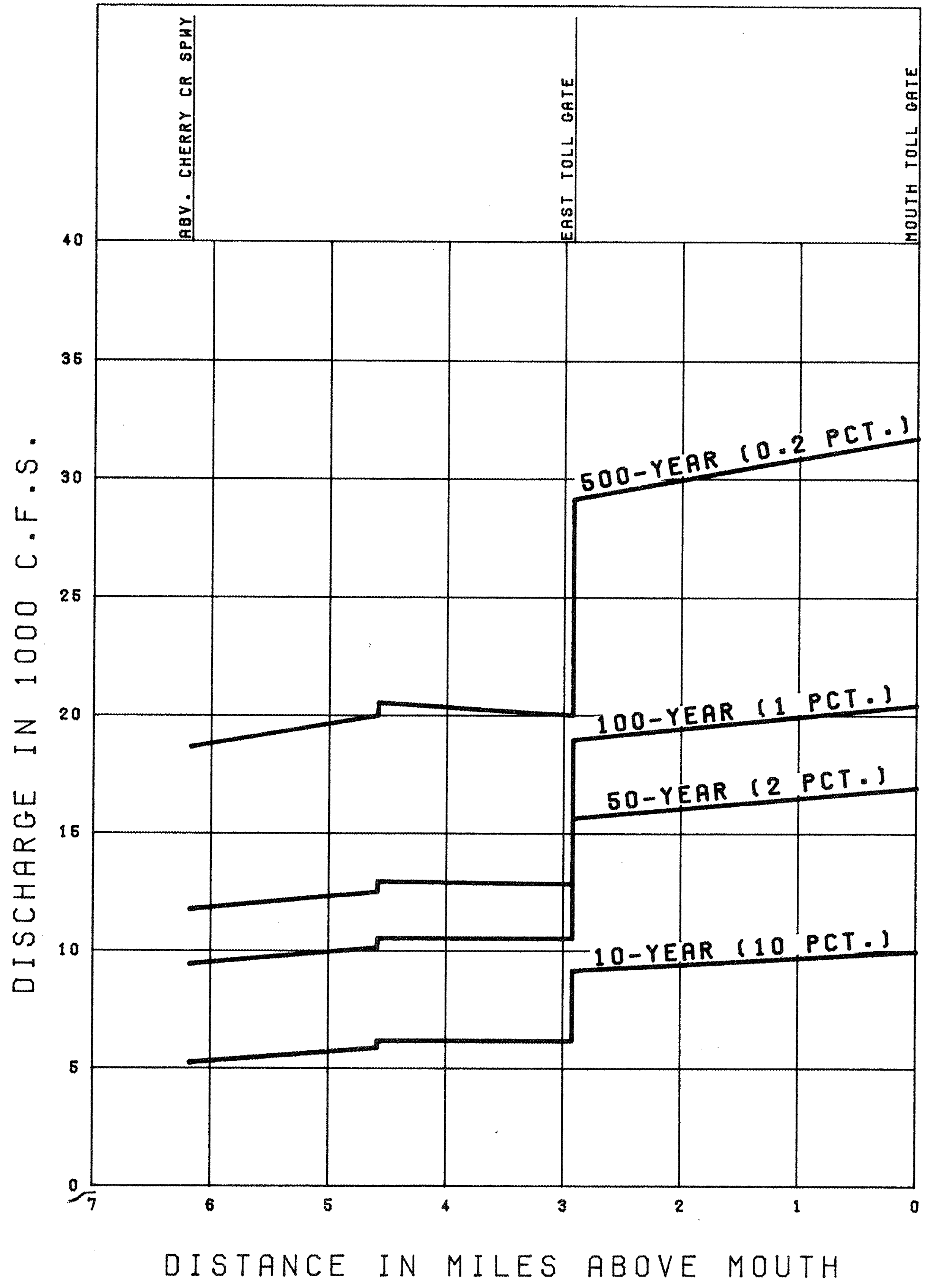
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

WEST TOLL GATE CREEK DISCHARGE PROBABILITY
PROFILES - 1990 LARGE LOT RESIDENTIAL
WITH IMPROVED CHANNEL

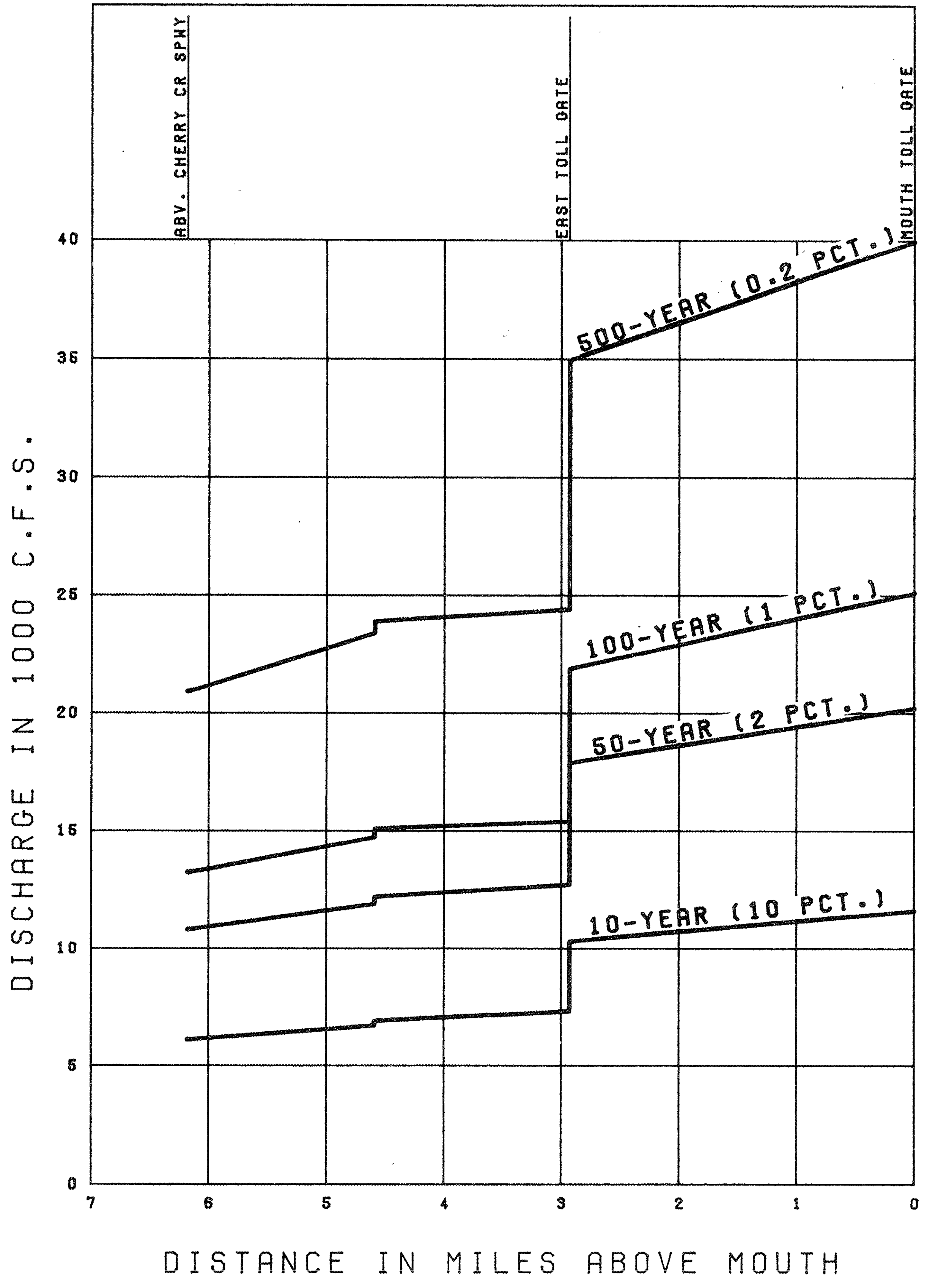
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

