NORMAL MONTHLY AND ANNUAL PRECIPITATION FOR EASTERN COLORADO

by

George L. Smith
and
Edmund F. Schulz

Colorado Agricultural Experiment Station
Civil Engineering Section
Colorado State University
Fort Collins, Colorado

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ABSTRACT

Isohyetal maps are given for each month of the year as well as the expected annual precipitation. The maps are for that portion of Colorado lying east of the region defined physiographically as the Rocky Mountain Foothills. They were prepared by means of the double-mass-curve technique, which identifies trends in precipitation data due to changes in station location or observing techniques. The data examined was for the period January 1, 1941 to December 31, 1961. The stations used in data analysis were grouped on both a geographic and physiographic basis.

I. INTRODUCTION

In Eastern Colorado the amount of precipitation that a given area will receive, either monthly or annually, will play a vital role in the future development of one or all of the following: (a) ranches, (b) farms, or (c) cities. As an initial step toward providing such desirable information, isohyetal maps--maps having contours of equal rainfall--are presented in this report. There is a map for each month of the year as well as a map showing expected annual precipitation. The bold block contour lines with numbers on each map identify the amounts of equal precipitation. The blue lines mark the major river systems or tributaries that drain Eastern Colorado. The South Platte drains the Northeastern corner; the Arkansas River drains the Southeastern corner. County lines, except where a river or its tributary forms a boundary, are identified by the red lines. The broad brown lines mark the areas established by the Soil Conservation Service as having similar physiographic features and similar problems in soil conservation. The area considered in this report extends westward to the Rocky Mountain Foothills.

The weather stations, whose data were used in developing the isohyetal portion of the map, were grouped both on a geographic and a physiographic basis. For example, those stations lying along the Arkansas River and its tributaries were also located in the same physiographic region. The consistency of the data was examined by use of the double-mass-curve technique as developed by Merriam (1) and Kohler (2). The data was then adjusted and used in the development of the maps of this report.

II. PHYSIOGRAPHIC DELIMITATION OF REGION OF STUDY

As evident from the maps of this report, primary emphasis was given to the region in eastern Colorado. The portion encompassing the area north of the Arkansas River and including most of the South Platte River and tributaries is known as the "Northern Brown Plains." The area encompassing the Arkansas River is called the "Plains of the Upper Arkansas and Purgatoire Rivers." An area similar to the "Northern Brown Plains" can be identified in the extreme Southwest portion of the maps south of the Arkansas River System. Brief descriptions of these areas, as given in an unpublished manuscript of the Soil Conservation Service, follows:

Northern Brown Plains

The Northern Brown Plains has a relief that is characterized by nearly level to gently rolling table land areas that break off into steeply rolling valley slopes. In eastern part of Colorado and southwestern Nebraska there are several relatively large areas of sand hills...

The average annual precipitation is about 14 to 18 inches...rainfall is quite variable...(with) the greater portion of the precipitation falling (at high rates) with high runoff and erosion rates...

Soils of the area are of four types: (1) deep medium textured soils on nearly level table land areas; (2) medium depth, medium textured soils on upland; (3) shallow medium textured soils and gravel; and (4) sandy soils on aeolian sand deposits.

Plains of Upper Arkansas and Purgatoire Rivers

The area is located in southeastern Colorado and covers an area of 6,795,000 acres. The relief is undulating to rolling 4,000 to 5,000 feet elevation above sea level. Rainfall is variable, 11 to 14 inches (annually). Soils are shallow to moderately deep, medium to moderately heavy texture on range land...

Erosion...slight sheet erosion on much of the area. Severe in local areas having poor cover...

Seven percent cultivated...90 percent grassland classed as semi-arid grazing land..., 3 percent miscellaneous, no forest.

The area forming the western border of the isohyetal map is known as the Rocky Mountain Foothills. Descriptions of this region from the aforementioned unpublished manuscript of the Soil Conservation Service follows:

Rocky Mountain Foothills

Along the eastern base of the Rocky Mountains uplift and associated structural ranges in Wyoming and Colorado is a transition zone of limited linear dimension with individualistic climate, soils, and topography...

Characteristic topography is hogback and cuesta.* Elevations range from 5,500 to 8,000 feet. Two precipitation zones are evident. The lower elevations receive about 10-14 inches per annum and the upper 15-19 inches. Maximums approach 21 inches and minimums about 7 inches per annum. Torrential rainstorms of violent, but short, duration encourage considerable runoff from depleted ranges.

Valley lands associated with the hills have deep, moderately permeable soils very favorable to crop production.

In contrast, the soils on the hogbacks are shallow and oftentimes stony.

* cuesta - a ridge or hill characterized by a steep escarpment on one side and a long, gentle slope on the other.

III. ADJUSTMENT OF PRECIPITATION DATA

The changes in time trends in precipitation data are the result of changes in the gage location, changes in immediate surroundings--construction of buildings, growth of trees, or changes in observing technique--change in observers, advances in recording equipment. These various changes are recorded in the substation history, but the effect of the changes are not evident in the published record of the climatological data, since it is Weather Bureau practice to continue a station under the same name as long as it has not moved more than 5 miles or 1000 feet in elevation. The consistency of a record may be determined and the necessary adjustment accomplished by use of the double-mass-curve technique as developed by Merriam (1) and Kohler (2).

The double-mass technique has been criticized because a change in trend could appear as the result of random fluctuations in precipitation received by a station. Adjustment of records should never be made unless the break in the trend can be definitely associated with a sound physical reason such as a change in exposure of the station.

The adjustment of the precipitation data is accomplished by a procedure that compares the accumulated annual, monthly, or seasonal precipitation to be tested with the concurrent accumulated values of mean precipitation for a group of base stations. For example, in Table I are listed the sixteen stations of the Northern Brown Plains region lying north of the Arkansas River. The period of record for each station was twenty-one years, January 1, 1941 to December 31, 1961. For each of the sixteen stations the annual precipitation was added concurrently beginning with 1961. Thus, the maximum accumulated value would occur in 1941. For each year the average of the total sixteen station values was computed. For each station, this average value was plotted against the accumulated station value. This gives the double mass curve.

A decided change in the precipitation regime of the station is indicated by an abrupt change in the slope of the double-mass curve. An abrupt change in slope indicates that the records of the station being tested suddenly have developed a consistent and continuing change in trend when compared to the records from the surrounding region. An occasional mistake by the observer or the chance occurrence of abnormally high or low precipitation at a station will not produce a consistent and continuing change in the slope of the line. On the basis of the difference in the slope of the two sections of the curve, if it exists, the records for the the given station should be adjusted to make the earlier records comparable with those for the present location. In determining the adjusted data, an adjustment factor was used.

Adjustment factor =

$$\frac{\text{Weather Bureau Average Annual Precipitation}}{\text{Adj. Ann. Ppt. from Double-Mass Curves}}$$

The average monthly and annual precipitation published by the Weather Bureau is computed on the basis of whatever length of record is available. When some stations have much shorter periods of record than others, the averages thus obtained should not be compared because the records may cover different climatic cycles. Thus, using the values obtained from a double-mass analysis provides averages from the same climatic cycle and provides a means for adjusting an inconsistent segment of record.

The average values given by the Weather Bureau were multiplied by the adjustment factor to give the adjusted annual or monthly precipitation value for each station used. The stations located in the Northern Brown Plains region north of the Arkansas River are given in Table I; those of the Plains of the Upper Arkansas and Purgatoire River region are given in Table II; those of the Northern Brown Plains region south of the Arkansas River and located in the extreme southeast corner of Colorado are given in Table III.

These adjusted monthly and annual precipitation amounts were used to prepare the isohyetal maps included in this bulletin. A map is shown for each month as well as the total annual precipitation. A word of caution is appropriate here. The foothills of the Rocky Mountains have a profound influence on the precipitation received within a distance of from 10 to 20 miles. The amount of data along the foothills is very limited. Therefore, these maps should not be used to determine the monthly or the annual precipitation west of the brown line indicating the western boundary of the Eastern Colorado Plains. In a number of instances isohyetal lines extend toward the west, past the boundary of the Rocky Mountain Foothills physiographic area. The details of the precipitation in the Rocky Mountain Foothills is now the subject of further research.

