SELECTED CLIMATIC CHARACTERISTICS OF THE SOUTHEASTERN UINTA BASIN, UTAH AND COLORADO

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WATER-RESOURCES INVESTIGATIONS
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Salt Lake City, Utah
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[Plates are in pocket]

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CONVERSION FACTORS

Numbers in this report are given in inch-pound units. For those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below. Multiply the inch-pound unit by the conversion factor to obtain the equivalent metric unit.

Inch pound unit	Abbreviation	Conversion factor	Metric unit
Acre-foot	acre-ft	0.001233	Cubic hectometer
		1,233	Cubic meter
Foot	ft	0.3048	Meter
Inch	in.	2.540	Centimeter
		25.40	Millimeter
Mile	mi	1.609	Kilometer
Square mile	mi^2	2.590	Square kilometer

Air temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$^{o}C = \frac{(^{o}F-32)}{1.8}$$

SELECTED CLIMATIC CHARACTERISTICS OF THE SOUTHEASTERN UINTA BASIN, UTAH AND COLORADO

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ABSTRACT

The southeastern Uinta Basin in Utah and Colorado contains large reserves of oil shale, the mining of which could affect the area's water resources. Climatic characteristics of the area, which were evaluated as one phase of a comprehensive hydrologic study, are presented to help provide the means of evaluating the impact of mining on the area's water resources.

Data for precipitation, air temperature, and evaporation obtained by the U.S. Geological Survey from October 1974 to September 1978 and similar short-term data obtained by other Federal agencies at sites in and near the study area were tabulated and adjusted to a 1941-70 base period. For all sites with incomplete records for 1941-70, the data were adjusted by relating them to concurrent data collected at one or more long-term National Oceanic and Atmospheric Administration sites.

Maps were prepared showing areal variance for normal annual precipitation, normal annual air temperature, and normal annual pan evaporation. The normal annual precipitation ranges from less than 8 inches for altitudes under 5,000 feet to more than 20 inches above 9,000 feet. The normal annual air temperature ranges from 37 to 47 degrees Fahrenheit and varies inversely with altitude and latitude. The normal annual pan evaporation ranges from 42 to 60 inches and varies directly with normal annual air temperature. Although not mapped, it is shown that the normal April 1 water content of the snowpack increases from about 5 inches at 7,000 feet to about 11 inches at 9,000 feet. In addition, the year-to-year and within-year variances of some climatic characteristics are illustrated.

The standard error of estimate when relating normal annual precipitation to altitude is 17 percent, which is equivalent to the standard error when relating the average for 5 years of observed record at a site to the long-term mean at the site. Thus, it appears that additional observation points would not improve areal coverage unless the observation sites were continued for 5 years or longer.

INTRODUCTION

Purpose and scope of the study

The southeastern Uinta Basin in Utah and Colorado contains large reserves of oil shale which could be mined to help meet the Nation's increasing energy needs. In order to provide data needed to evaluate the impact of mining on the area's water resources, the U.S. Geological Survey undertook a comprehensive hydrologic study of the area. Information obtained during the study pertaining to climatic characteristics of the area is given in this report.

The objectives of this report are to: (1) Define the areal and time distribution of precipitation, air temperature, evapotranspiration, and the water content of the April 1 snowpack and (2) describe a climatic monitoring network that would meet future needs of the area.

Data used in this report were obtained from the following sources: Published records from NOAA (National Oceanic and Atmospheric Administration), information provided by the SCS (U.S. Soil Conservation Service), the BLM (U.S. Bureau of Land Management), the BIA (U.S. Bureau of Indian Affairs), and the WRSP (White River Shale Project), and a monitoring network established during 1974 as part of a study by the Geological Survey. Data collected by the Geological Survey consisted of precipitation (totals and intensities), snow (depth and water content), air temperature, and pan evaporation. The data collected by the Geological Survey from October 1974 to September 1978 (water years 1975-78) were related to concurrent data available for long-term NOAA and SCS sites. Using these relations, normal annuals and selected extremes for 1941-70 for climatic characteristics at the long-term sites were used to compute representative normals and extremes for the short-term sites. The computed data, combined with normals published by other agencies for sites in the vicinity of the study area, were used to develop relations of climatic characteristics to altitude and location.

Location and general description of the area

The study area of about 3,000 square miles is shown in figure 1. The Roan Plateau in the southern part of the area and the Uinta Mountains to the north are orographic barriers for much of the summer moisture moving north from the Gulf of Mexico; the Wasatch Range is an orographic barrier for winter moisture moving east from the Pacific Ocean. Land-surface altitudes range from less than 5,000 to more than 9,000 feet above sea level[1]. Deep, narrow canyons dissect the surface of the area, forming large prominent mesas and high flats.

About 56 percent of the land in the study area is owned or administered by the Federal Government, 24 percent is in Indian Trust and a little less than 10 percent is in private ownership. The remainder, which is in State ownership, consists of about four sections per township. The area is sparsely populated, with less than 50 permanent residents. Livestock grazing and the production of oil and gas are the main industries.

Previous studies and acknowledgments

Fields and Adams (1976) provided estimates for average annual air temperature and precipitation for 1941-70 for northeastern Utah. All data collected by the Geological Survey during 1974-78 are summarized in Conroy and Fields (1977) and Conroy (1979, 1980). The U.S. Weather Bureau (1963) prepared a map showing normal annual precipitation for Utah for 1931-60. The

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[1]The datum used in this report is the National Geodetic Vertical Datum of 1929 (NGVD of 1929); a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

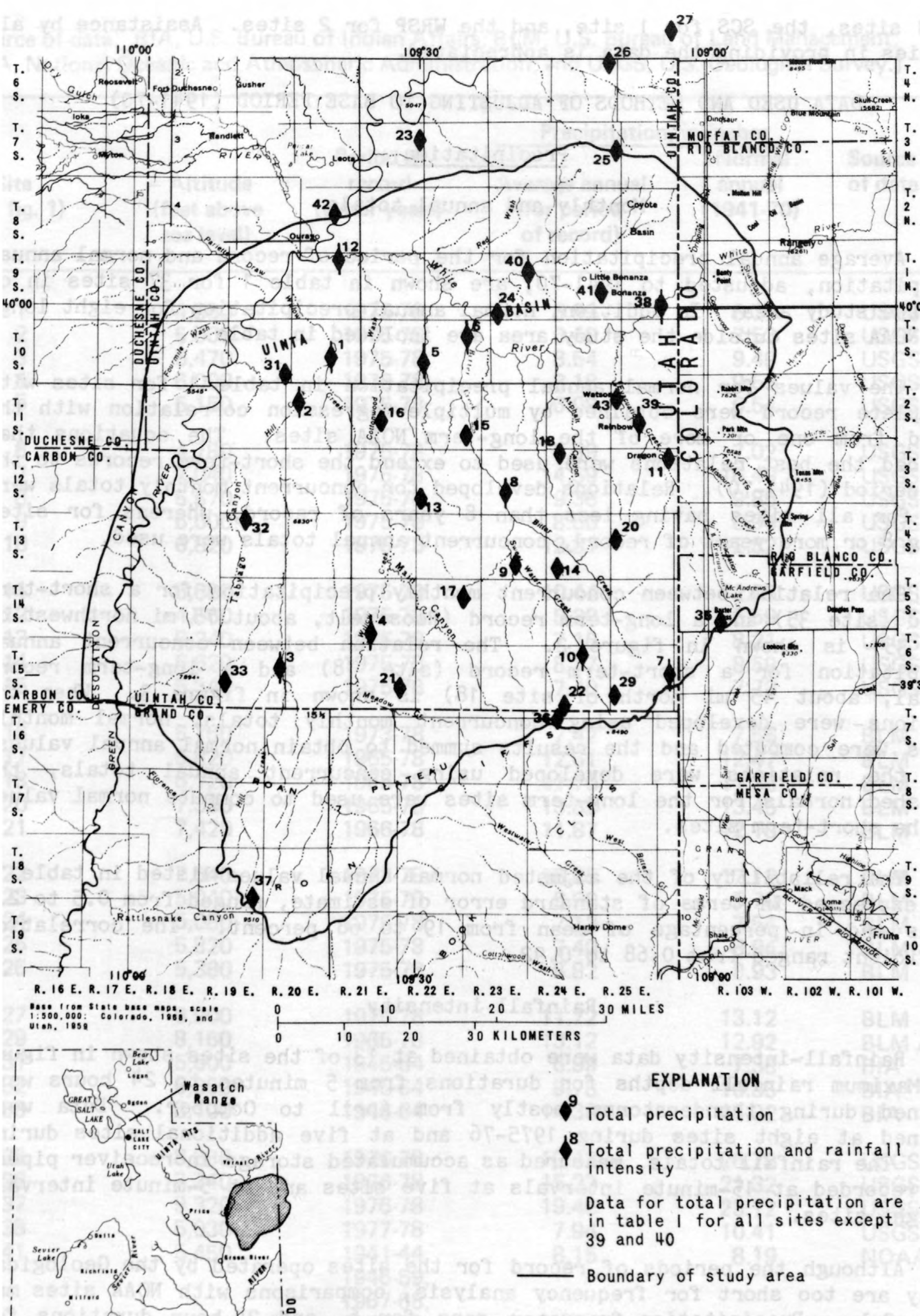

Figure 1.— Location of precipitation-measurement sites.

National Oceanic and Atmospheric Administration (1973) published climatic normals for its long-term sites. The BLM provided data for 12 sites, the BIA for 3 sites, the SCS for 1 site, and the WRSP for 2 sites. Assistance by all agencies in providing the data is appreciated.

DATA USED AND METHODS OF ADJUSTING TO BASE PERIOD (1941-70)

Precipitation

Monthly and annual totals

Average annual precipitation for the period of record and normal annual precipitation, adjusted to 1941-70, are shown in table 1 for 37 sites in or near the study area. In addition, normal annual precipitation for eight long-term NOAA sites outside the study area are included in table 1.

The values for normal annual precipitation in table 1 for sites with incomplete record were obtained by multiple-regression correlation with the record from one or more of the long-term NOAA sites. The equations that provided the best relations were used to extend the short-term records to the base period (1941-70). Relations developed for concurrent monthly totals were used for all sites having less than 8 years of record, whereas for sites having 8 or more years of record, concurrent annual totals were used.