WEST TOLL GATE CREEK DISCHARGE PROBABILITY
PROFILES - 1990 NORMAL DENSITY RESIDENTIAL
WITH UNIMPROVED CHANNEL

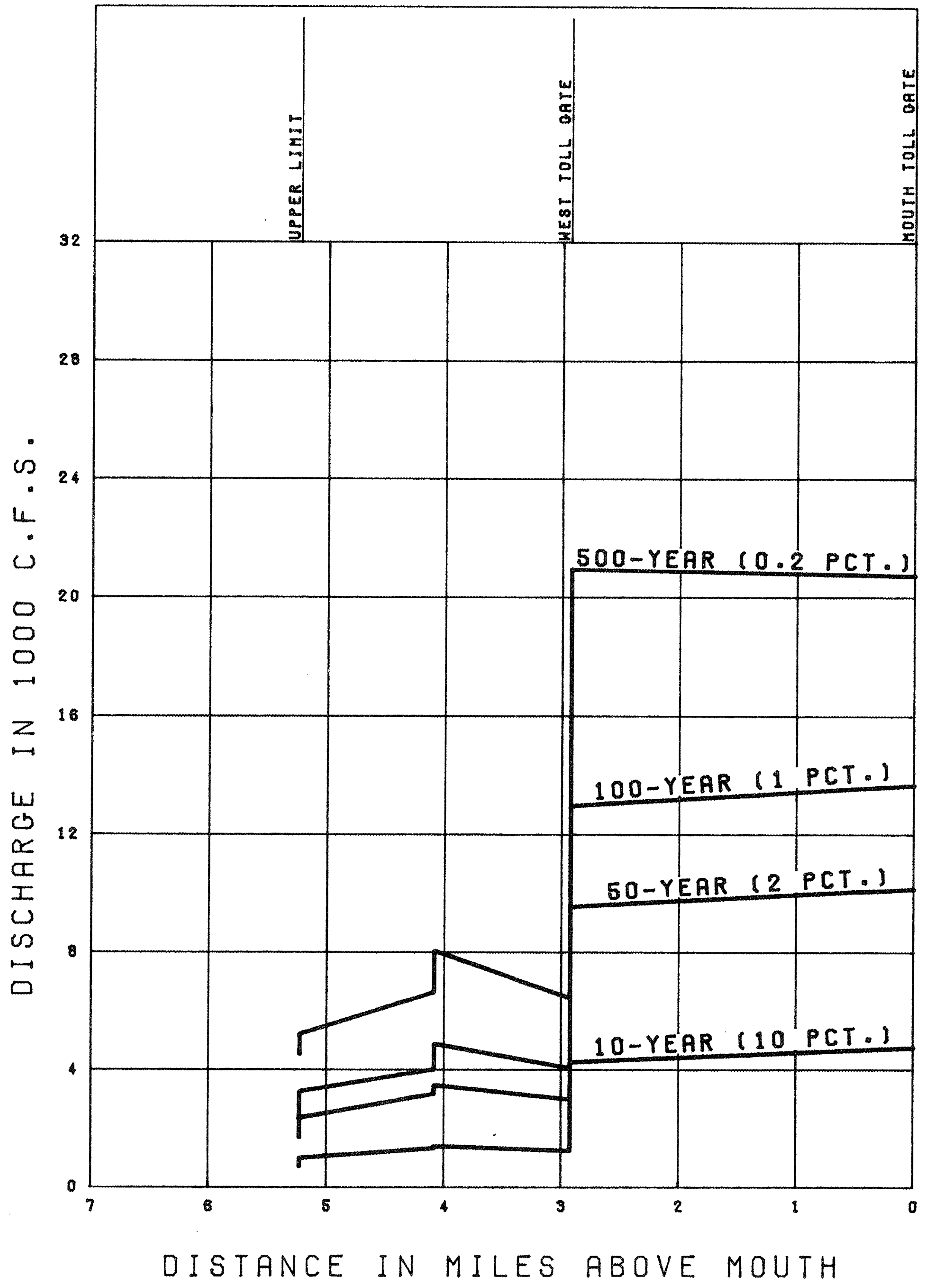
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

WEST TOLL GATE CREEK DISCHARGE PROBABILITY PROFILES - 1990 NORMAL DENSITY RESIDENTIAL WITH IMPROVED CHANNEL

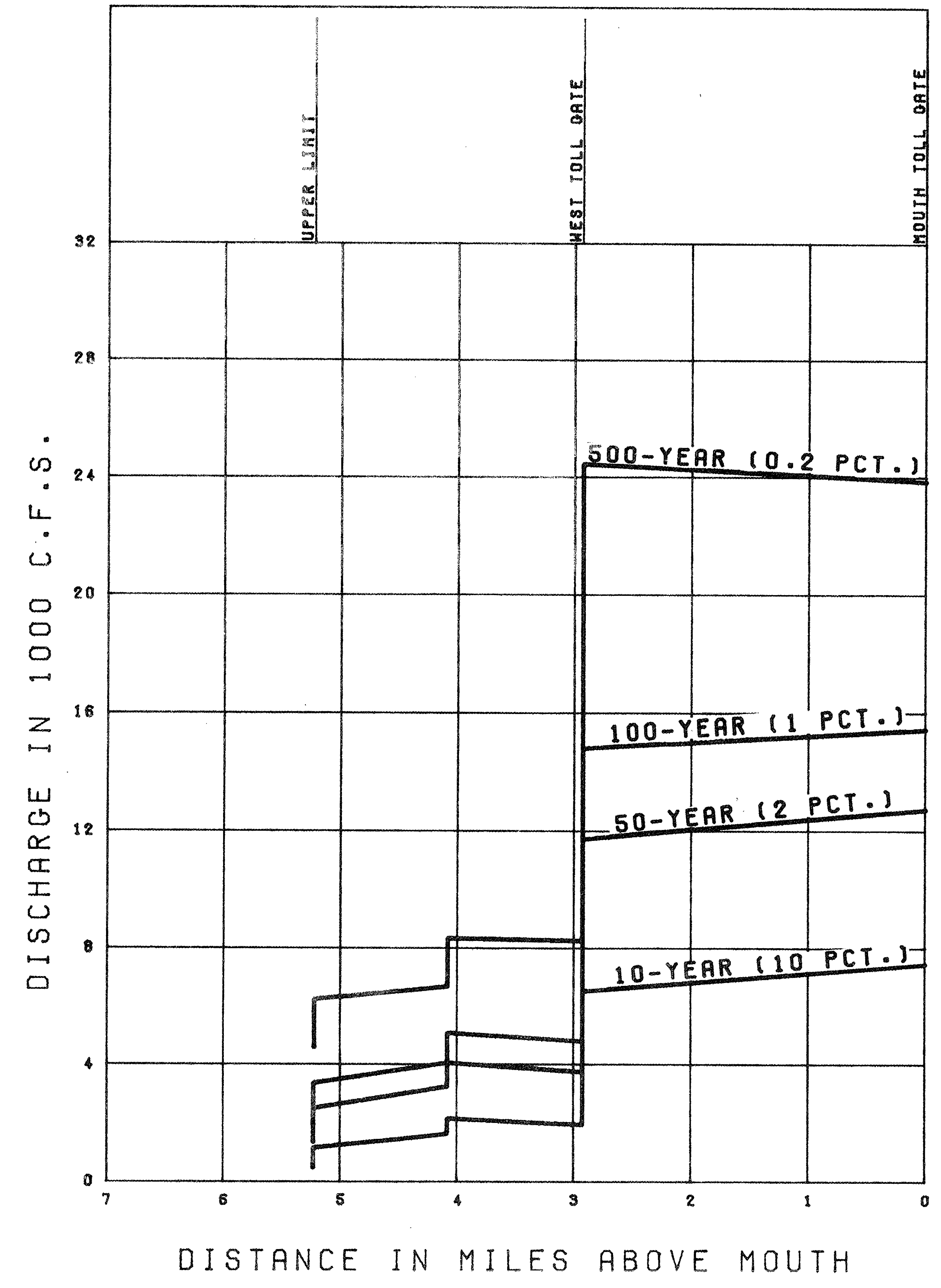
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

EAST TOLLGATE CREEK
DISCHARGE PROBABILITY PROFILES
1975 CONDITIONS

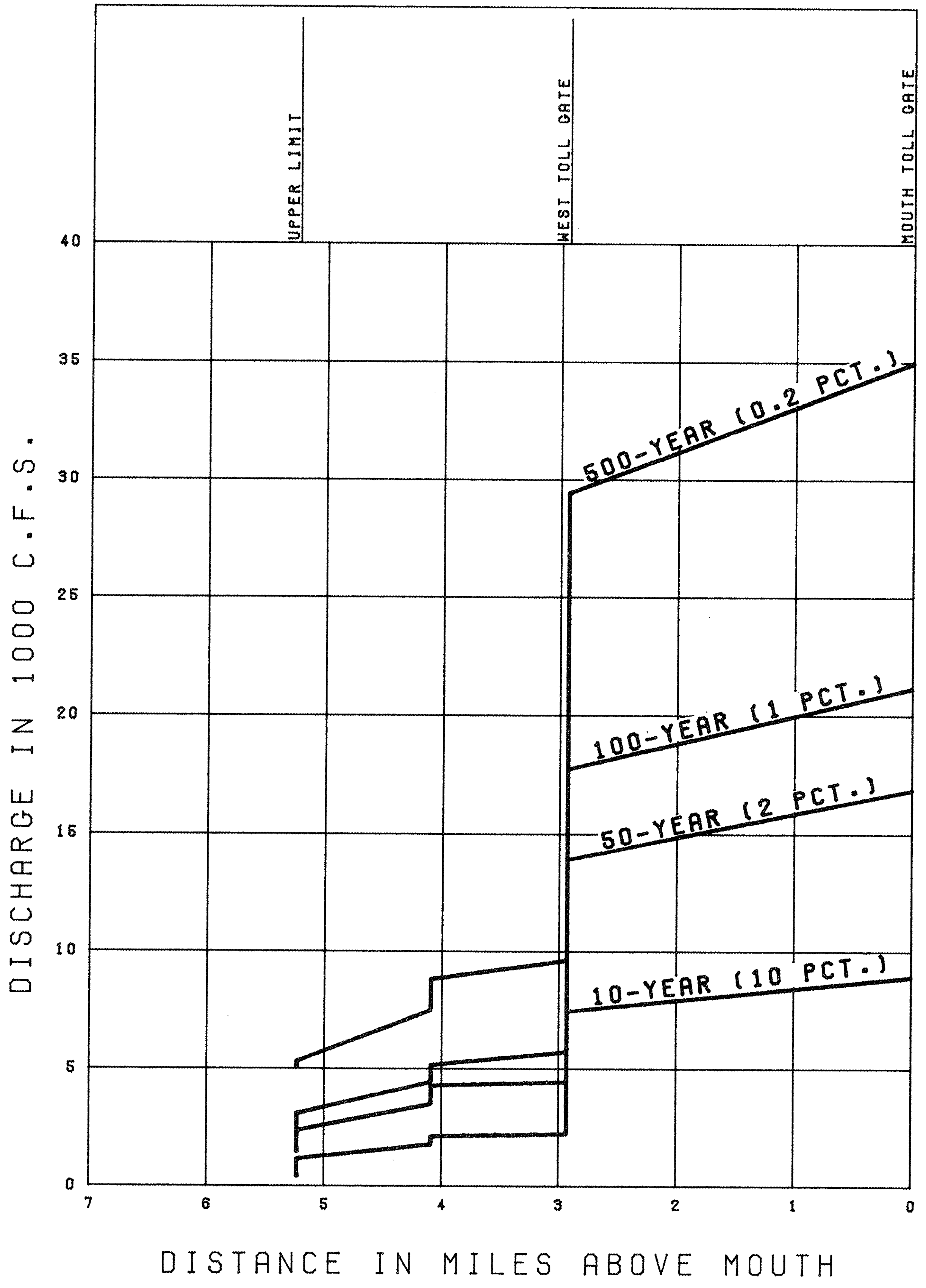
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