IV. COMPARISON TO LONG-TERM RECORDS

The base period 1941 to 1961 was selected because if it were longer, some station records would have been rejected on the basis of missing data prior to 1941. As a consequence, the reduction in the number of station records would have affected the desired detail of the isohyetal maps. It is significant, however, that the length of record chosen precludes the influence on the computed mean precipitation amounts by the random occurrence of unusually wet or dry years at any station. On the other hand, the length of station record was not of sufficient length to span long-term cyclic trends.

There are a few stations having much longer periods of record; for example, Fort Collins (1887-1961) with 75 years' record; Denver (1872-1961) with 90 years' record; Pueblo (1897-1961) with 64 years' record; and Fort Morgan (1900-1961) with 62 years' record. Examination of the histories of all of these stations disclosed that each of the stations had been moved several times. Some of these moves resulted in a discontinuity in the records obtained. The records obtained at Fort Collins appear to be the most consistent. There is good reason for this because the station was established on the campus of Colorado State University and care was taken to maintain good exposure at all times. The records obtained by the Denver City station have similar consistency although there were several moves recorded in its station history. The gage site was situated on top of various buildings all located in the downtown area. The following tabulation shows a comparison of the long-term mean obtained from the entire 75- and 90-year record at Fort Collins and Denver with the adjusted normal used in preparing these isohyetal maps.

	Length of Record	Long-Term Mean	1941-61 Adj. Normal	Difference
Fort Collins	75	14.84	15.50	-4%
Denver	90	14.41	13.15	+1%

This comparison indicates that the 1941-61 period of record used in developing the data for these maps was within 5% of the long-term trend based on data measured at two stations whose records appear to be consistent.

V. REFERENCES

1. Merriam, C. F., Progress report on the analysis of rainfall data, Trans. Am. Geophys. Union, Vol. 19, pp. 529-532, 1938.

2. Kohler, M. A., Double-mass analysis for testing the consistency of records and for making required adjustments, Am. Meteorological Soc. Bull., Vol. 30, pp. 188-189, 1949.

Stations North of the Arkansas River

D-13 Region* Stations

Table I. Stations located in the Northern Great Plains Region North of the Arkansas River

	Station	Drainage	Lat.	Long.	County	W. B. Ave. Annual Ppt.	Adjusted Normal Ppt.
1.	Burlington	Kansas	39° 18'	102° 16'	Kit Carson	15.64	16.52
2.	Byers	So. Platte	39° 43'	103° 13'	Arapahoe	13.91	14.10
3.	Cheyenne Wells	Kansas	38° 49'	102° 21'	Cheyenne	14.23	16.52
4.	Denver City	So. Platte	39° 45'	105° 00'	Denver	13.43	13.15
5.	Ft. Collins	So. Platte	40° 35'	105° 05'	Larimer	14.07	15.50
6.	Ft. Morgan	So. Platte	40° 15'	103° 48'	Morgan	12.73	13.75
7.	Greeley	So. Platte	40° 26'	104° 41'	Weld	10.96	12.05
8.	Grover	So. Platte	40° 52'	104° 25'	Weld	12.85	15.21
9.	Holyoke	So. Platte	40° 35'	102° 18'	Phillips	17.71	17.55
10.	Julesburg	So. Platte	41° 00'	102° 15'	Sedgwick	16.01	18.00
11.	Leroy	Kansas	40° 29'	103° 01'	Logan	17.69	18.56
12.	Limon	Arkansas	39° 09'	103° 46'	Lincoln	14.67	14.51
13.	Longmont	So. Platte	40° 10'	105° 04'	Boulder	11.66	12.70
14.	Rush	Arkansas	38° 52'	104° 05'	El Paso	12.98	13.32
15.	Wray	Kansas	40° 04'	102° 13'	Yuma	17.20	16.70
16.	Yuma	Kansas	40° 07'	102° 44'	Yuma	16.18	16.95

*Region is defined as areas having similar physiographic features and similar problems in soil conservation.

D-20 Region Stations

Table II. Stations located in the Plains of Upper Arkansas and Purgatoire Rivers.

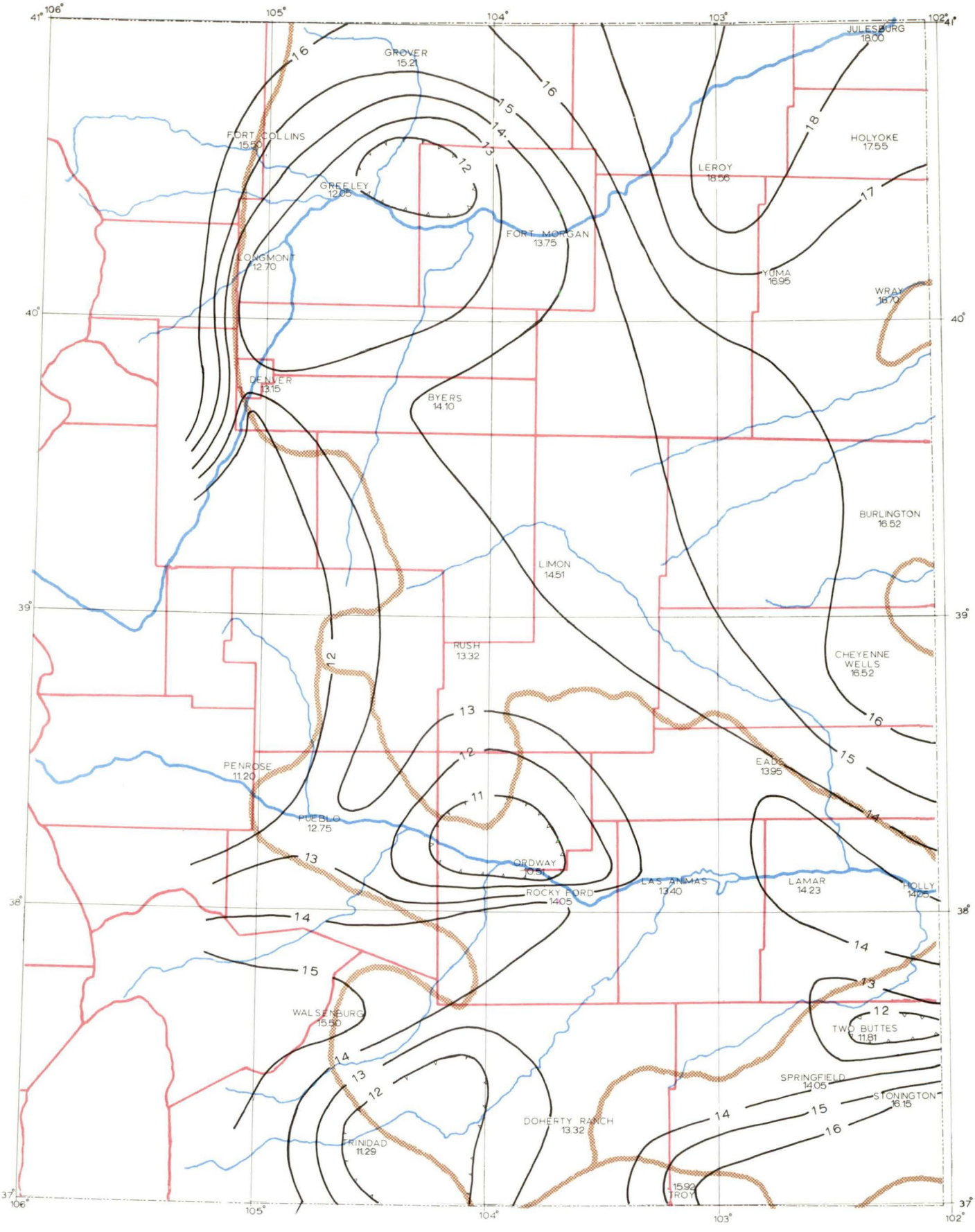
	Station	Drainage	Lat.	Long.	County	W. B. Ave. Annual Ppt.	Adjusted Normal Ppt.
1.	Eads	Arkansas	38° 29'	102° 47'	Kiowa	13.64	13.95
2.	Holly	Arkansas	38° 03'	102° 07'	Prowers	14.87	14.05
3.	Lamar	Arkansas	38° 04'	102° 37'	Prowers	14.02	14.23
4.	Las Animas	Arkansas	38° 04'	103° 13'	Bent	11.65	13.40
5.	Ordway	Arkansas	38° 13'	103° 45'	Crowley	11.26	10.51
6.	Penrose	Arkansas	38° 27'	105° 04'	Fremont	11.32	11.20
7.	Pueblo	Arkansas	38° 17'	104° 31'	Pueblo	11.85	12.75
8.	Rocky Ford	Arkansas	38° 02'	103° 42'	Otero	12.32	14.05
9.	Trinidad	Arkansas	37° 10'	104° 29'	Las Animas	13.71	11.29
.0.	Walsenburg	Arkansas	37° 37'	104° 48'	Huerfano	14.81	15.50
.1.	Doherty Ranch	Arkansas	37° 23'	103° 53'	Las Animas	14.59	13.32