The relation between concurrent monthly precipitation for a short-term record (site 35) and a long-term record (Roosevelt, about 75 mi northwest of site 35) is shown in figure 2. The relation between concurrent annual precipitation for a short-term record (site 18) and a long-term record (Vernal, about 45 mi north of site 18) is shown in figure 3. When the relations were developed using concurrent monthly totals, normal monthly values were computed and the results summed to obtain normal annual values. When the relations were developed using concurrent annual totals, the published normals for the long-term sites were used to compute normal values for the short-term sites.

The reliability of the adjusted normal annual values listed in table 1, when expressed in terms of standard error of estimate, ranged from 0.5 to 2.2 inches and in percentage of mean from 19 to 68 percent. The correlation coefficient ranged from 0.68 to 0.92.

Rainfall intensity

Rainfall-intensity data were obtained at 13 of the sites shown in figure 1. Maximum rainfall depths for durations from 5 minutes to 24 hours were obtained during thunderstorms mostly from April to October. Data were obtained at eight sites during 1975-76 and at five additional sites during 1977. The rainfall totals, measured as accumulated storage in receiver pipes, were recorded at 15-minute intervals at five sites and at 5-minute intervals at eight sites.

Although the periods of record for the sites operated by the Geological Survey are too short for frequency analysis, comparisons with NOAA sites may be useful. Precipitation-frequency maps for 6- and 24-hour durations for return periods from 2 to 100 years and formulas and nomograms for obtaining values for 1-, 2-, 3-, and 12-hour durations are available in Miller, Frederick, and Tracey (1973).

Table 1.—Summary of annual precipitation in and near the study area

[Source of data: BIA, U.S. Bureau of Indian Affairs; BLM, U.S. Bureau of Land Management; NOAA, National Oceanic and Atmospheric Administration; and USGS, U.S. Geological Survey.]

Site (see fig. 1)	Altitude (feet above sea level)	Period of record (water years)	Precipitation, in inches: Average annual (for period of record)	Precipitation, in inches: Normal annual (1941-70)	Source of data
1	4,860	1975-78	5.99	6.34	USGS
2	5,060	1975-78	6.49	7.53	USGS
3	6,470	1975-78	8.54	9.49	USGS
4	6,000	1975-78	8.18	9.53	USGS
5	5,150	1975-78	6.08	6.54	USGS
6	4,780	1975-78	6.39	7.02	USGS
7	7,040	1975-78	14.59	16.49	USGS
8	5,570	1975-78	9.36	9.85	USGS
9	6,000	1975-78	8.60	8.94	USGS
10	6,820	1975-78	12.31	12.82	USGS
11	5,680	1975-78	10.44	12.05	USGS
12	4,660	1975-78	5.20	5.59	USGS
13	6,240	1975-78	7.16	8.21	USGS
14	6,620	1975-78	8.17	8.59	USGS
15	5,340	1975-78	7.40	7.72	USGS
16	5,760	1973-78	7.42	7.66	BLM
17	6,820	1965-78	12.61	12.47	BLM
18	6,120	1965-78	11.70	11.36	BLM
20	7,330	1965-78	13.63	13.45	BLM
21	7,420	1966-78	11.87	12.18	BLM
22	7,640	1973-78	16.65	17.12	BLM
23	5,040	1975-78	5.50	5.70	BLM
24	5,080	1975-78	7.12	7.54	BLM
25	5,820	1975-78	7.40	8.94	BLM
26	5,380	1975-78	8.82	8.93	BLM
27	6,900	1975-78	11.72	13.12	BLM
29	8,160	1965-78	13.12	12.92	BLM
31	5,500	1945-64	6.99	7.38	BIA
32	6,350	1945-64	9.78	10.35	BIA
33	8,100	1946-64	14.36	15.32	BIA
35	8,330	1976-78	19.43	26.78	USGS
36	7,740	1976-78	15.27	21.32	USGS
37	9,320	1976-78	19.46	23.12	USGS
38	5,030	1977-78	7.94	10.41	USGS
41	5,450	1941-44, 1946-59, 1967-68, 1970-78	8.15	8.19	NOAA

Table 1.—Summary of annual precipitation in and near the study area—Continued

Site (see fig. 1)	Altitude (feet above sea level)	Period of record (water years)	Precipitation, in inches: Average annual (for period of record)	Precipitation, in inches: Normal annual (1941-70)	Source of data
42	4,670	1956-78	6.33	6.75	NOAA
43	6,210	1912-37	11.36	10.91	NOAA
Duchesne, Utah[1]	5,510	—	—	8.71	NOAA
Fort Duchesne, Utah[2]	4,990	—	—	7.23	NOAA
Grand Junction, Colo.[1]	4,860	—	—	8.41	NOAA
Green River, Utah[1]	4,070	—	—	6.11	NOAA
Jensen, Utah[1]	4,720	—	—	7.94	NOAA
Myton, Utah[2]	5,030	—	—	6.80	NOAA
Roosevelt, Utah[2]	5,090	—	—	7.44	NOAA
Vernal, Utah[1]	5,280	—	—	7.82	NOAA

[1] Published normals are given by National Oceanic and Atmospheric Administration (1973). Site is not in study area nor shown in figure 1.

[2] Published normals are given by National Oceanic and Atmospheric Administration (1973). Site is not in study area.

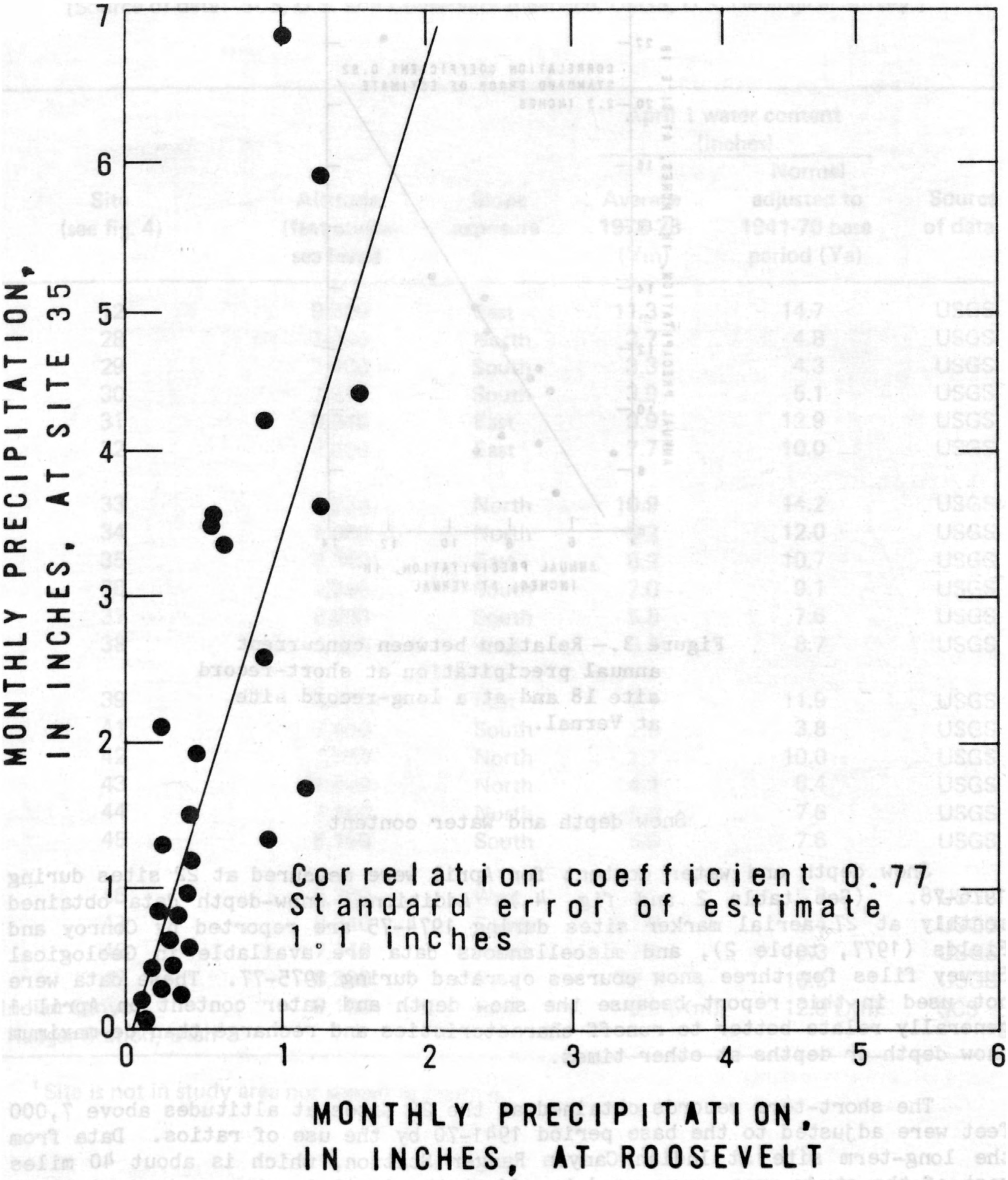

Figure 2.— Relation between concurrent monthly precipitation at short-record site 35 and at a long-record site at Roosevelt.

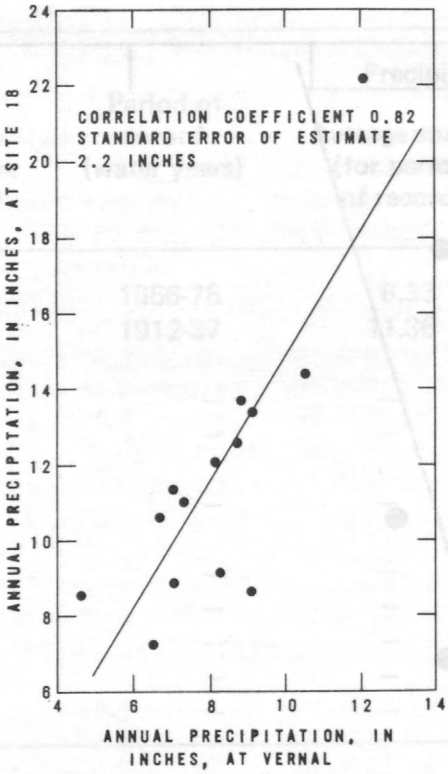

Figure 3.— Relation between concurrent annual precipitation at short-record site 18 and at a long-record site at Vernal.