EAST TOLL GATE CREEK DISCHARGE PROBABILITY
PROFILES - 1990 LARGE LOT RESIDENTIAL
WITH UNIMPROVED CHANNEL

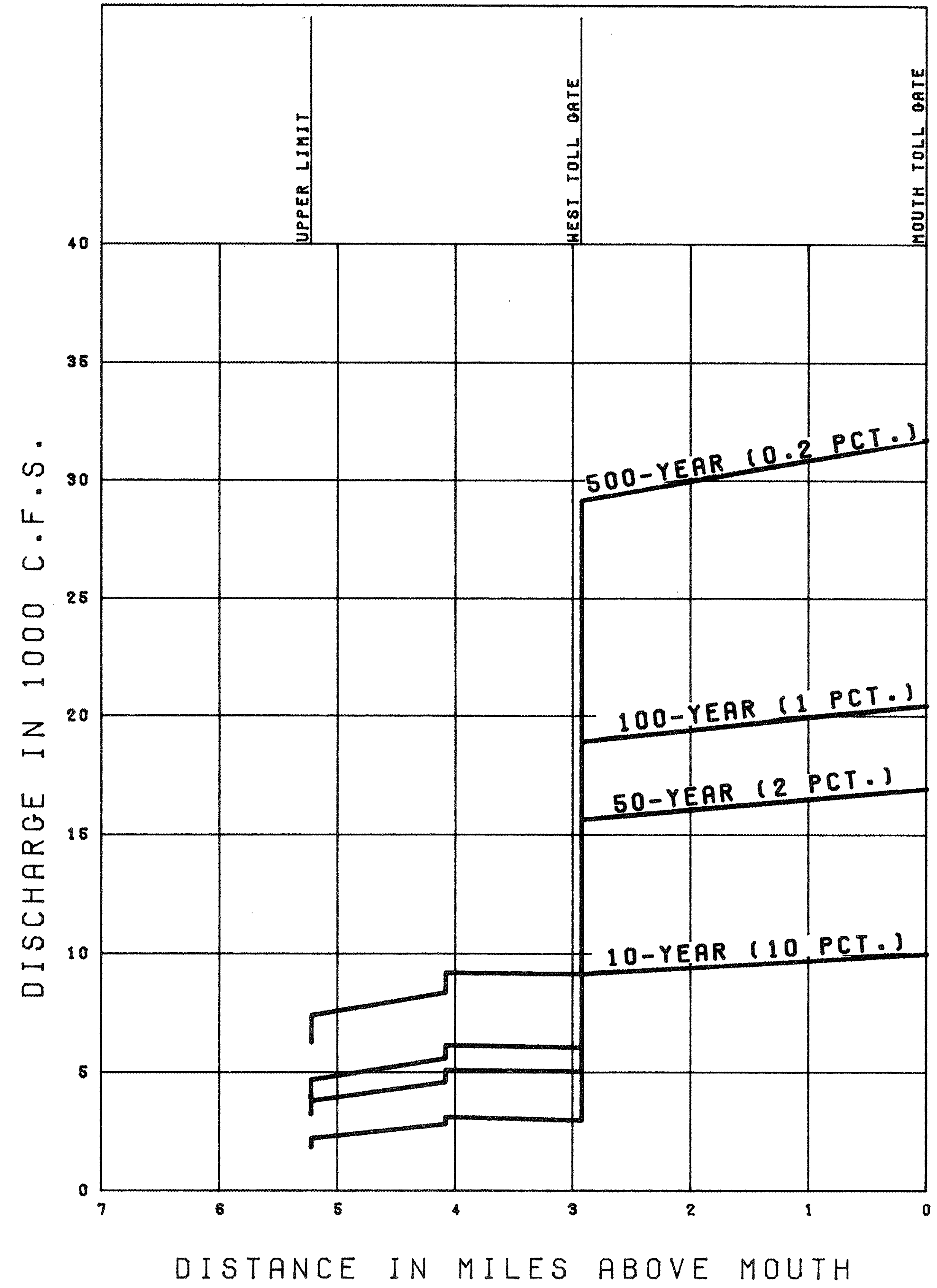
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

EAST TOLL GATE CREEK DISCHARGE PROBABILITY
PROFILES - 1990 LARGE LOT RESIDENTIAL
WITH IMPROVED CHANNEL

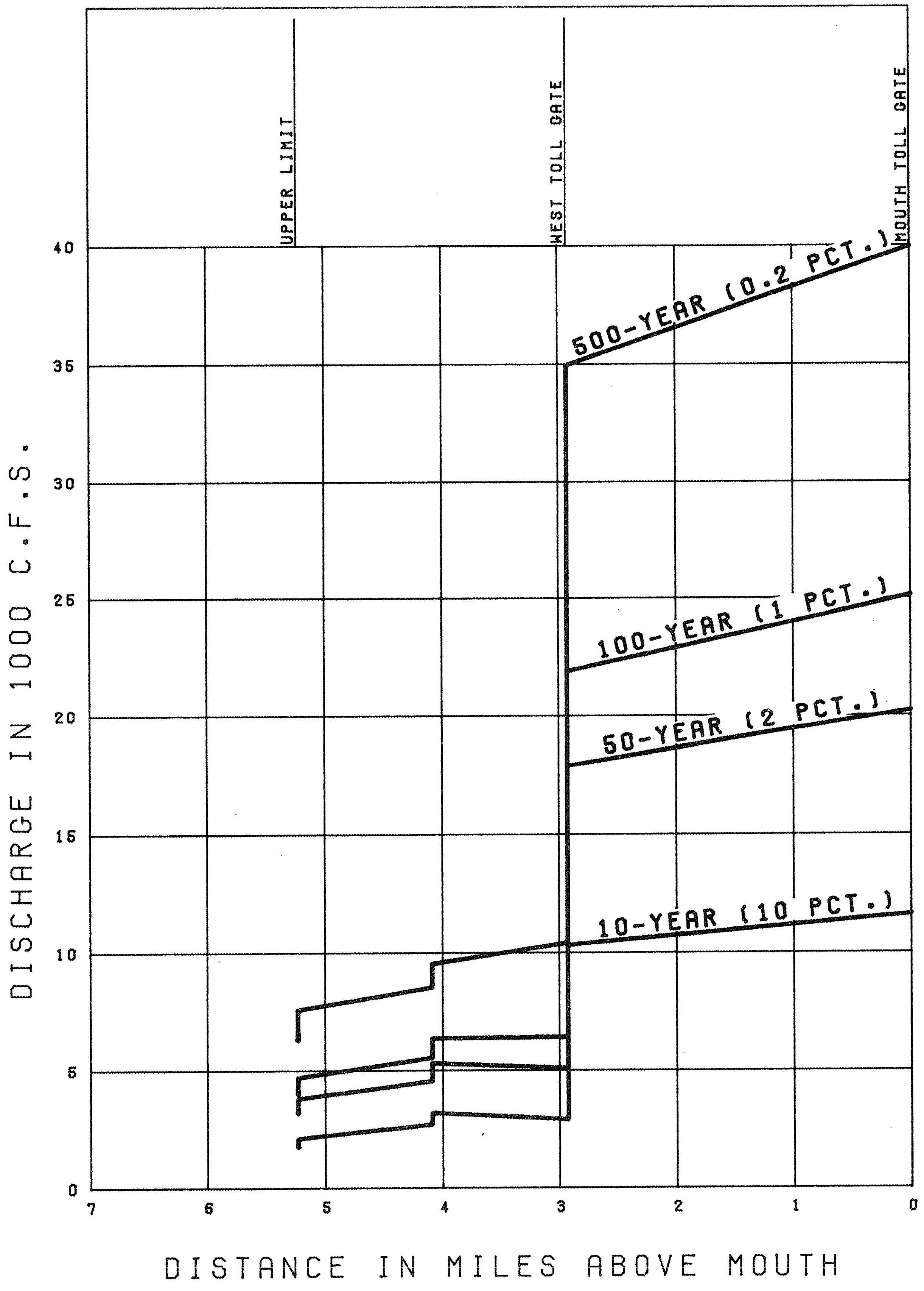
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