Stations South of the Arkansas River

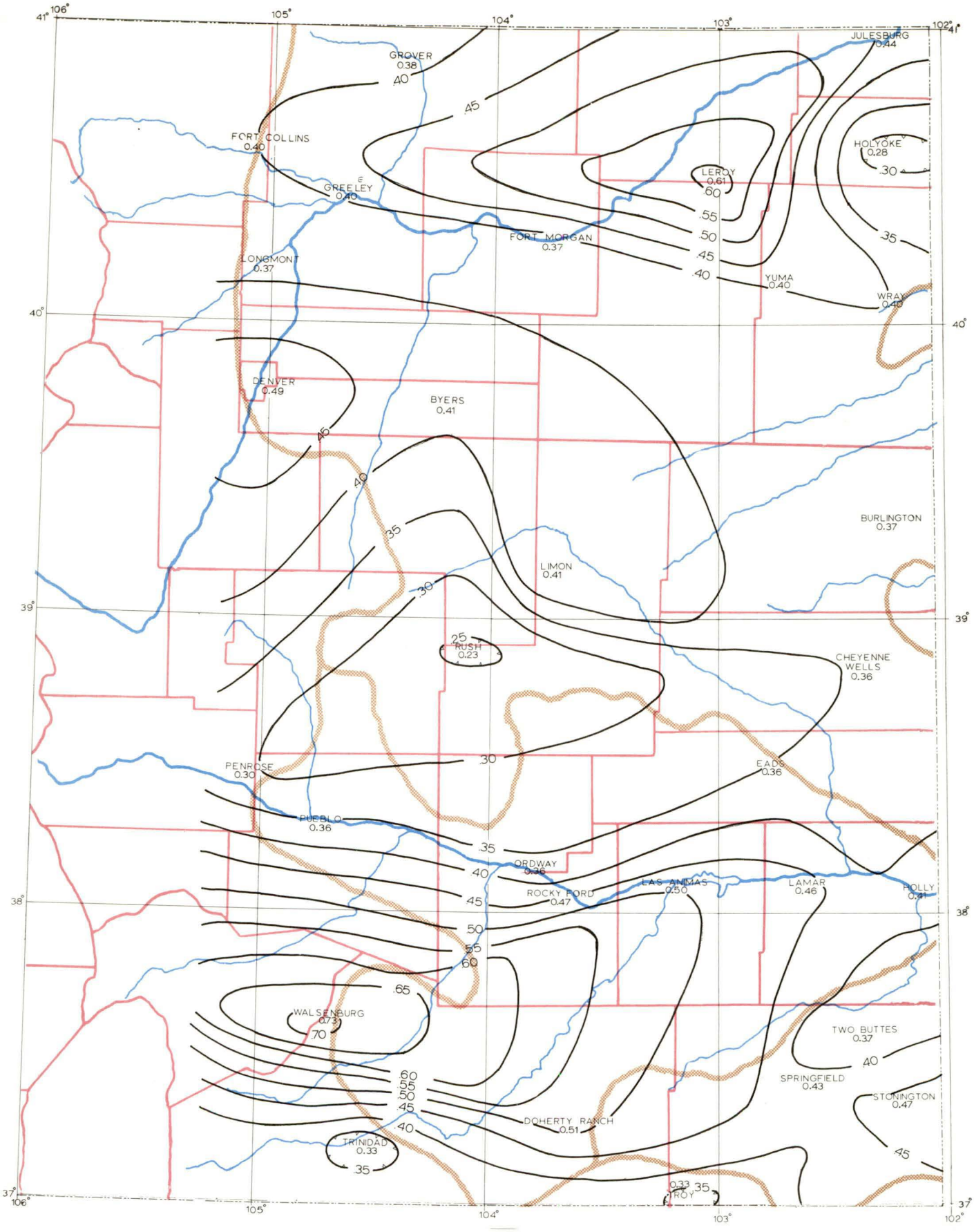
D-13 Region Stations

Table III. Stations located in the Northern Great Plains Region South of the Arkansas River

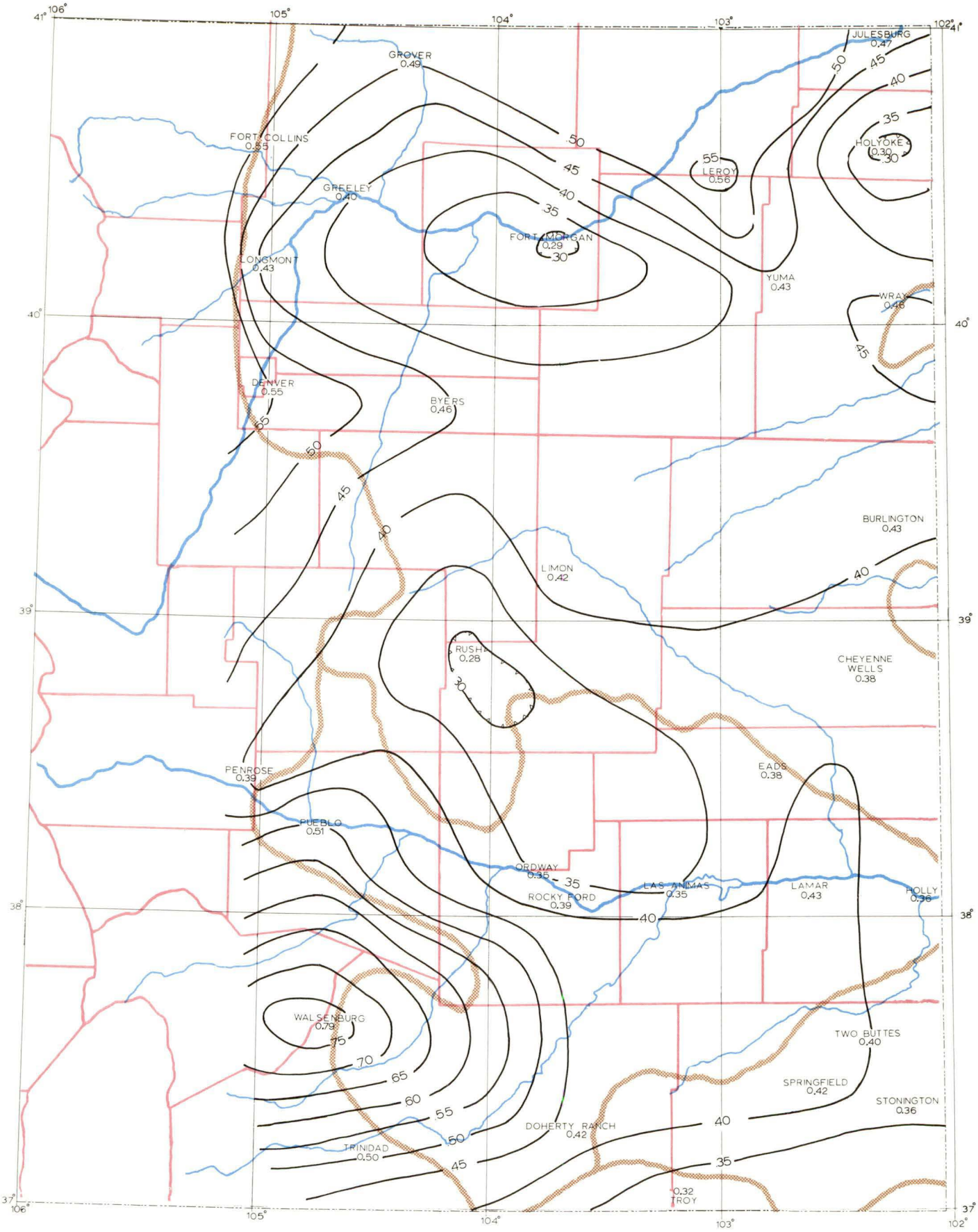
	Station	Drainage	Lat.	Long.	County	W. B. Ave. Annual Ppt.	Adjusted Normal Ppt.
1.	Springfield		37° 24'	102° 36'	Baca	14.68	14.05
2.	Stonington		37° 17'	102° 11'	Baca	17.60	16.15
3.	Troy 1 SE		37° 08'	103° 19'	Las Animas	17.11	15.92
4.	Two Buttes		37° 34'	102° 24'	Baca	14.21	11.81