Snow depth and water content

Snow depth and water content for April were measured at 22 sites during 1976-78. (See table 2 and fig. 4.) Additional snow-depth data obtained monthly at 27 aerial marker sites during 1974-75 are reported by Conroy and Fields (1977, table 2), and miscellaneous data are available in Geological Survey files for three snow courses operated during 1975-77. These data were not used in this report because the snow depth and water content on April 1 generally relate better to runoff characteristics and recharge than do maximum snow depth or depths at other times.

The short-term records obtained at the 22 sites at altitudes above 7,000 feet were adjusted to the base period 1941-70 by the use of ratios. Data from the long-term site at Indian Canyon Ranger Station, which is about 40 miles west of the study area, were used to adjust the April 1 water content at these 22 sites (table 2). The April 1 water-content data for Indian Canyon Ranger Station were obtained from the SCS (Bob L. Whaley, written commun., 1979).

The ratio method assumes that the ratio of concurrent annual averages is directly proportional to the ratio of the respective 1941-70 average annual

Table 2.—Summary of April 1 water content of snowpack in and near the study area

[Source of data: SCS, U.S. Soil Conservation Service; USGS, U.S. Geological Survey.]

Site (see fig. 4)	Altitude (feet above sea level)	Slope exposure	April 1 water content (inches)		Source of data
			Average 1976-78 (Ym)	Normal adjusted to 1941-70 base period (Ya)	
12	9,320	East	11.3	14.7	USGS
28	7,040	North	3.7	4.8	USGS
29	7,400	South	3.3	4.3	USGS
30	7,820	South	3.9	5.1	USGS
31	9,040	East	9.9	12.9	USGS
32	8,400	East	7.7	10.0	USGS
33	8,230	North	10.9	14.2	USGS
34	7,800	North	9.2	12.0	USGS
35	8,340	East	8.2	10.7	USGS
36	9,280	South	7.0	9.1	USGS
37	8,800	South	5.8	7.6	USGS
38	8,560	West	6.7	8.7	USGS
39	8,700	East	9.1	11.9	USGS
41	7,460	South	2.9	3.8	USGS
42	7,540	North	7.7	10.0	USGS
43	7,480	North	4.9	6.4	USGS
44	7,160	North	5.8	7.6	USGS
45	8,160	South	5.8	7.6	USGS
46	8,300	West	4.1	5.3	USGS
47	8,340	South	7.2	9.4	USGS
48	7,740	North	7.9	10.3	USGS
49	8,330	East	12.7	16.5	USGS
Indian Canyon Ranger Station, Utah[1]	9,100	East	9.9 (Xm)	12.9 (Xn)	SCS

[1] Site is not in study area nor shown in figure 4.

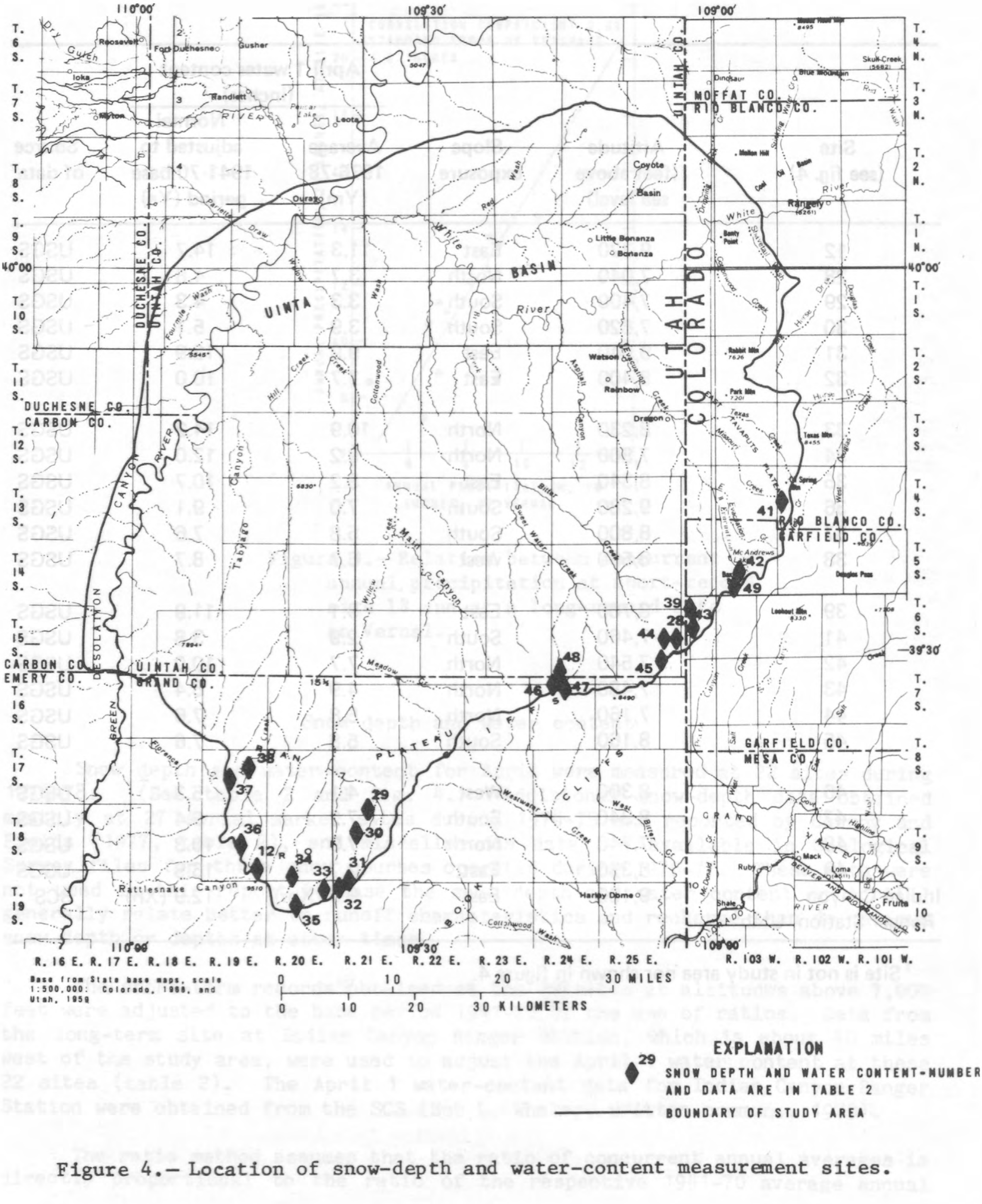

Figure 4.—Location of snow-depth and water-content measurement sites.

values. The following equation was used to estimate the normal April 1 water content at the 22 sites:

$$Ya = \frac{Ym}{Xm} \times Xn \qquad (1)$$

where

Ya is the adjusted average for the short-term record, representing the 1941-70 base period, in inches;

Ym is the average measured for the short-term site, in inches;

Xm is the average measured for the concurrent record at a long-term site, in inches; and

Xn is the normal or average for the period 1941-70 for the long-term site, in inches.

Because Xn = 12.9 and Xm = 9.9 (table 2), the equation simplifies to:

$$Ya = \frac{12.9}{9.9} Ym = 1.30 Ym$$

Air temperature

Continuous records of air temperature were obtained at seven sites in the study area during 1975-78 and intermittent records were obtained at one site during 1975-76. (See table 3 and fig. 5.) Because equipment was moved to new sites periodically, only about 1 year of record was obtained at each of the continuous-record sites. In addition, daily temperatures were measured at Bonanza and Ouray (sites 9 and 10, table 3) by NOAA for most days since 1966. Other miscellaneous temperature observations were obtained at eight sites by the WRSP and are summarized by VTN Colorado, Inc. (1977).

The daily-mean air temperatures for the eight sites operated by the Geological Survey were related to concurrent data obtained at NOAA sites for which normal annual temperatures were available for the 1941-70 period. The long-term NOAA sites were Duchesne, Roosevelt, Vernal, and Grand Junction, Colo. (about 40 mi southeast of the study area). The relation between concurrent daily air temperatures obtained for site 4 and those published for Duchesne (National Oceanic and Atmospheric Administration, 1973), which is about 70 miles northwest of site 4, is shown in figure 6.

The reliability of the adjusted normal annual values computed from the relation and listed in table 3 when expressed in terms of standard error of estimate, ranged from 2.6 to 5.8 degrees Fahrenheit and in percentage of mean from 5 to 10 percent. The correlation coefficient ranged from 0.93 to 0.99.

Evaporation

Evaporation data were obtained at a class A pan from May to October during 1975 and 1976 (site 1 in fig. 7 and table 4). In addition to pan evaporation, air and water temperatures, wind movement, relative humidity, precipitation, and total incoming solar radiation were measured. Additional evaporation data were obtained during the same period at two sites (sites 2 and 3 in fig. 7) operated by the WRSP.

Table 3.—Summary of air temperature in and near the study area

[Source of data: NOAA, National Oceanic and Atmospheric Administration; USGS, U.S. Geological Survey.]

Site (see fig. 5)	Altitude (feet above sea level)	Latitude (degrees)	Type of record	Normal annual air temperature, 1941-70 (degrees Fahrenheit)	Source of data
1	4,860	39.94°N	Continuous	48.0	USGS
2	5,570	39.75	do.	44.0	USGS
3	8,330	39.58	do.	36.5	USGS
4	9,320	39.21	do.	35.0	USGS
5	6,000	39.57	do.	45.0	USGS
6	6,820	39.54	do.	41.5	USGS
7	7,040	39.52	do.	42.0	USGS
8	7,900	39.51	Intermittent	41.5	USGS
9	5,450	40.02	Daily	48.0	NOAA
10	4,670	40.13	do.	46.0	NOAA
Duchesne, Utah[1]	5,510	40.17	do.	[2]45.5	NOAA
Grand Junction, Colo.[1]	4,860	39.12	do.	[2]52.5	NOAA
Roosevelt, Utah[1]	5,090	40.30	do.	[2]46.5	NOAA
Vernal, Utah[1]	5,280	40.45	do.	[2]44.5	NOAA

[1] Site is not in study area nor shown in figure 5.