EAST TOLL GATE CREEK DISCHARGE PROBABILITY
PROFILES - 1990 NORMAL DENSITY RESIDENTIAL
WITH UNIMPROVED CHANNEL

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

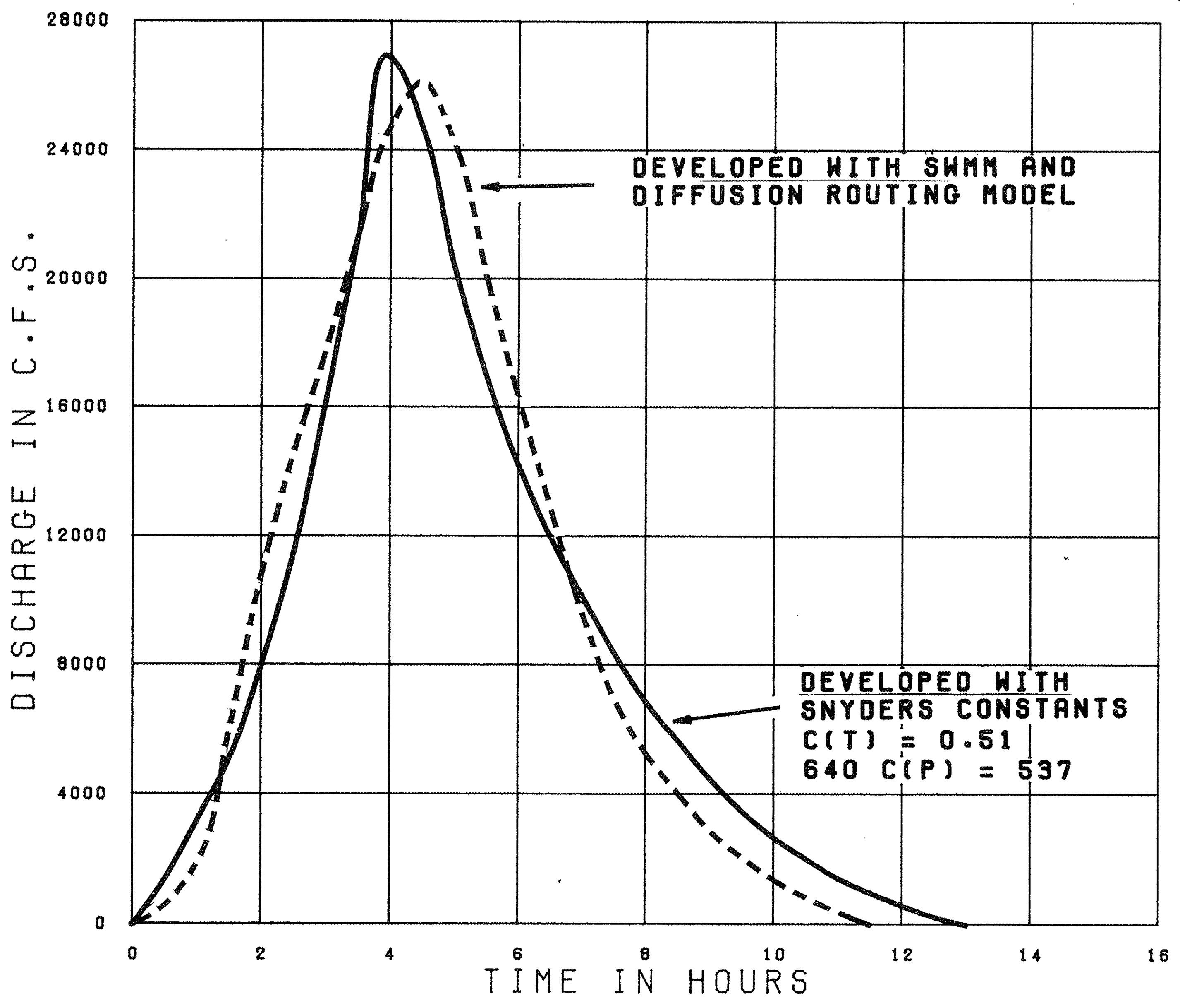
EAST TOLL GATE CREEK DISCHARGE PROBABILITY
PROFILES - 1990 NORMAL DENSITY RESIDENTIAL
WITH IMPROVED CHANNEL