Adjusted Normal Annual Precipitation Eastern Colorado Period 1941 – 1961



Adjusted Normal Monthly Precipitation Eastern Colorado Month of January



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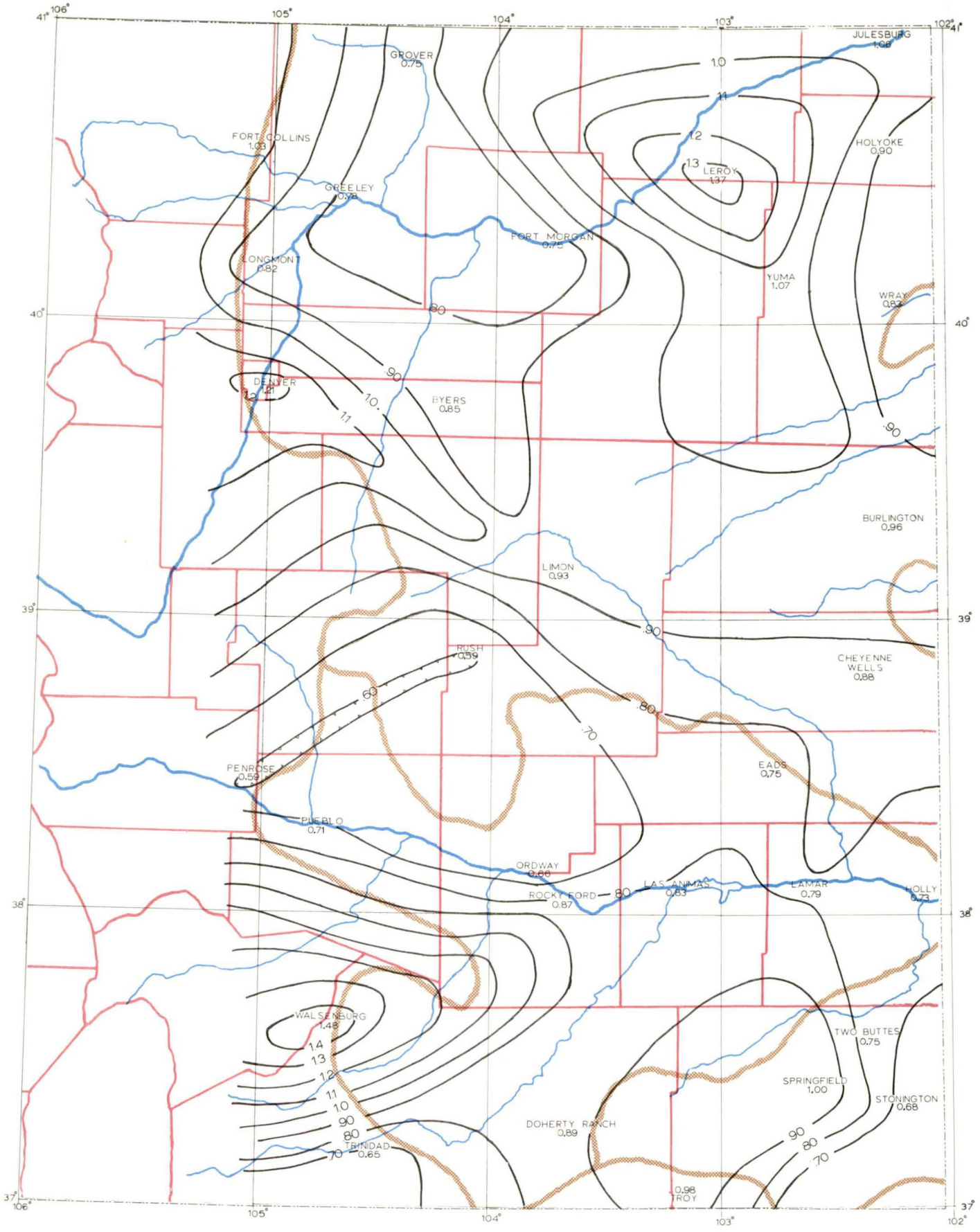

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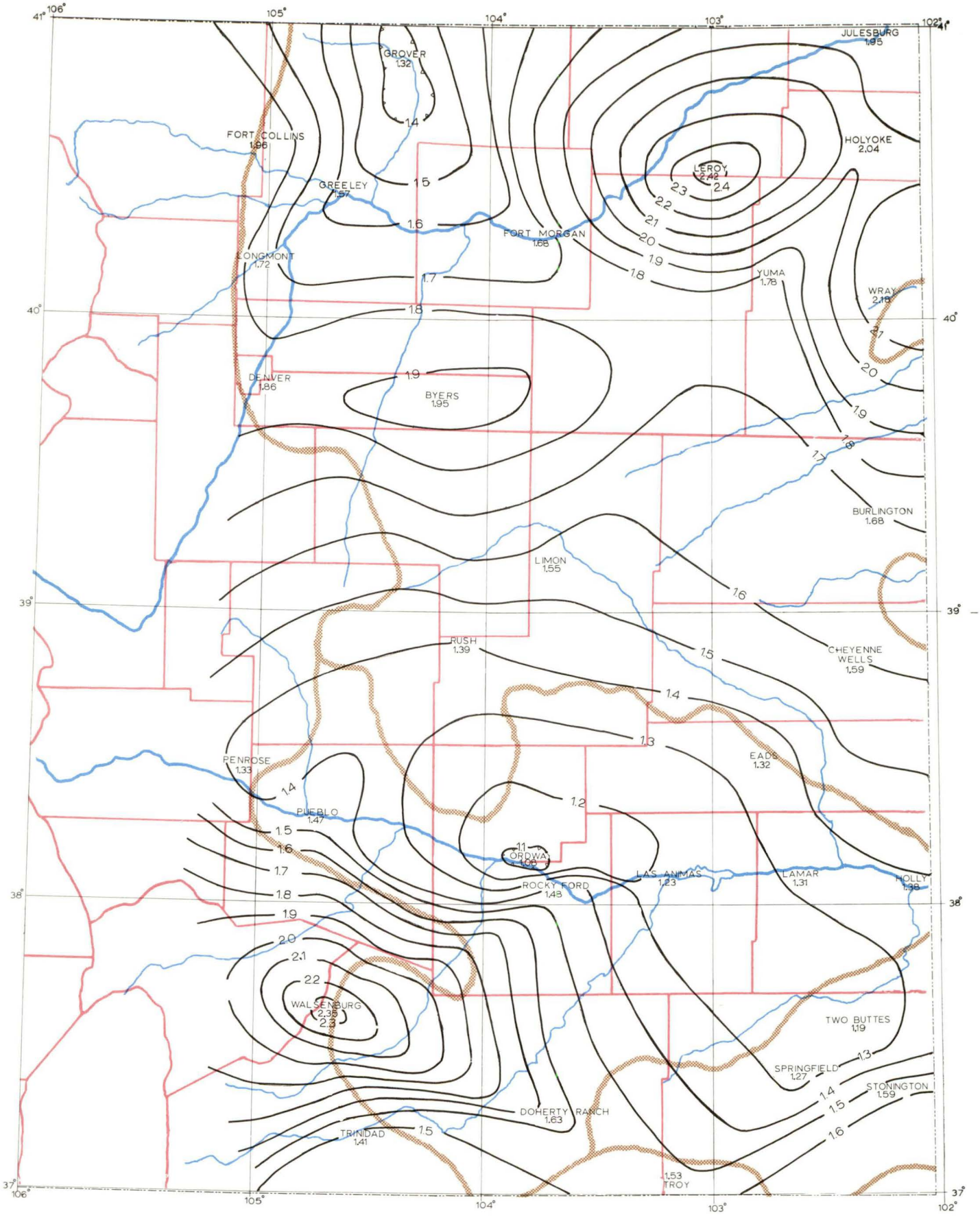