[2] Rounded to nearest 0.5°F.

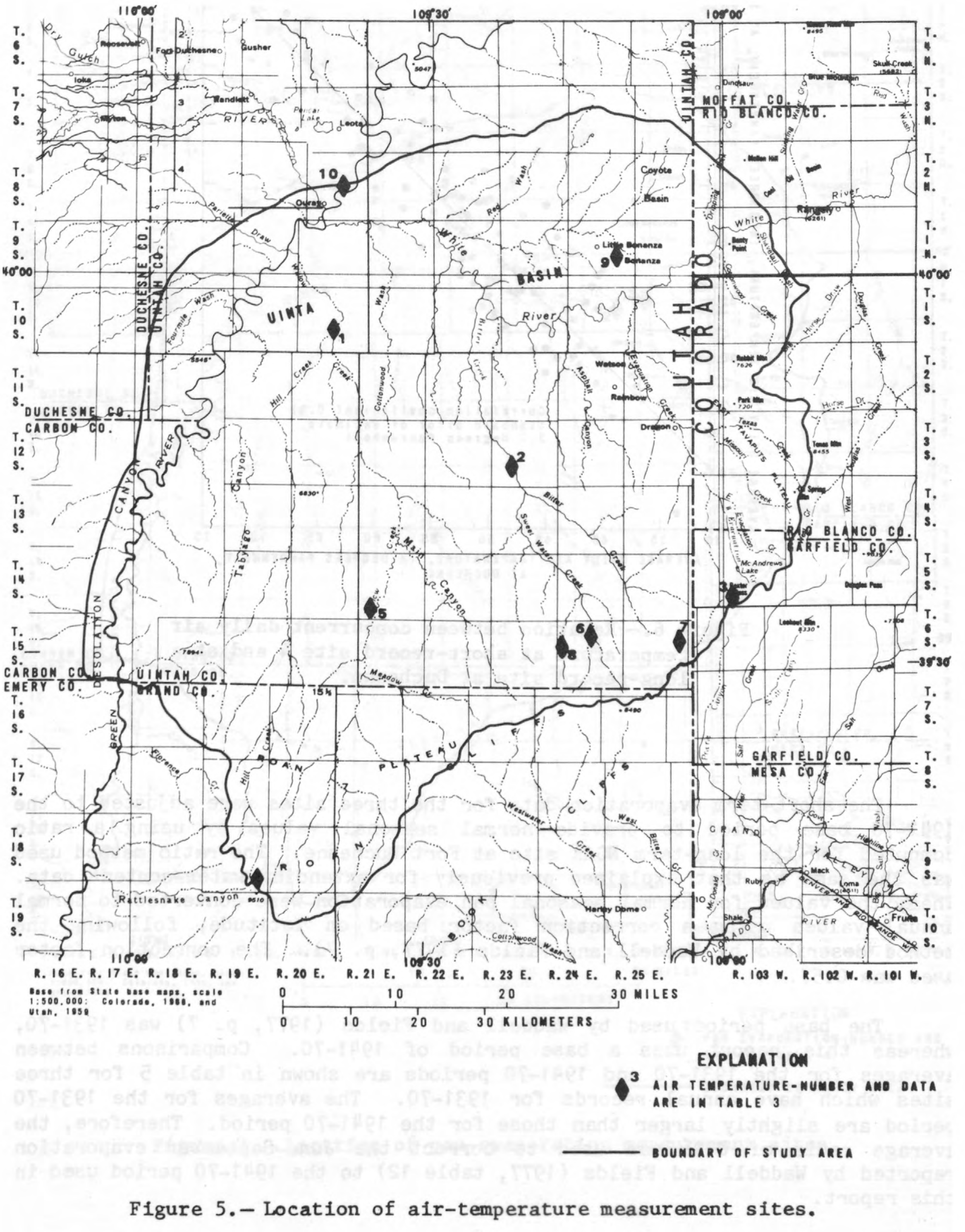

Figure 5.— Location of air-temperature measurement sites.

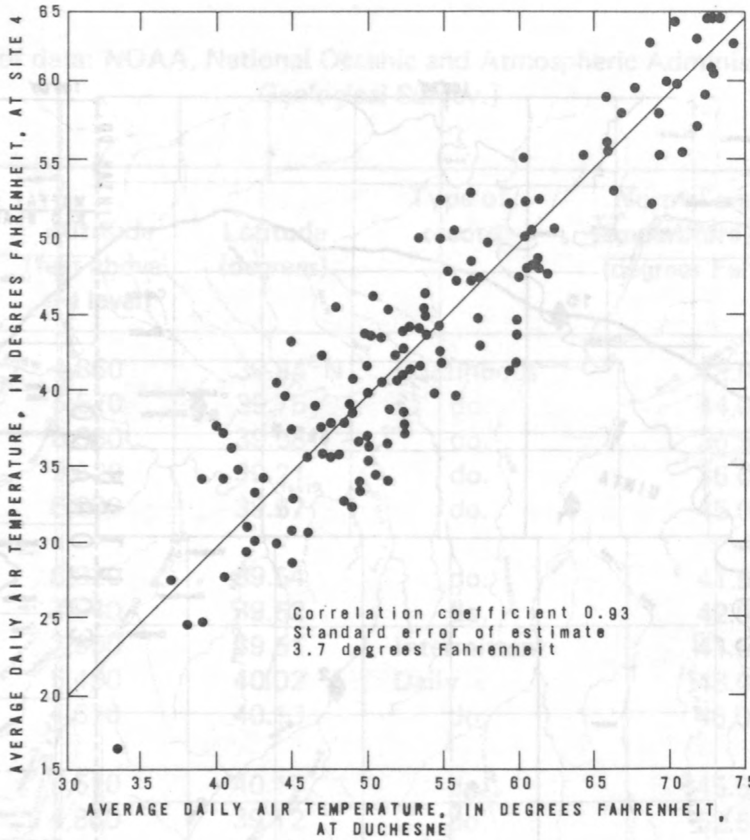

Figure 6.— Relation between concurrent daily air temperature at short-record site 4 and at a long-record site at Duchesne.

The short-term evaporation data for the three sites were adjusted to the 1941-70 base period to provide normal seasonal values by using a ratio computed for the long-term NOAA site at Fort Duchesne. The ratio method used was the same as that explained previously for extending water-content data. Then, the values for normal seasonal pan evaporation were converted to normal annual values using a correction factor based on latitude, following the method described by Waddell and Fields (1977, p. 7). The correction factor used was 0.57.

The base period used by Waddell and Fields (1977, p. 7) was 1931-70, whereas this report uses a base period of 1941-70. Comparisons between averages for the 1931-70 and 1941-70 periods are shown in table 5 for three sites which have annual records for 1931-70. The averages for the 1931-70 period are slightly larger than those for the 1941-70 period. Therefore, the average ratio of 0.96 was used to correct the June-September evaporation reported by Waddell and Fields (1977, table 12) to the 1941-70 period used in this report.

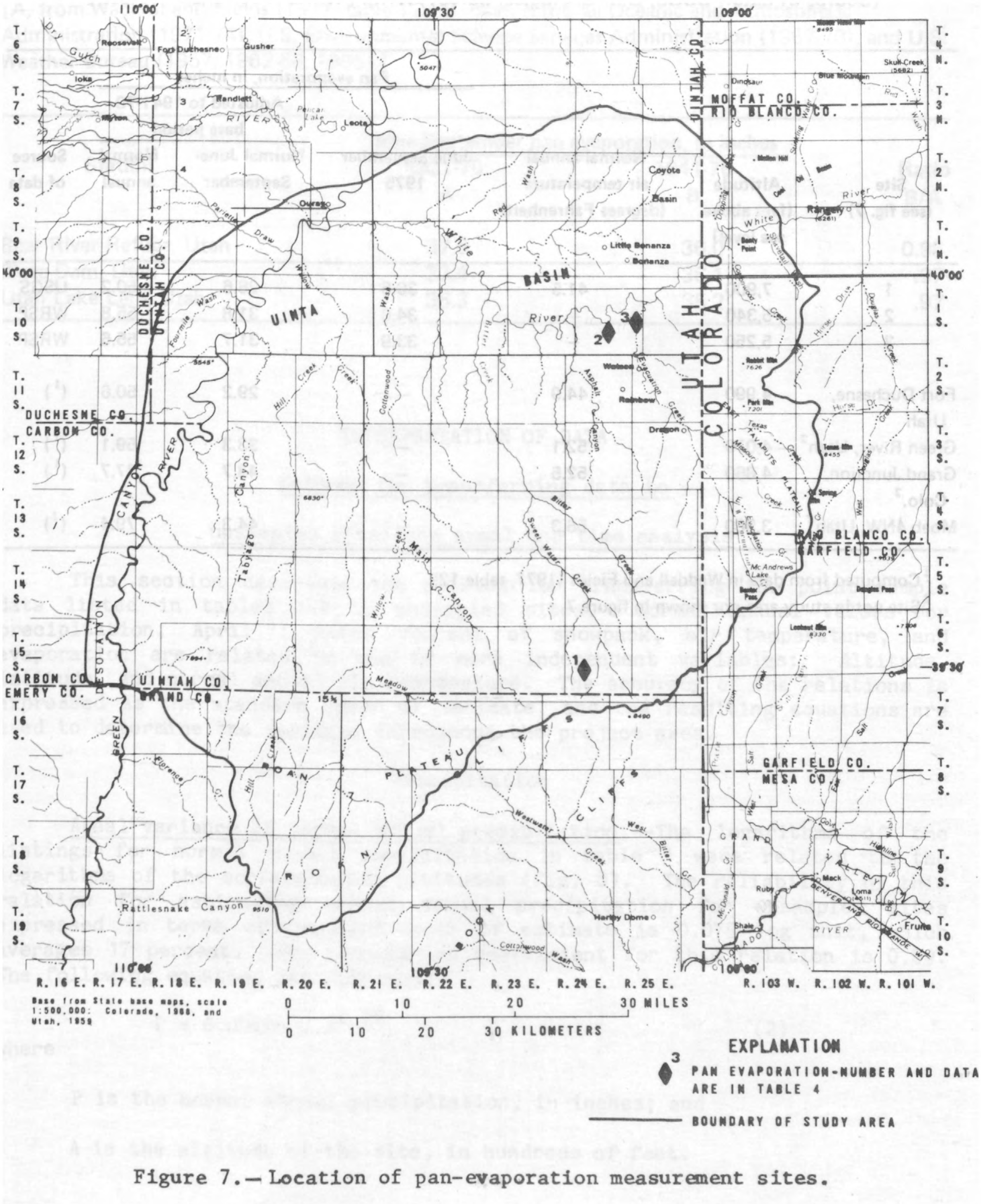

Figure 7.—Location of pan-evaporation measurement sites.