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977

DRAINAGE AREA = 189 SQUARE MILES

TOTAL LENGTH = 38 MILES

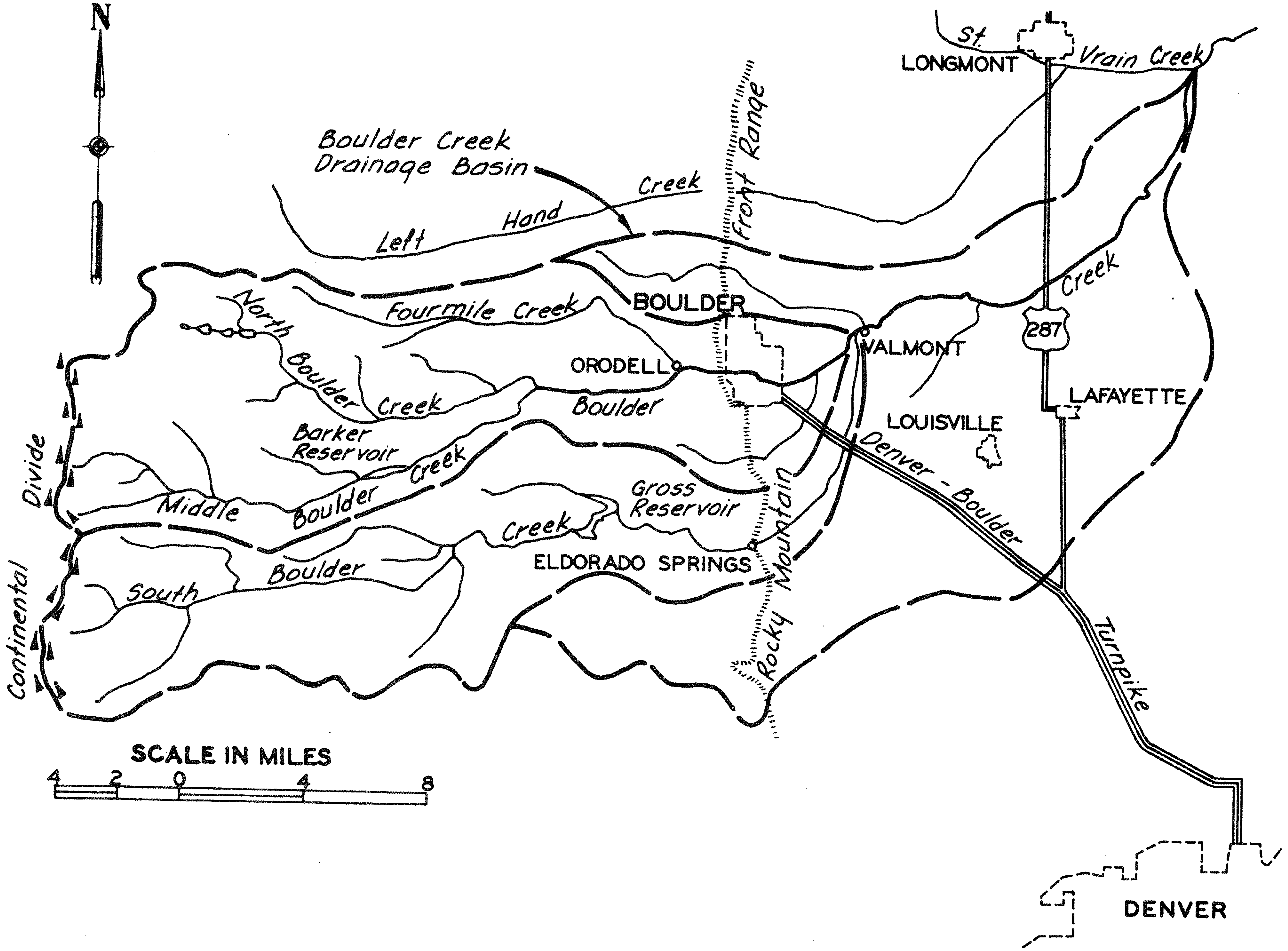
LENGTH FROM CENTROID = 18 MILES




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

SAND CREEK AT THE MOUTH
UNIT GRAPH COMPARISON

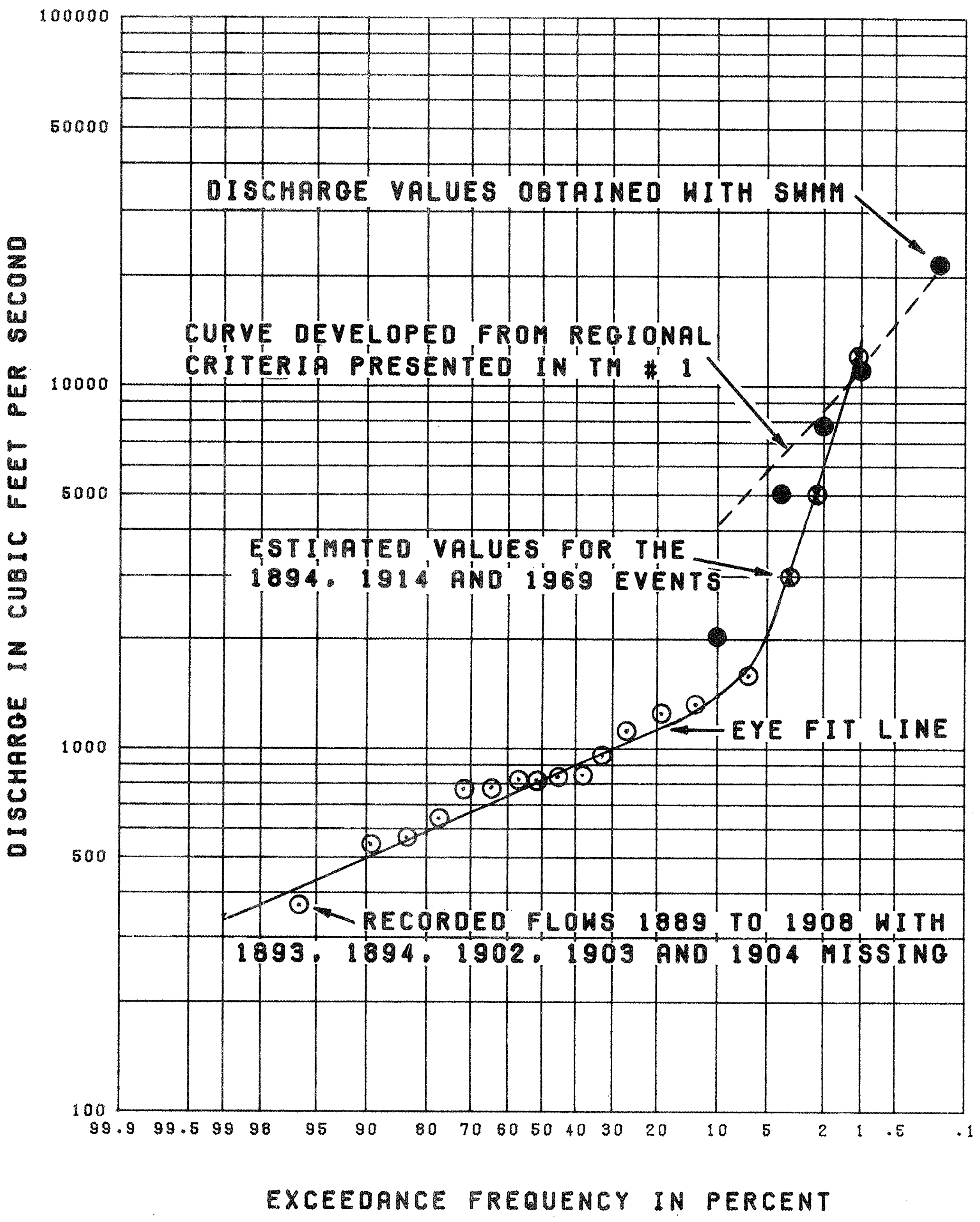
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

BOULDER CREEK
BASIN MAP

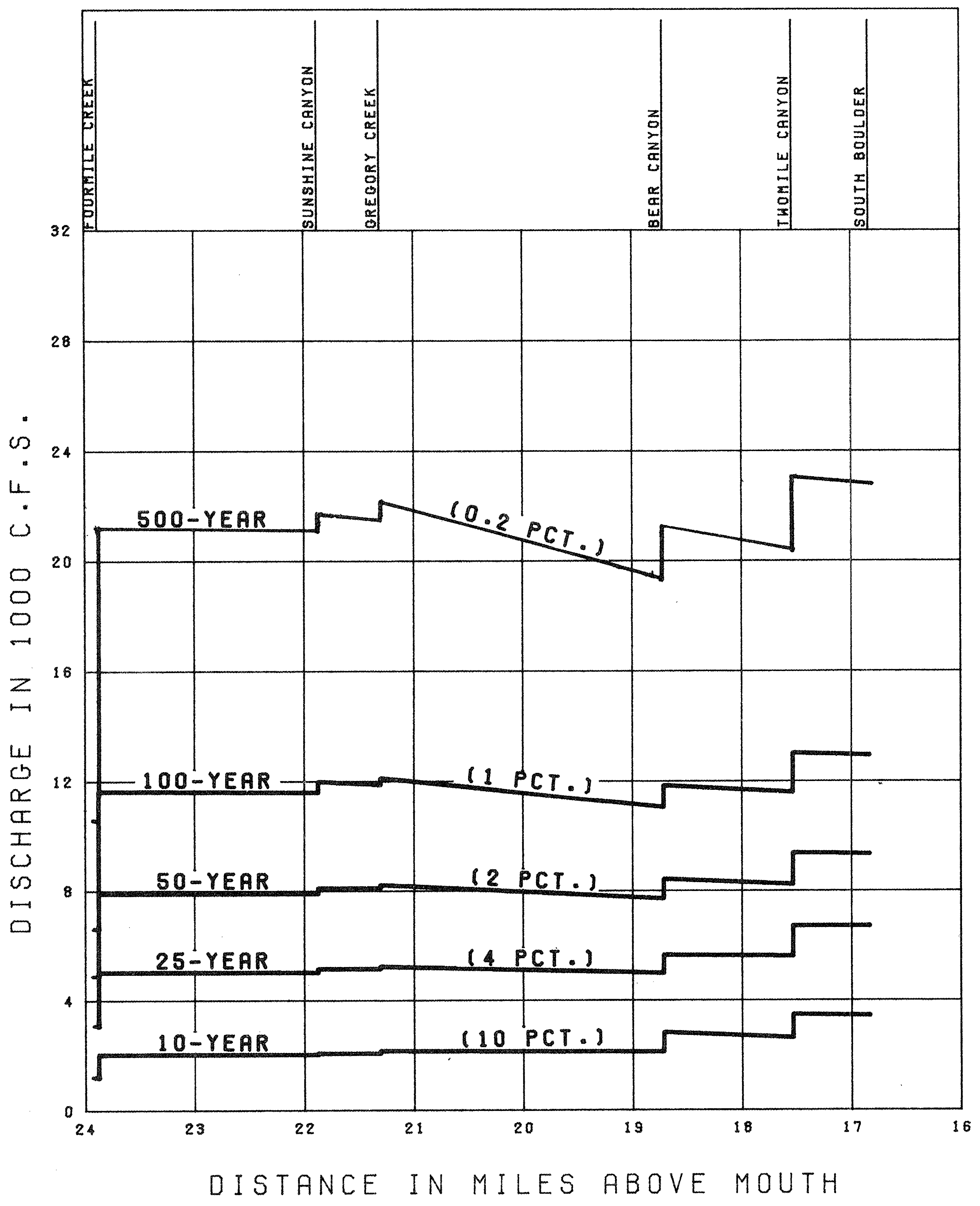
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

BOULDER CREEK
DISCHARGE PROBABILITY
BY THREE METHODS

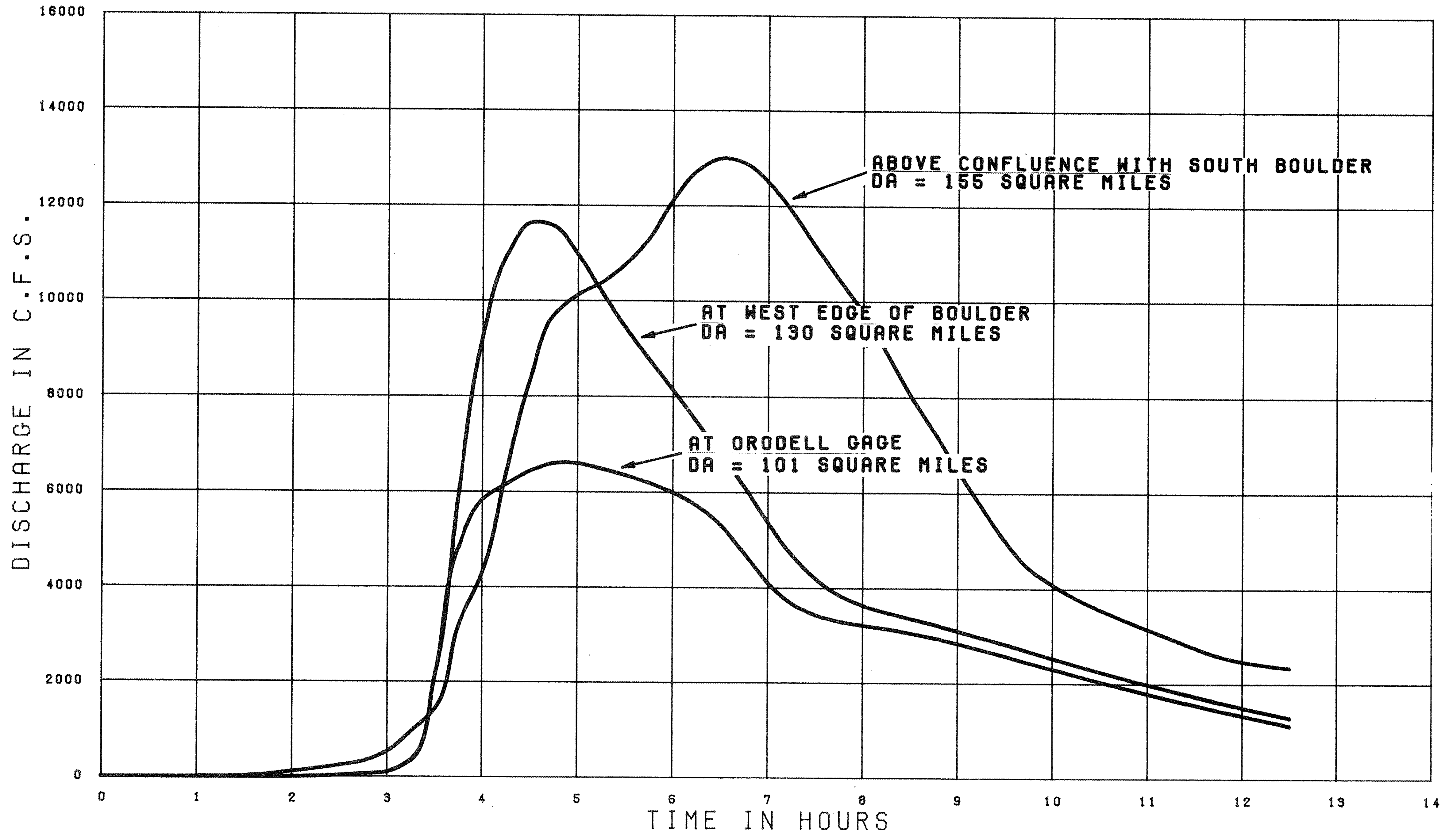
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