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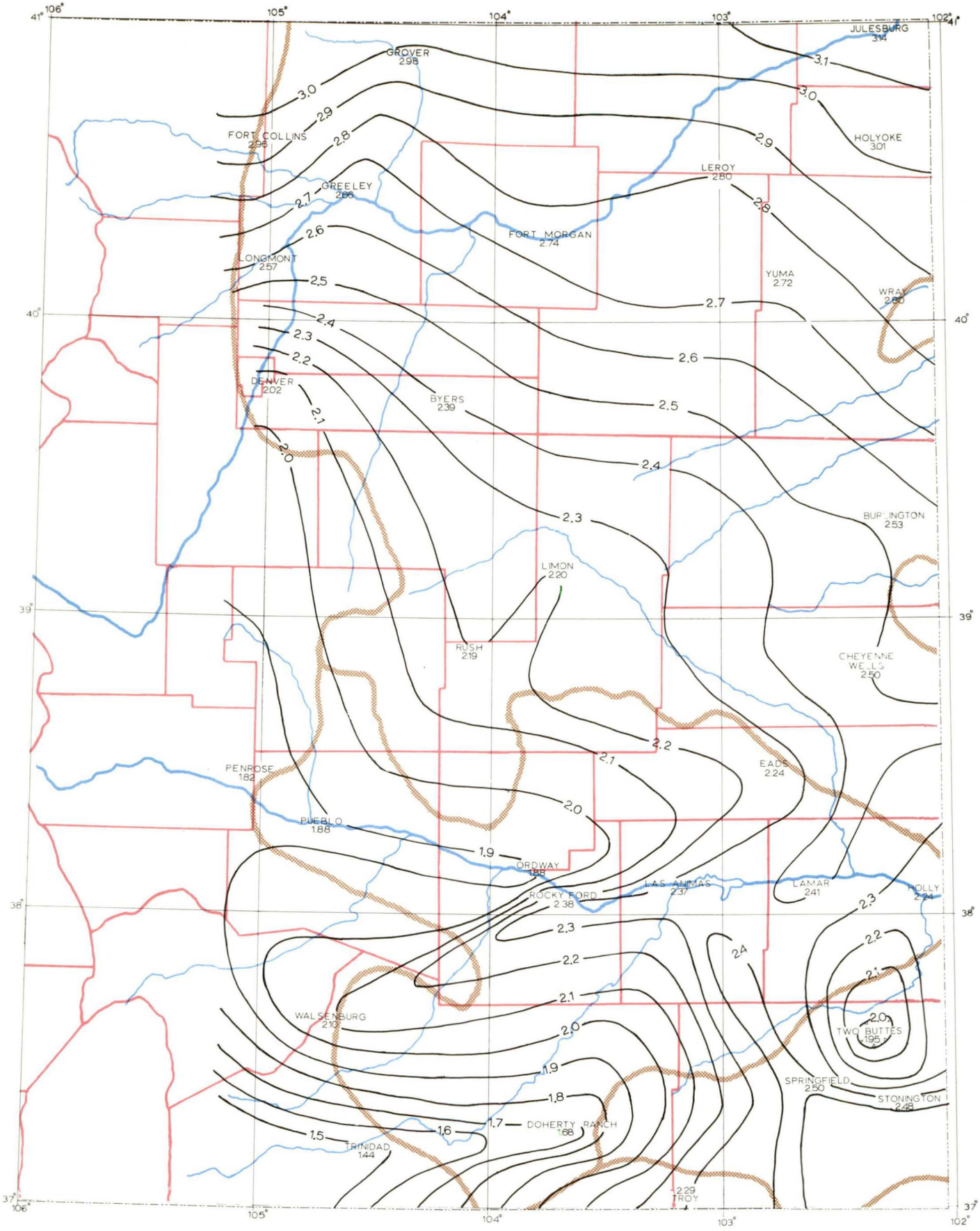
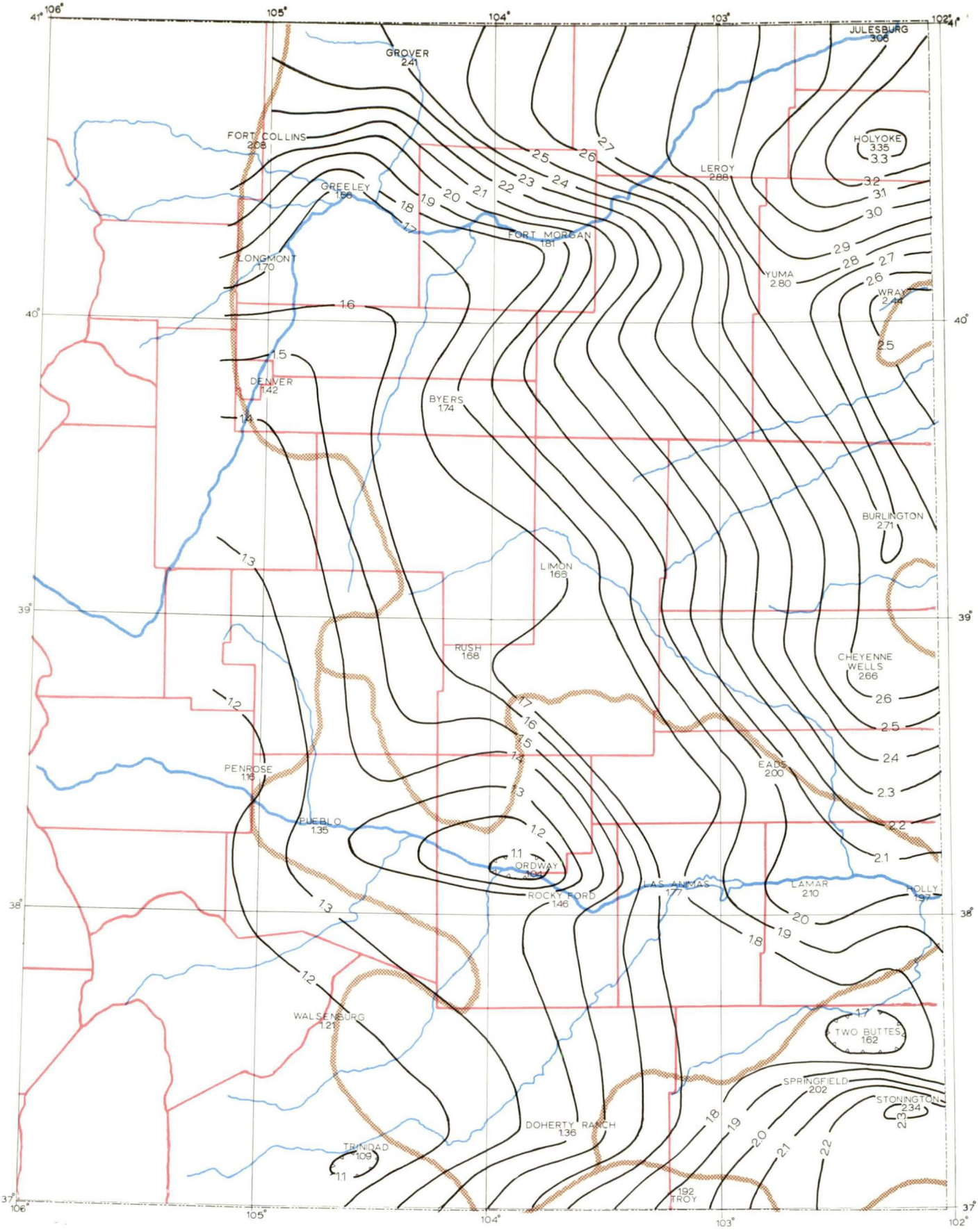