Table 4.–Summary of pan evaporation in and near the study area

[Source of data: USGS, U.S. Geological Survey; WRSP, White River Shale Project.]

Site (see fig. 7)	Altitude (feet above sea level)	Normal annual air temperature (degrees Fahrenheit)	Pan evaporation, in inches: June-September 1975	Pan evaporation, in inches: Adjusted to 1941-70 base period: Normal June-September	Pan evaporation, in inches: Adjusted to 1941-70 base period: Normal annual	Source of data
1	7,900	41.5	30.6	28.6	50.2	USGS
2	5,340	–	34.0	31.8	55.8	WRSP
3	5,250	–	33.9	31.7	55.6	WRSP
Fort Duchesne, Utah	4,990	44.9	–	29.2	50.6	([1])
Green River, Utah[2]	4,070	52.1	–	33.3	59.1	([1])
Grand Junction, Colo.[2]	4,860	52.5	–	43.7	77.7	([1])
Moab 4NW, Utah[2]	3,960	56.3	–	44.3	79.4	([1])

[1] Computed from data in Waddell and Fields (1977, table 12).

[2] Site not in study area nor shown in figure 7.

Table 5.—Comparisons between pan evaporation for different base periods

[A, from Waddell and Fields (1977, table 12); B, from National Oceanic and Atmospheric Administration (1971-74), U.S. Environmental Science Services Administration (1967-70), and U.S. Weather Bureau (1957, 1962-66, 1965).]

Station	June-September pan evaporation, in inches 1931-70 A	1941-70 B	Ratio B/A
Bear River Refuge, Utah	37.6	36.0	0.96
Piute Dam, Utah	37.4	36.1	.97
Utah Lake Lehi, Utah	36.3	35.2	.97

INTERPRETATION OF DATA

Methods for transferring data to unsampled sites and areal and time analysis

This section describes the methods for transferring the point sample data listed in tables 1-4 to unsampled sites. Normal annual values for precipitation, April 1 water content of snowpack, air temperature, and evaporation are related to one or more independent variables: Altitude, latitude, and normal annual air temperature. The accuracy of the relations is expressed as the standard error of estimate, and the resulting equations are used to determine the variance throughout the project area.

Precipitation

Areal variance of normal annual precipitation.--The logarithms of the listings for normal annual precipitation in table 1 were related to the logarithms of the corresponding altitudes (fig. 8). The reliability of this relation for estimating normal annual precipitation for unsampled sites expressed in terms of standard error of estimate is 0.075 log unit, which averages 17 percent. The correlation coefficient for this relation is 0.89. The following equation was obtained:

$$P = 0.00804 \times A^{1.74} \quad (2)$$

where

P is the normal annual precipitation, in inches; and

A is the altitude of the site, in hundreds of feet.

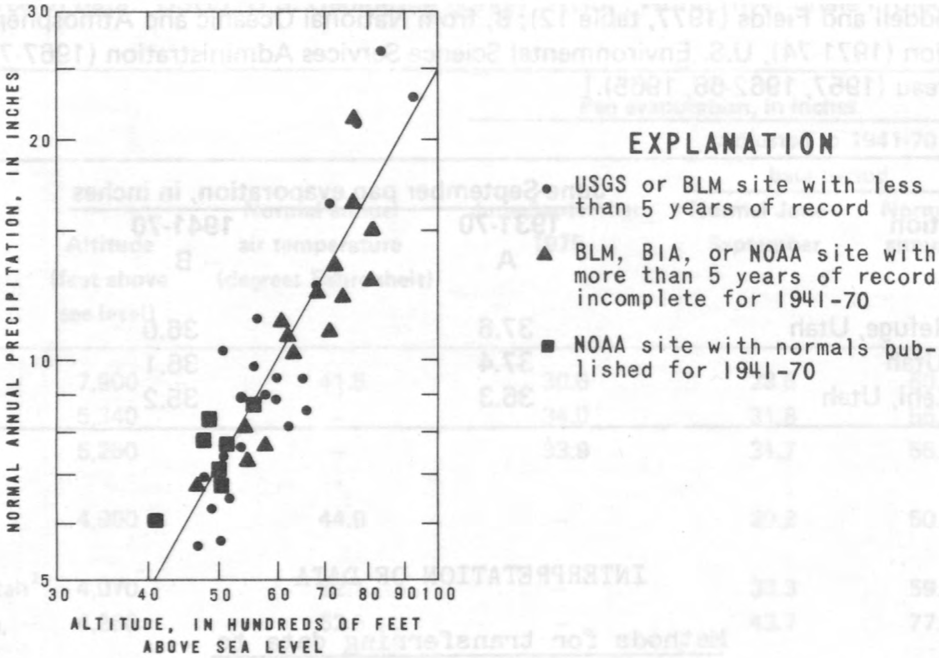

Figure 8.— Relation of normal annual precipitation to altitude.

The relation between normal annual precipitation and altitude (fig. 8) was used with a topographic map to construct lines of equal normal annual precipitation for the study area (pl. 1). The lines generally were drawn near the center of bands of altitude, but adjustments were made where narrow canyons are deeply incised. The map needs to be used with caution for areas where the topography changes drastically within short distances. In such areas, the user needs to compute annual values, using the relation shown in figure 8 (equation 2), and compare with plate 1. As shown on plate 1, the normal annual precipitation ranges from less than 8 inches in the northwest part of the area, where altitudes are less than 5,000 feet, to more than 20 inches in the headwaters of Willow Creek, where altitudes can exceed 9,000 feet. The average precipitation, weighted by area, is 11.0 inches, which is equivalent to 1.8 million acre-feet per year for the entire study area.

Time variance of monthly and annual precipitation.--Normal seasonal variance of precipitation at four representative sites is illustrated in figure 9. The precipitation is well distributed through the year, but the greatest monthly precipitation generally occurs during June-October and the least during January-March.

In addition to varying seasonally, precipitation varies considerably from year to year. The annual variation of precipitation from 1941 to 1978 for site 41 is illustrated in figure 10. A minimum of 4.14 inches was recorded during 1958 and a maximum of 13.77 inches during 1941.

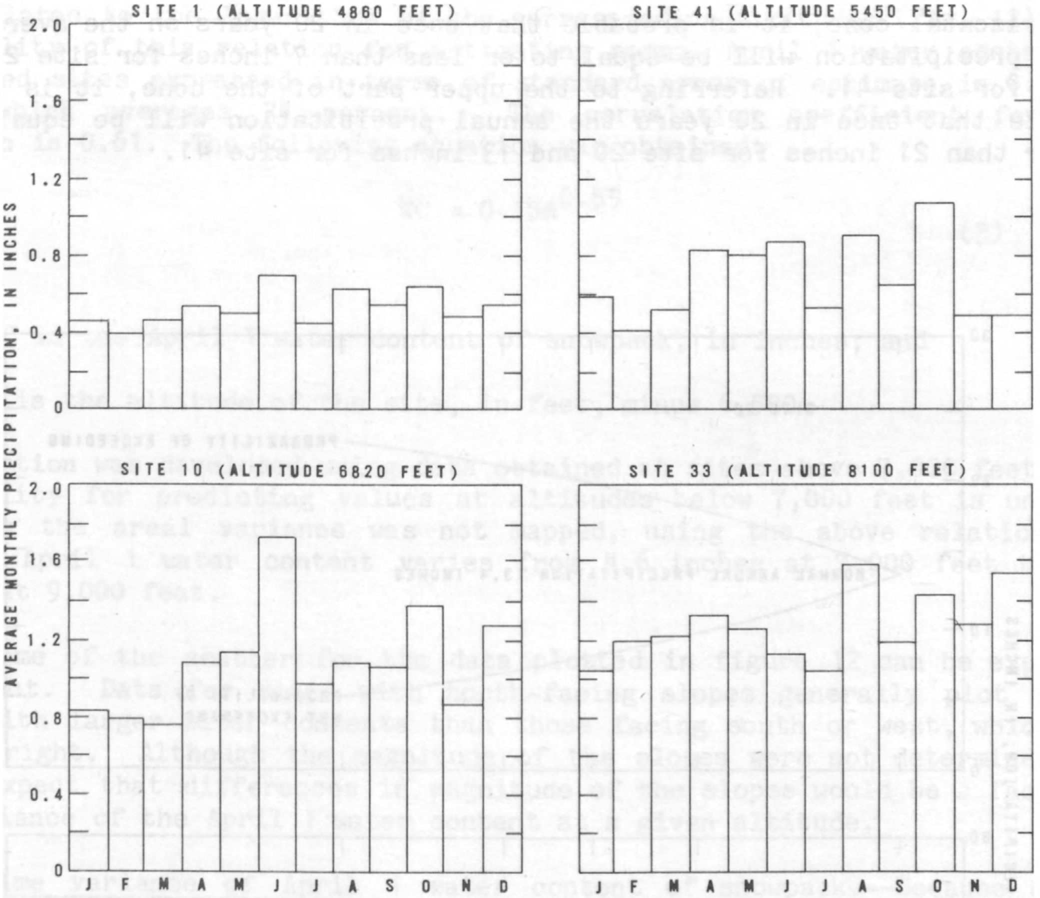

Figure 9.— Seasonal variations in precipitation at four representative sites, 1941-70. (See figure 1 for locations.)