BOULDER CREEK
DISCHARGE PROBABILITY PROFILES
EXISTING CONDITIONS

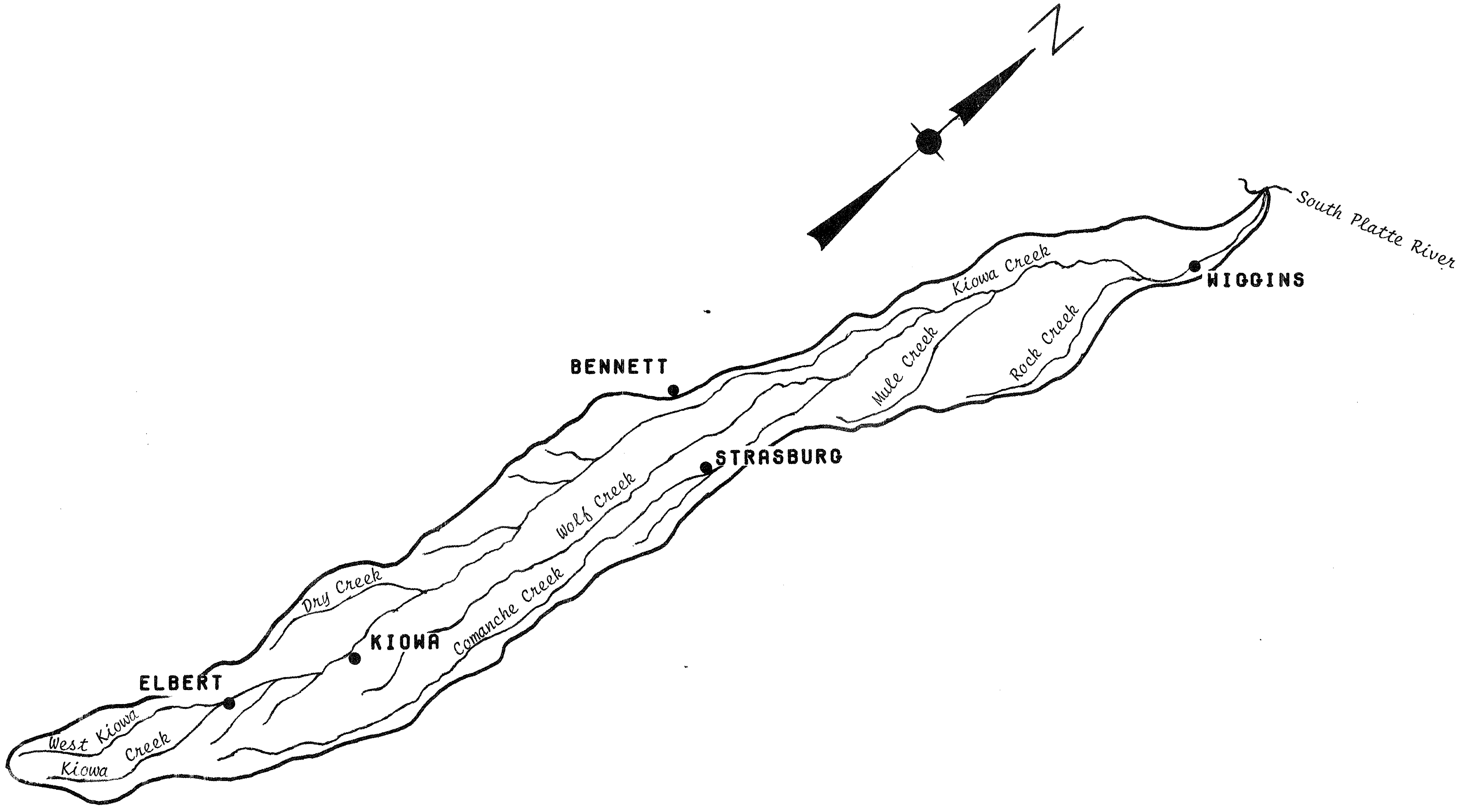
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