Adjusted Normal Monthly Precipitation Eastern Colorado Month of May



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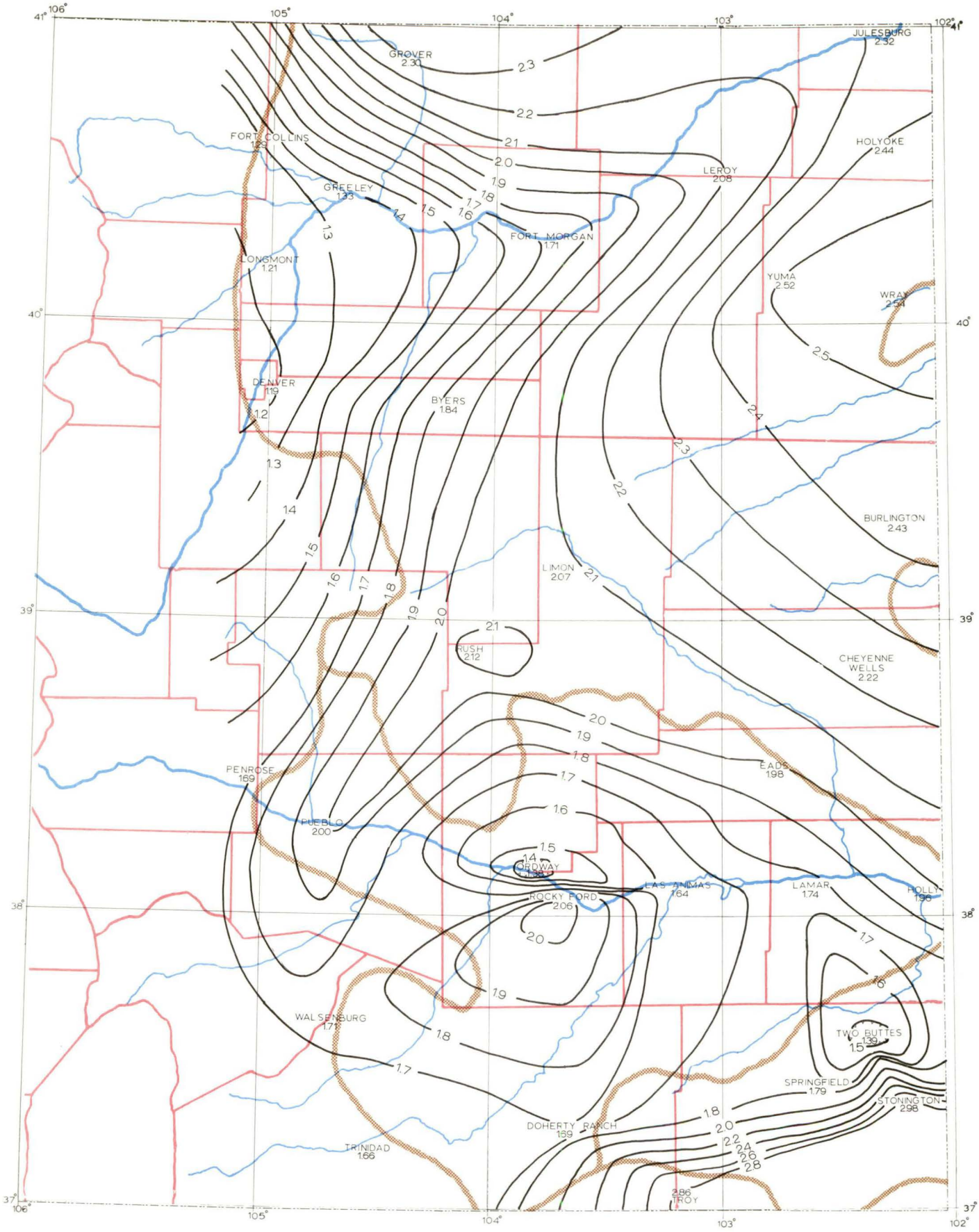

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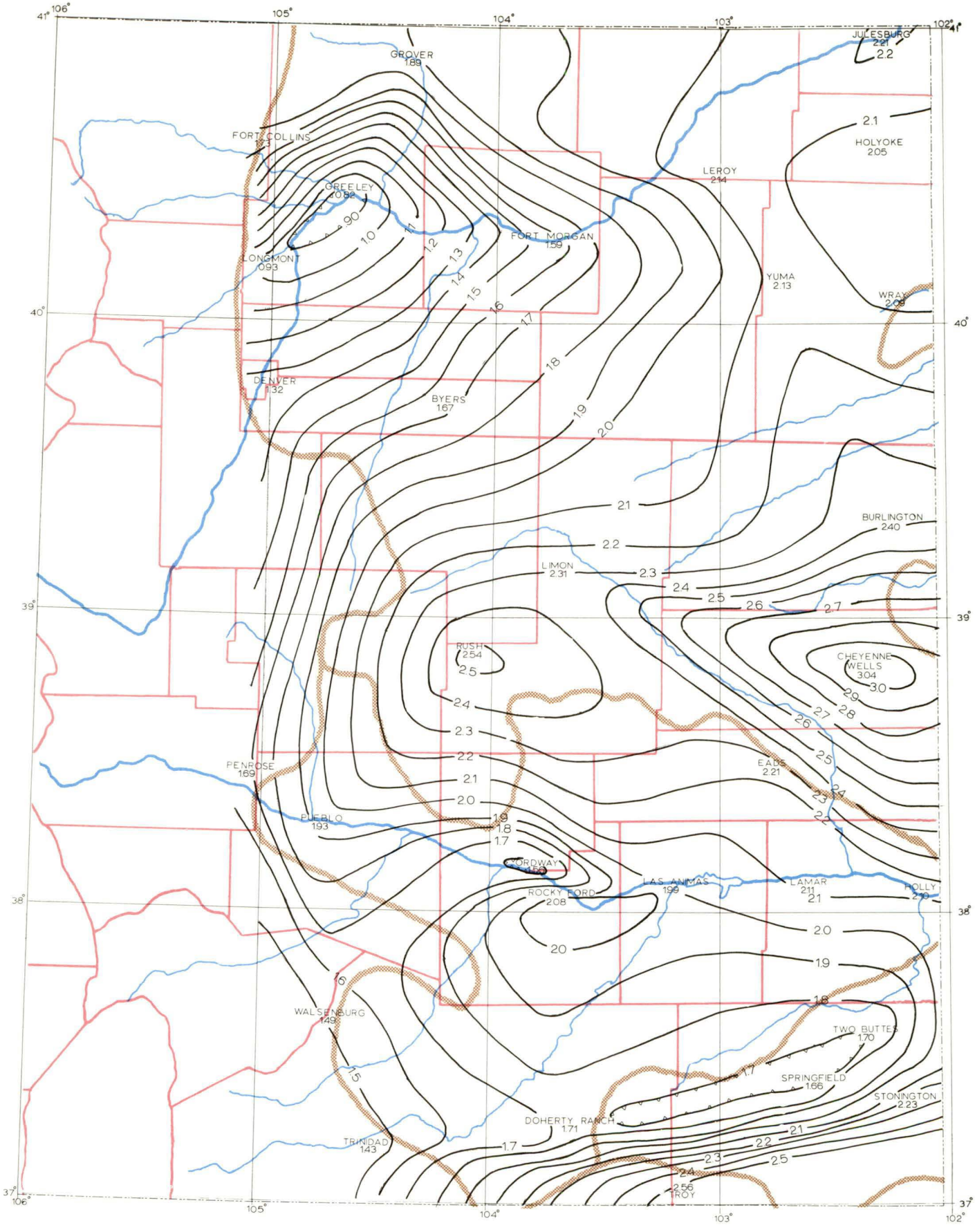