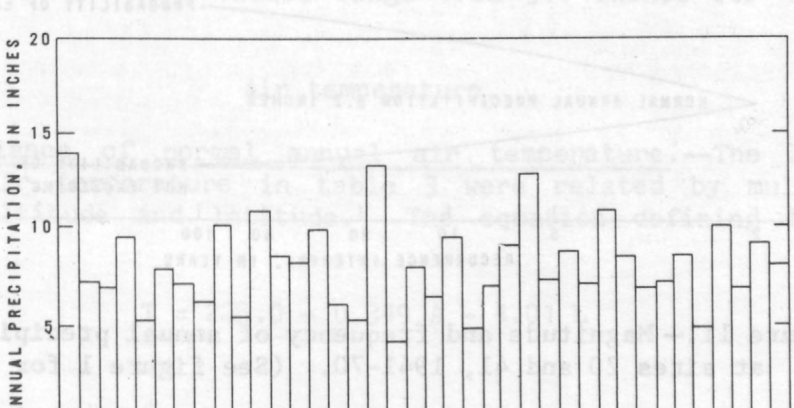

Figure 10.— Variance in annual precipitation at site 41, 1941-78. (Gaps in record estimated by correlation with data available for Vernal.)

The magnitude and frequency of the annual precipitation for sites 20 and 41 are illustrated in figure 11. For example, referring to the lower part of the horizontal cone, it is probable that once in 20 years on the average the annual precipitation will be equal to or less than 7 inches for site 20 and 5 inches for site 41. Referring to the upper part of the cone, it is equally probable that once in 20 years the annual precipitation will be equal to or greater than 21 inches for site 20 and 13 inches for site 41.

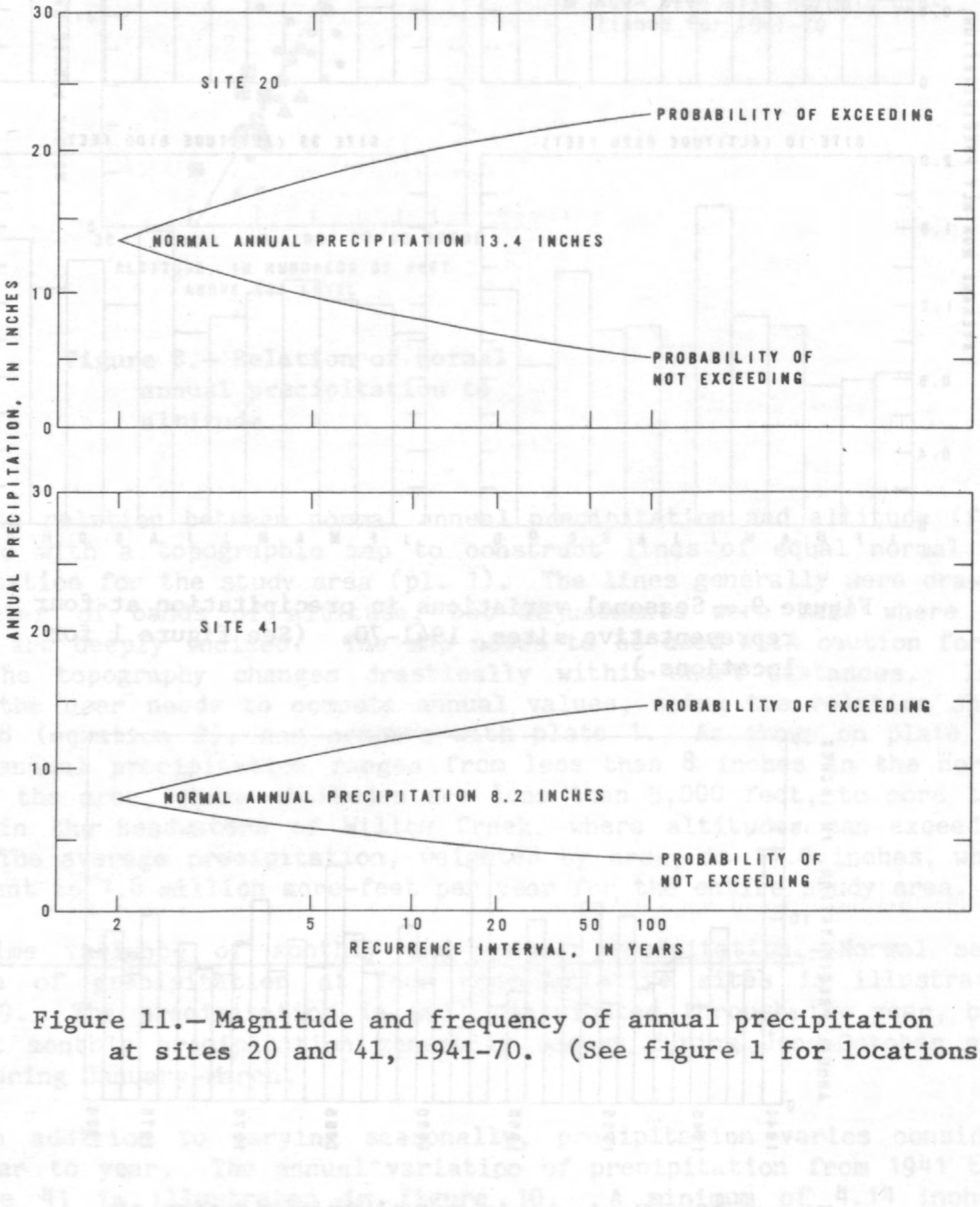

Figure 11.— Magnitude and frequency of annual precipitation at sites 20 and 41, 1941-70. (See figure 1 for locations.)

Areal variance of normal April 1 water content of snowpack.--The logarithms of the listings for adjusted normal April 1 water content in table 2 were related to the logarithms of the corresponding altitudes (fig. 12). The reliability of this relation for estimating normal April 1 water content for unsampled sites expressed in terms of standard error of estimate is 0.15 log unit, which averages 34 percent. The correlation coefficient for this relation is 0.61. The following equation was obtained:

$$WC = 0.15A^{0.55} \tag{3}$$

where

WC is the April 1 water content of snowpack, in inches; and

A is the altitude of the site, in feet, minus 6,500.

The equation was developed using data obtained at sites above 7,000 feet. The reliability for predicting values at altitudes below 7,000 feet is unknown. Although the areal variance was not mapped, using the above relation, the average April 1 water content varies from 4.6 inches at 7,000 feet to 11.1 inches at 9,000 feet.

Some of the scatter for the data plotted in figure 12 can be explained by aspect. Data for sites with north-facing slopes generally plot to the left, with larger water contents than those facing south or west, which plot to the right. Although the magnitude of the slopes were not determined, one would expect that differences in magnitude of the slopes would be a factor in the variance of the April 1 water content at a given altitude.

Time variance of April 1 water content of snowpack.--Because only 3 years of data are available for the sites within the project area, the year-to-year variance in the April 1 water content for these sites is not well defined. However, the variance for the SCS site at the Indian Canyon Ranger Station is considered to be representative, and figure 13 illustrates that variance for 1941-78. The values range from 3.1 inches for 1977 to 25.7 inches for 1952.

Air temperature

Areal variance of normal annual air temperature.--The listings for normal annual air temperature in table 3 were related by multiple-linear regression to altitude and latitude. The equation defining the relation follows:

$$T = 225.0 - 0.349\ A - 4.01\ L \tag{4}$$

where

T is the normal annual air temperature, in degrees Fahrenheit;

A is the altitude, in hundreds of feet; and

L is the latitude, in degrees.

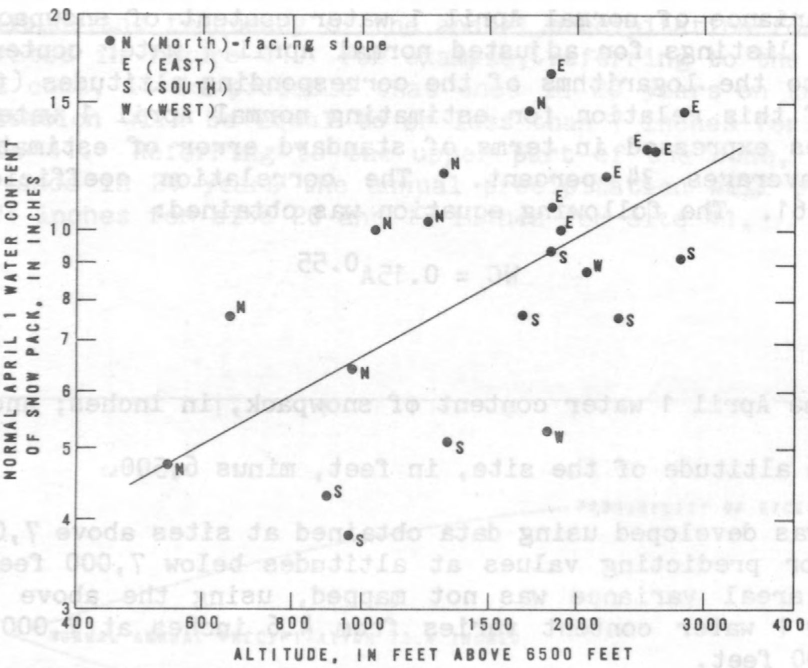

Figure 12.— Relation of normal April 1 water content of snowpack to altitude.

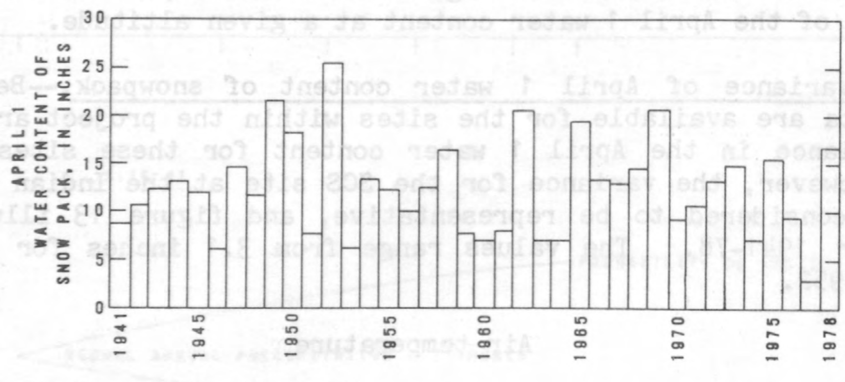

Figure 13.— Variance of April 1 water content of snowpack at Indian Canyon Ranger Station, 1941-78.