BOULDER CREEK
100-YEAR HYDROGRAPHS
AT SELECTED LOCATIONS

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977

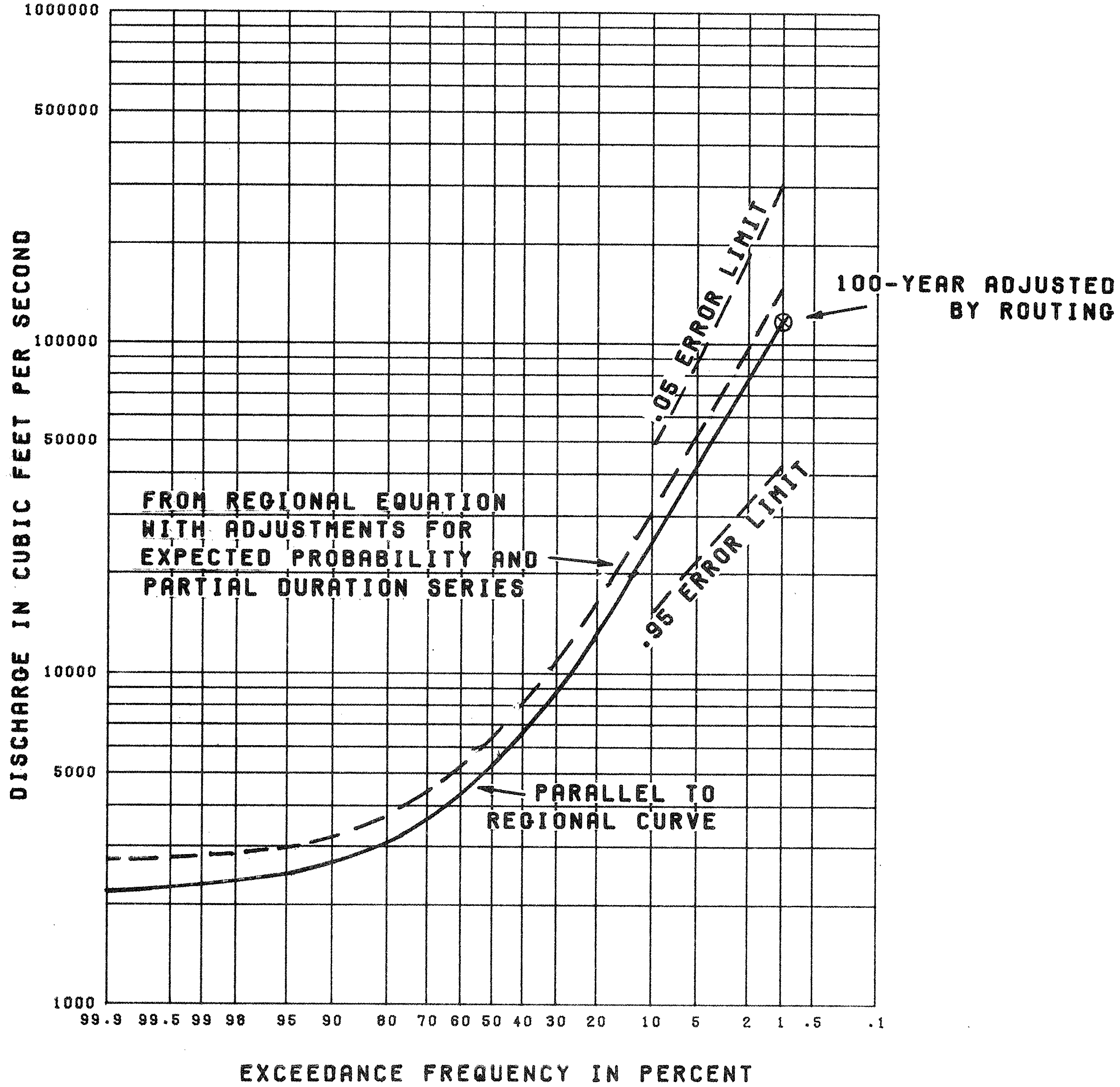



APPROXIMATE SCALE 1 INCH = 8 MILES

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

KIOWA CREEK
BASIN MAP

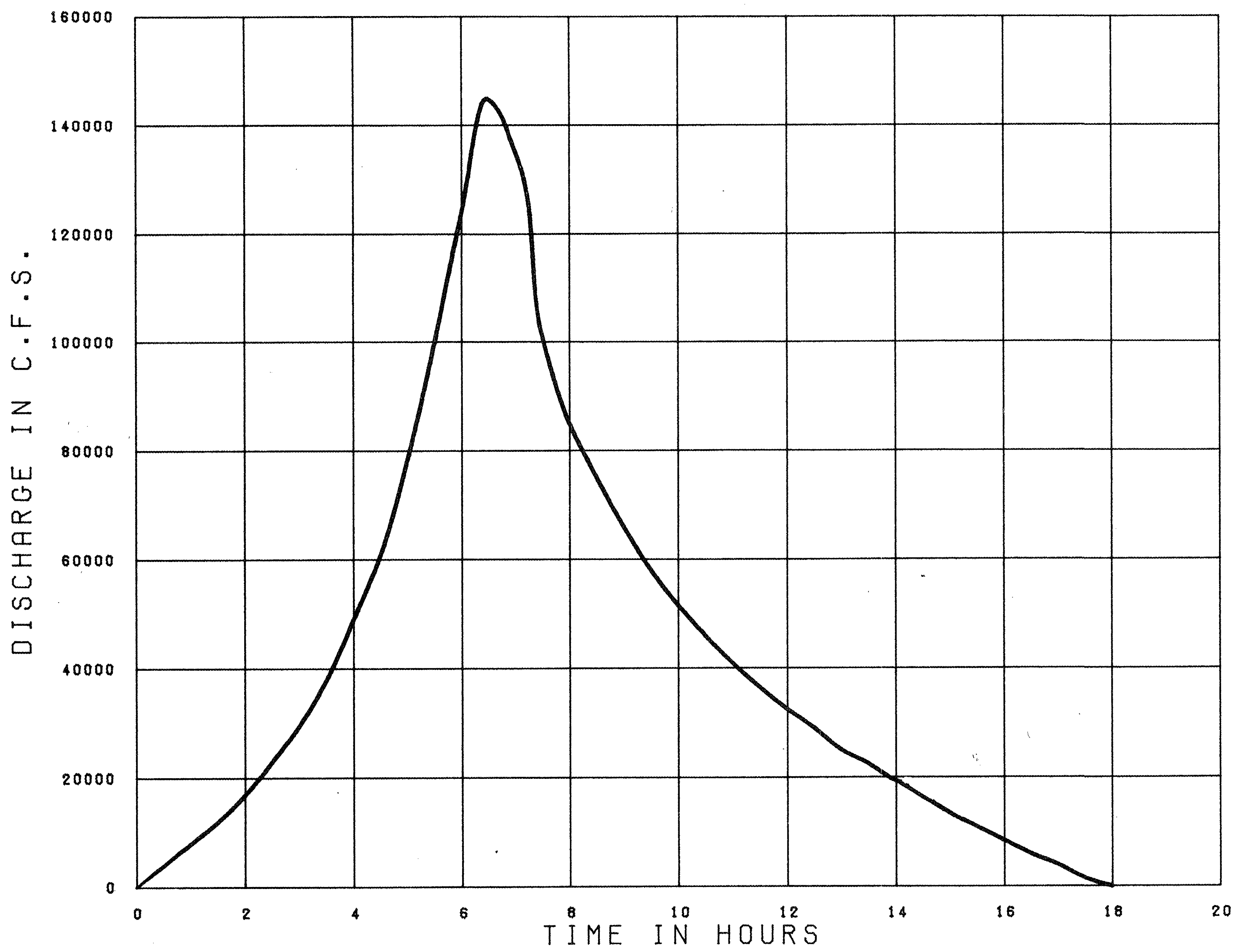
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

KIOWA CREEK
DISCHARGE PROBABILITY
FROM REGIONAL CRITERIA

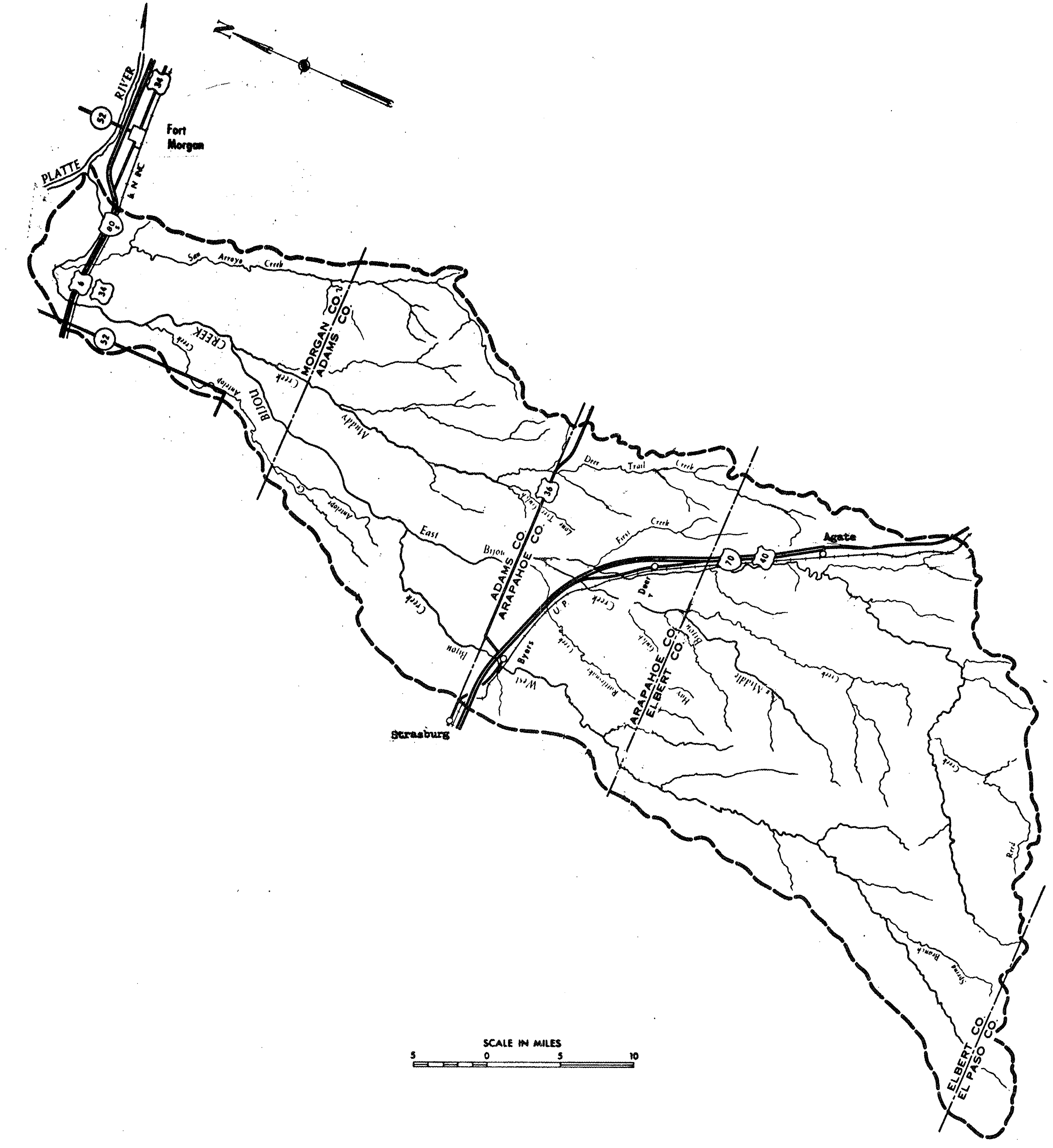
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977




METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

KIOWA CREEK
UNADJUSTED 100-YEAR
FLOOD HYDROGRAPH

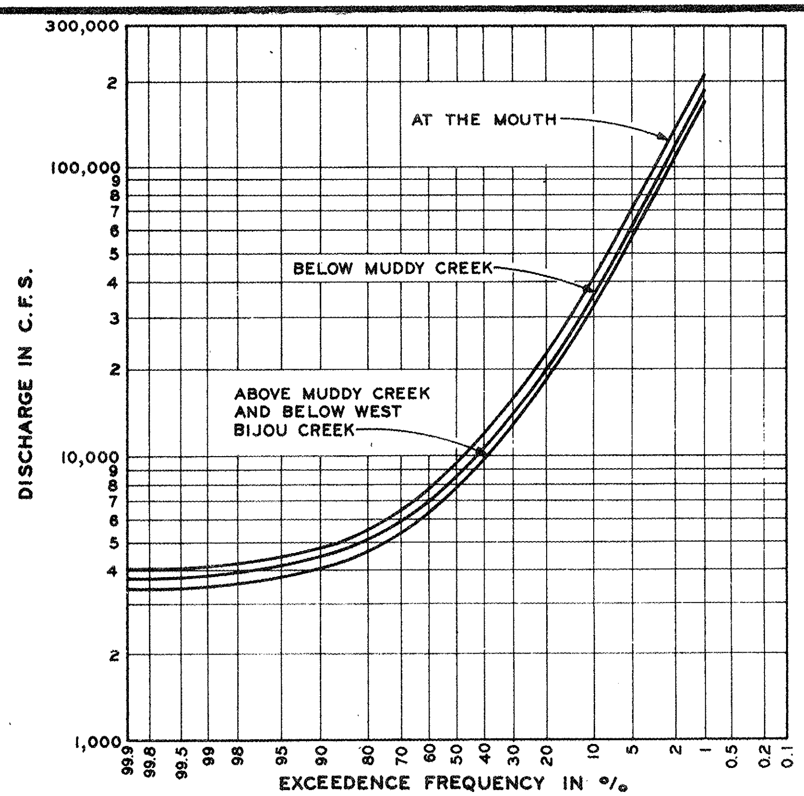
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977