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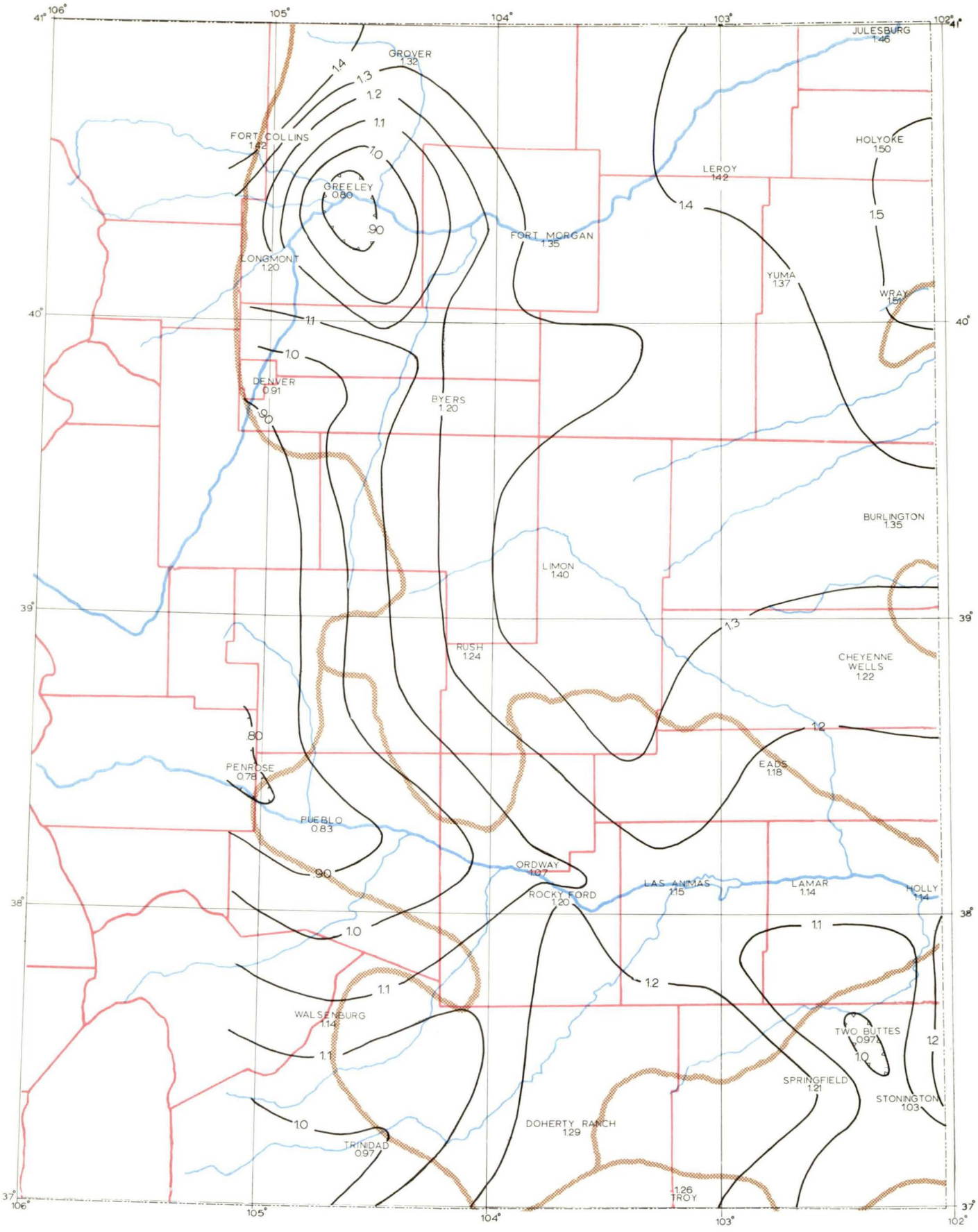

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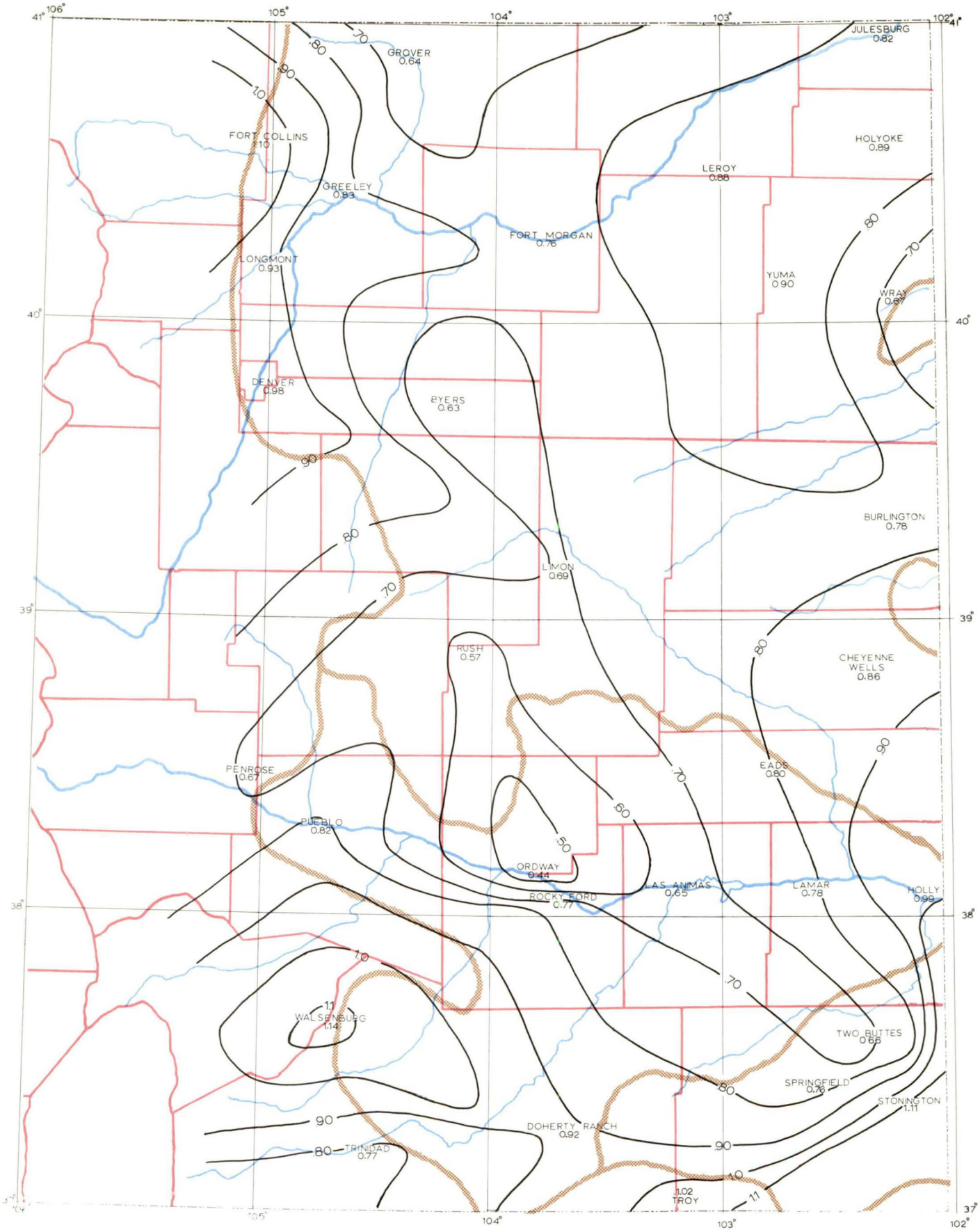