The reliability of this relationship for estimating normal annual air temperature for unsampled sites is shown in figure 14, which is a plot of the normals listed in table 3 against the normals calculated by the equation given above. The reliability of the relation shown in figure 14 expressed in terms of standard error of estimate is 1.5 degrees Fahrenheit or 4 percent of the average temperature. The correlation coefficient is 0.95. At 39.5 degrees latitude, the equation defines a lapse rate of 3.5 degrees Fahrenheit per 1,000 feet, which compares with an average decrease of 3.6 degrees Fahrenheit for most areas of the United States (Linsley and others, 1958, p. 11).

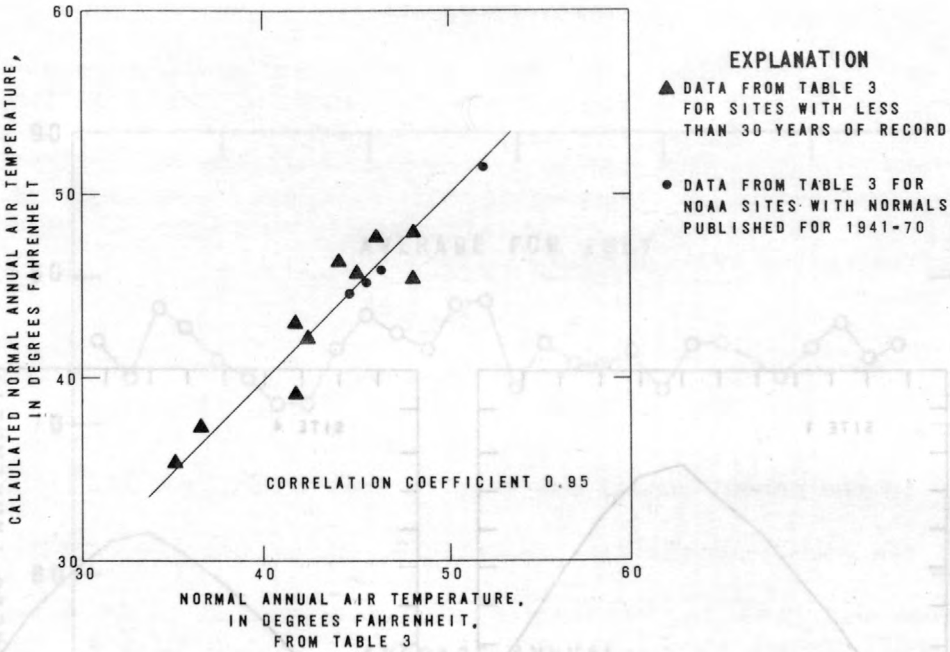

Figure 14.— Relation between calculated and normal annual air temperature, 1941-70.

The above equation was used with a topographic map to construct lines of equal normal annual air temperature for the study area (pl. 2). Values were computed at grid points that averaged 5 miles apart, and the lines of equal normal annual air temperature generally were constructed by interpolation between grid points. However, adjustments were made where the topography changes drastically within short distances. As shown on plate 2, the normal annual air temperature ranges from about 47 degrees Fahrenheit near the mouth of the White River to about 37 degrees Fahrenheit on Post Canyon Ridge where altitudes exceed 8,800 feet.

Time variance of monthly and annual air temperatures at selected sites.--The seasonal variance of air temperature for four representative sites in the study area is illustrated in figure 15. The normal January temperature for site 9, which is at an altitude of 5,450 feet, is 17 degrees Fahrenheit whereas for July it is 75 degrees Fahrenheit. At site 4, which is at an altitude of 9,320 feet, the normal January temperature is 8 degrees Fahrenheit whereas for July it is 59 degrees Fahrenheit. Thus, the difference in temperatures between these two sites is considerably larger during the summer than during the winter. This results from temperature inversions that are common during the winter months and tend to equalize temperatures throughout the area.

The annual variance of air temperature at site 9 for the entire year and for January and July for 1951-78 is illustrated in figure 16. During the 28-year period, the annual variance was 9.5 degrees Fahrenheit, and the variances for January and July were 22.5 and 6.5 degrees Fahrenheit. This probably was due to the percentage of days with cloud cover. For example, during some years cloud cover prevails for the entire month of January, whereas during others, clear skies prevail.

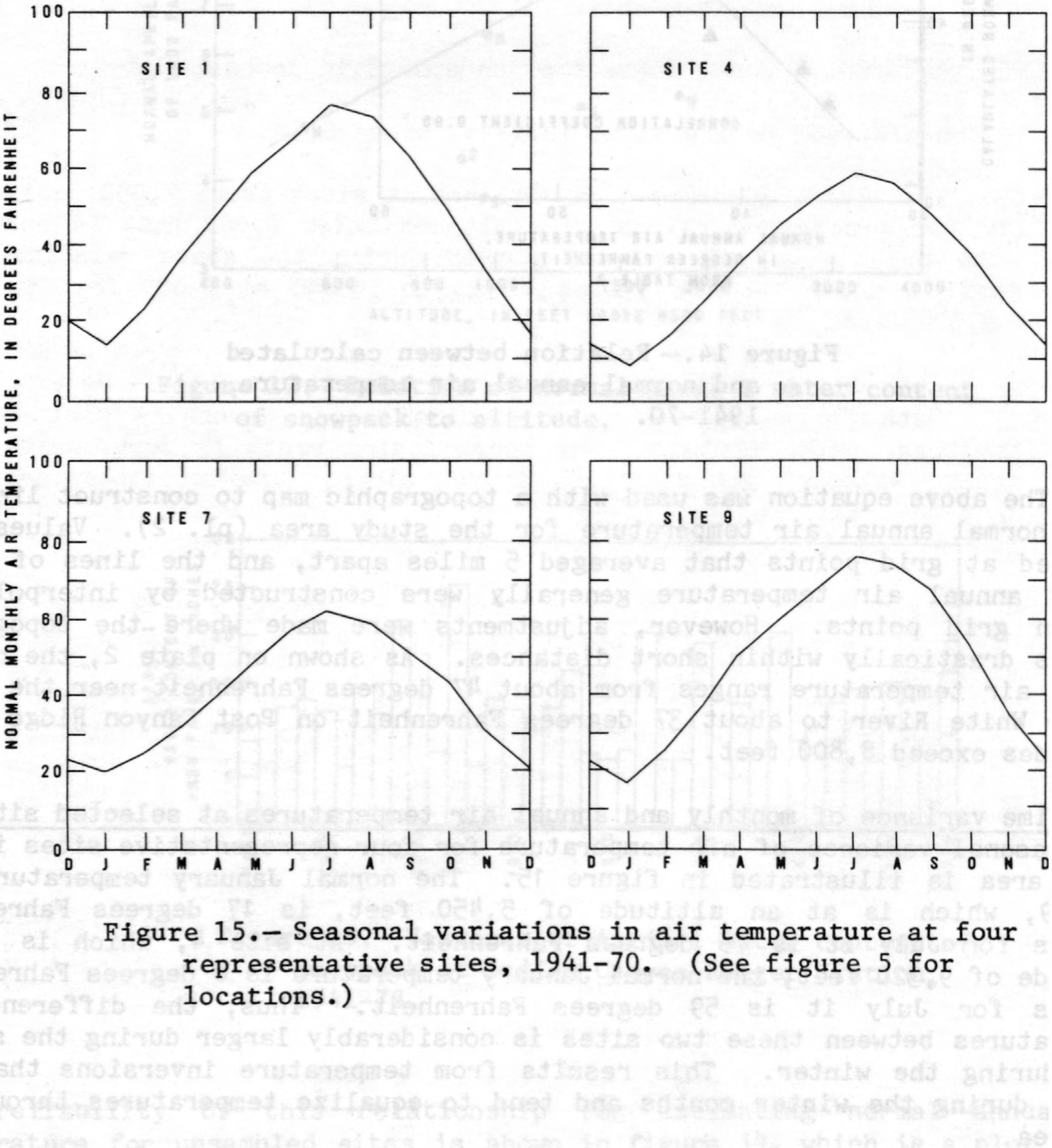

Figure 15.— Seasonal variations in air temperature at four representative sites, 1941-70. (See figure 5 for locations.)