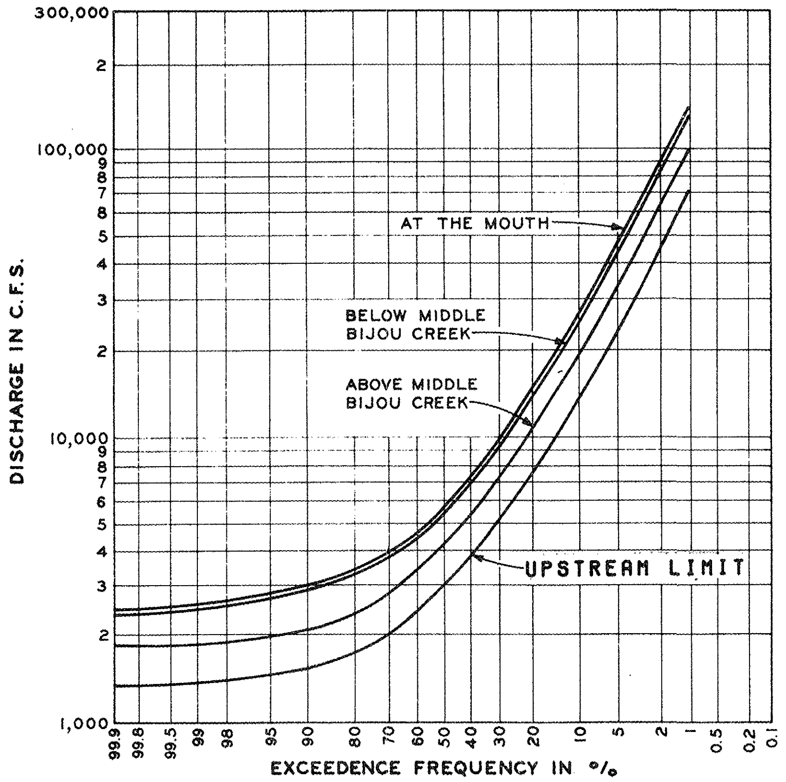

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

BIJOU CREEK
BASIN MAP

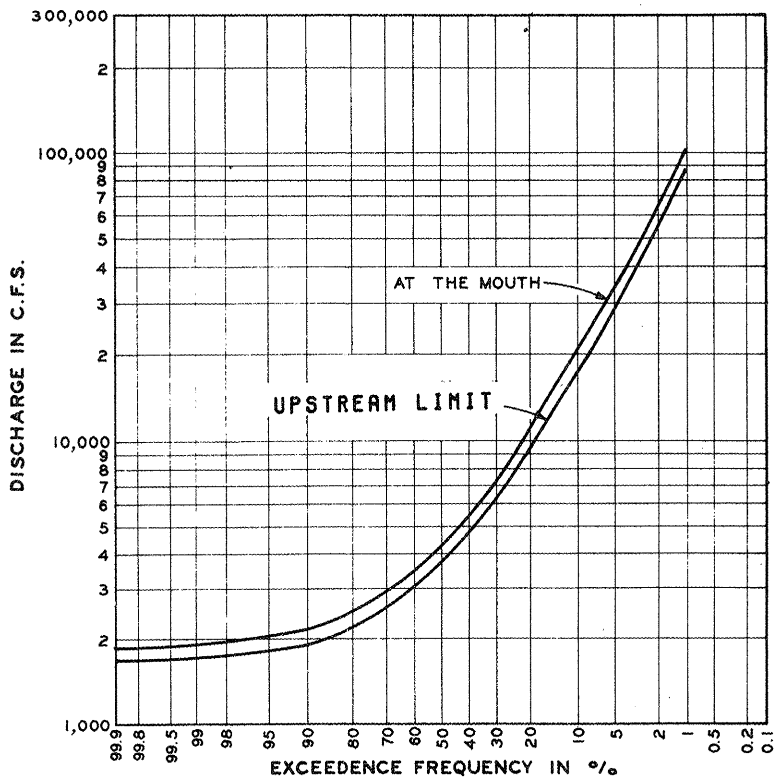
U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977



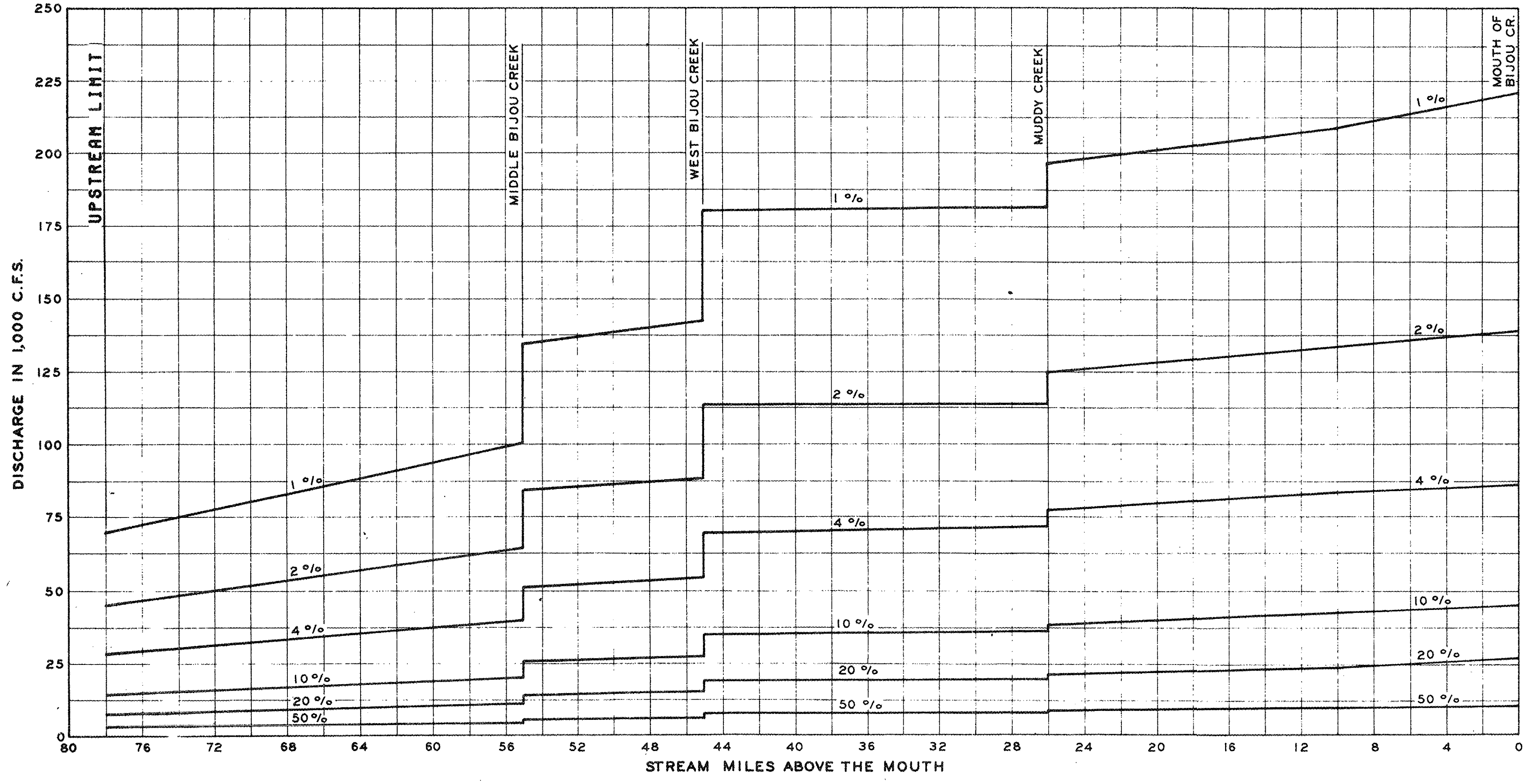

BIJOU CREEK



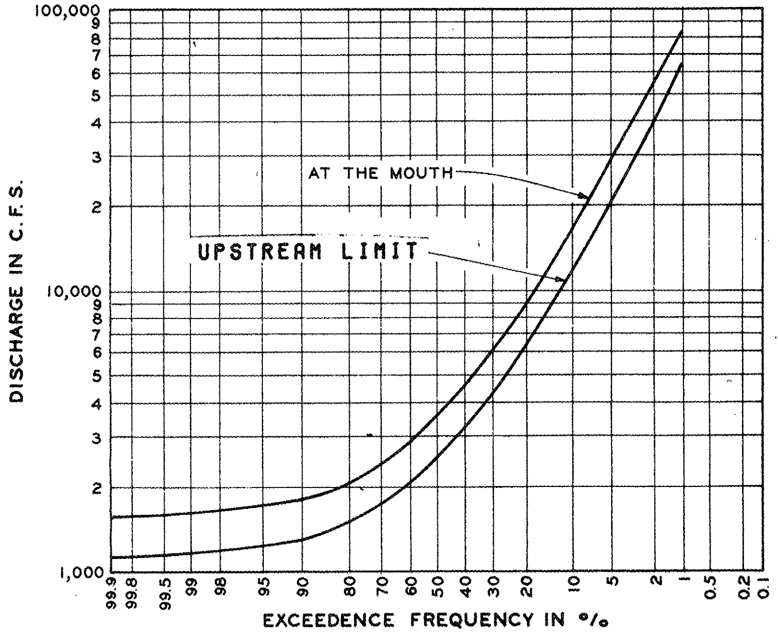

EAST BIJOU CREEK




WEST BIJOU CREEK




EAST BIJOU CREEK——+——BIJOU CREEK




MUDDY CREEK

METROPOLITAN DENVER AND
SOUTH PLATTE RIVER AND TRIBUTARIES
COLORADO, WYOMING AND NEBRASKA

BIJOU CREEK
DISCHARGE PROBABILITY RELATIONSHIPS

U.S. ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1977