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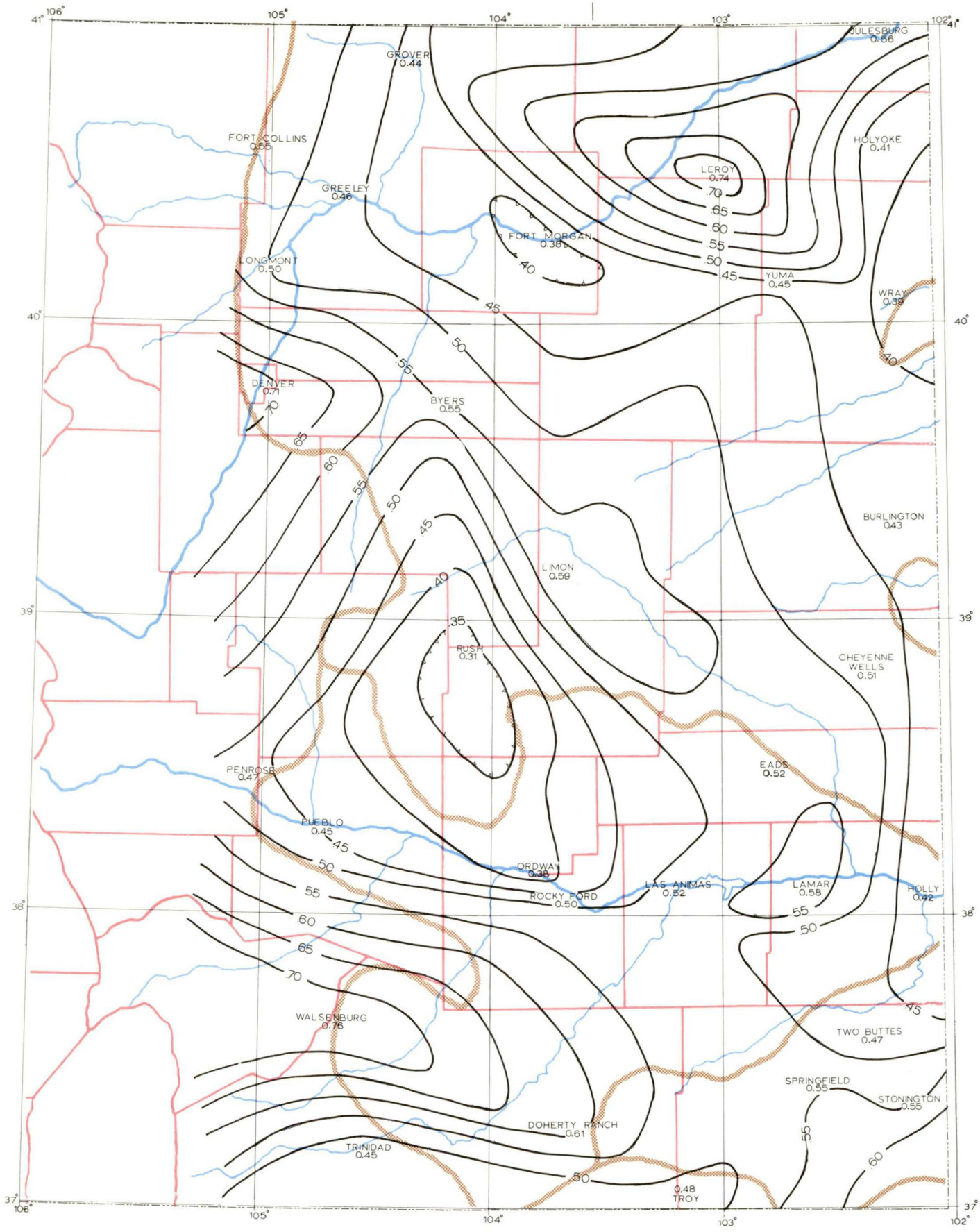

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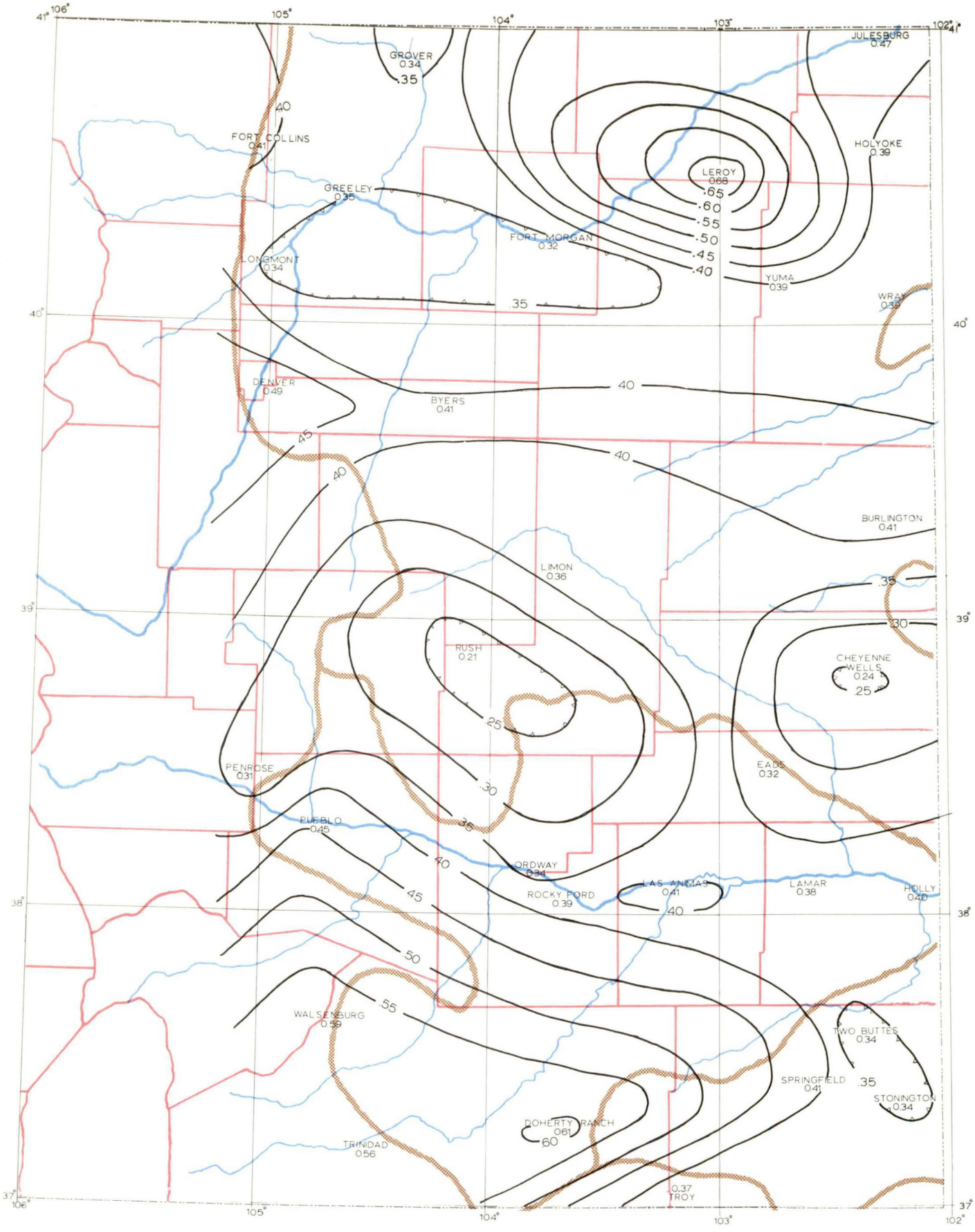

Adjusted Normal Monthly Precipitation Eastern Colorado Month of December