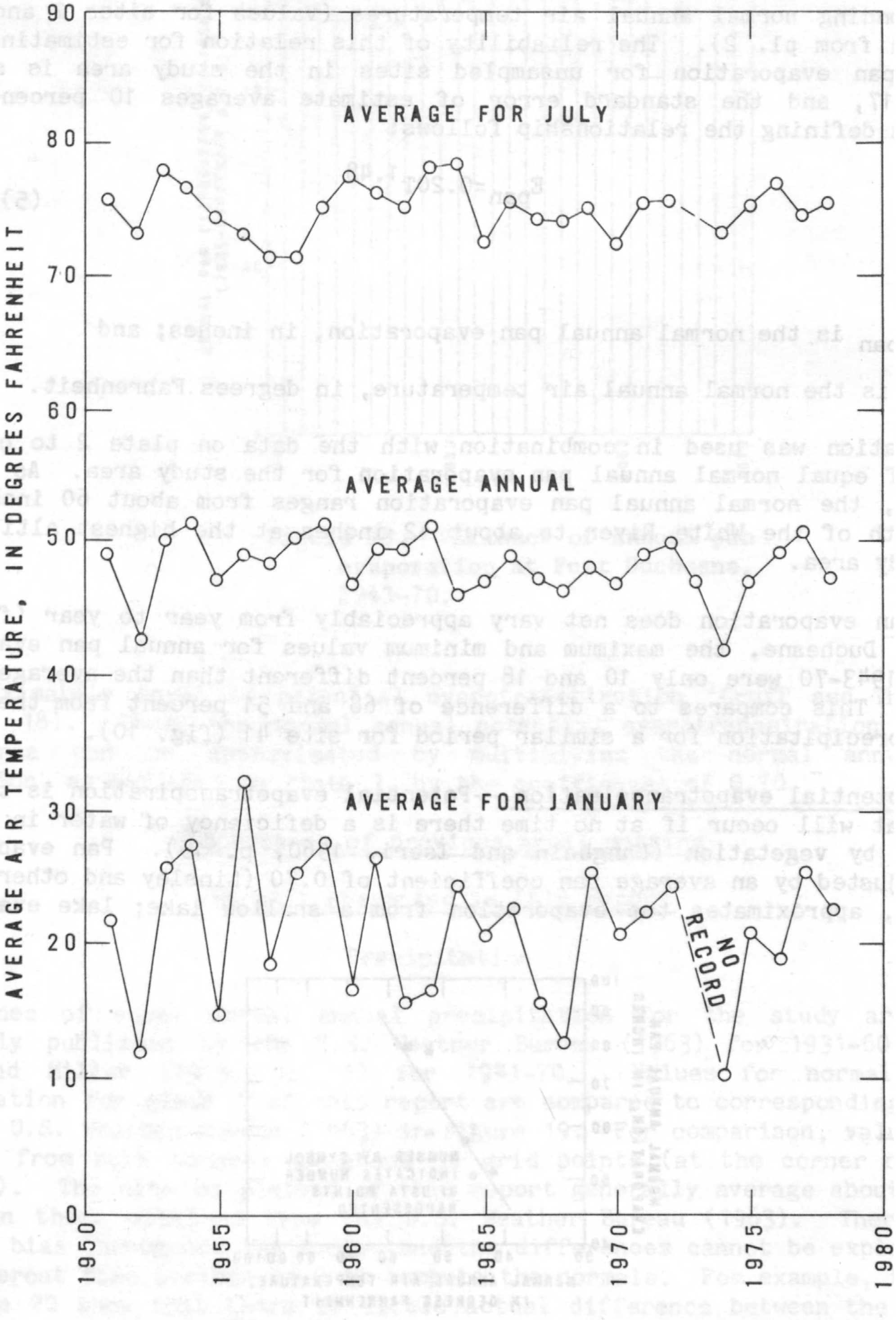

Figure 16.—Variance of average air temperatures at site 9, 1951-78. (See figure 5 for location.)

Pan evaporation.--The logarithms of the listings for adjusted normal annual pan evaporation in table 4 were related to the logarithms of the corresponding normal annual air temperatures (values for sites 2 and 3 were obtained from pl. 2). The reliability of this relation for estimating normal annual pan evaporation for unsampled sites in the study area is shown in figure 17, and the standard error of estimate averages 10 percent. The equation defining the relationship follows:

$$E_{pan}=0.20T^{1.48} \quad (5)$$

where

E_{pan} is the normal annual pan evaporation, in inches; and

T is the normal annual air temperature, in degrees Fahrenheit.

The equation was used in combination with the data on plate 2 to construct lines of equal normal annual pan evaporation for the study area. As shown on plate 3, the normal annual pan evaporation ranges from about 60 inches near the mouth of the White River to about 42 inches at the highest altitudes of the study area.

Pan evaporation does not vary appreciably from year to year (fig. 18). At Fort Duchesne, the maximum and minimum values for annual pan evaporation during 1943-70 were only 10 and 18 percent different than the average of 50.6 inches. This compares to a difference of 68 and 51 percent from the average annual precipitation for a similar period for site 41 (fig. 10).

Potential evapotranspiration.--Potential evapotranspiration is the water loss that will occur if at no time there is a deficiency of water in the soil for use by vegetation (Langbein and Iseri, 1960, p. 15). Pan evaporation, when adjusted by an average pan coefficient of 0.70 (Linsley and others, 1958, p. 108), approximates the evaporation from a shallow lake; lake evaporation

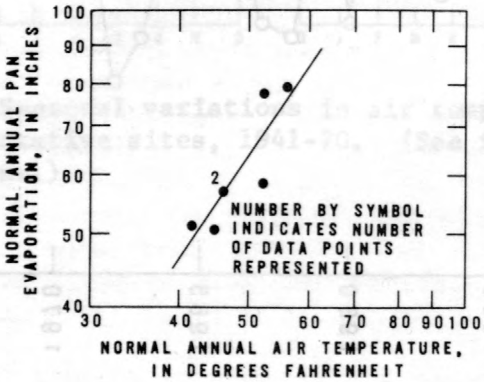

Figure 17.— Relation between normal annual pan evaporation and normal annual air temperature.

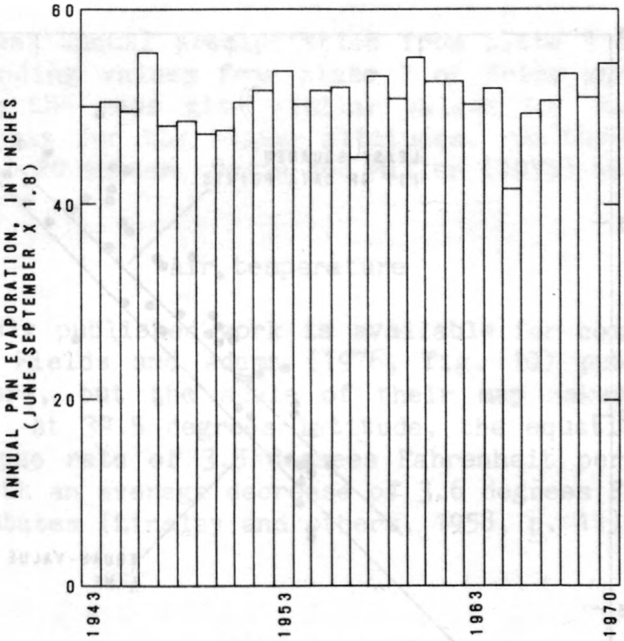

Figure 18.— Variance of annual pan evaporation at Fort Duchesne, 1943-70.

is approximately equal to potential evapotranspiration (Cruff and Thompson, 1967, p. 18). Thus, the normal annual potential evapotranspiration for the study area can be approximated by multiplying the normal annual pan evaporation, as outlined on plate 3, by the coefficient of 0.70.

Comparisons of previous areal mapping to that presented in this report

Precipitation

Lines of equal normal annual precipitation for the study area were previously published by the U.S. Weather Bureau (1963) for 1931-60 and by Price and Miller (1975, pl. 1) for 1941-70. Values for normal annual precipitation for plate 1 of this report are compared to corresponding values from the U.S. Weather Bureau (1963) in figure 19. For comparison, values were obtained from both sources at about 50 grid points (at the corner of every township). The data on plate 1 of this report generally average about 1 inch less than those obtained from the U.S. Weather Bureau (1963). There is no apparent bias throughout the range, and the differences cannot be explained by the different time periods used to compute the normals. For example, the data in figure 20 show that there is little actual difference between the normals for both periods for eight long-term NOAA sites which are near the study area. (See table 1.) Thus, the difference between values on plate 1 of this report and those of the U.S. Weather Bureau (1963) is believed to reflect the larger quantity of data that was available for the preparation of plate 1.

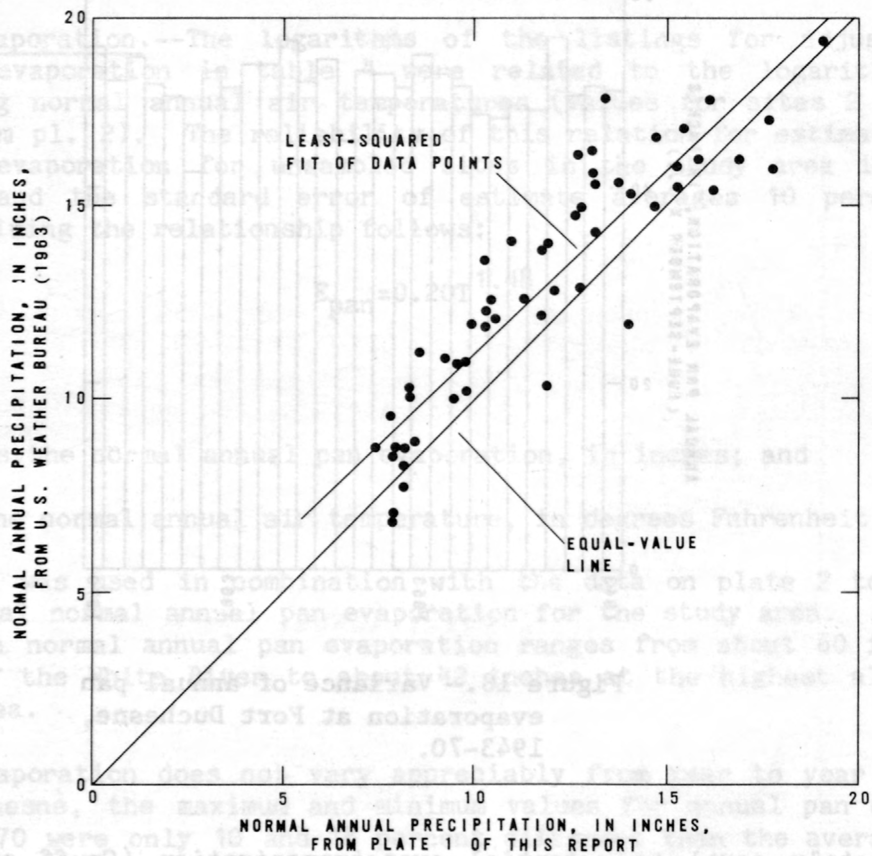

Figure 19.—Comparison of normal annual precipitation values from plate 1 of this report and from the U.S. Weather Bureau (1963).

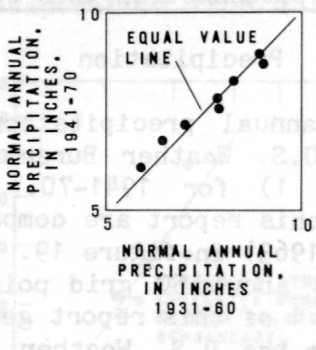

Figure 20.—Relation between normal annual precipitation for 1931-60 and 1941-70 for eight long-term National Oceanic and Atmospheric Administration sites. (See table 1.)

Values for normal annual precipitation from plate 1 of this report are compared to corresponding values from plate 1 of Price and Miller (1975) in figure 21. Although the maps give similar values for the lower altitudes, they differ considerably for the higher altitudes. On the average, for sites where values are about 20 inches, Price and Miller (1975) underestimated by as much as 5 inches.

Air temperature

Little previously published work is available for comparison with plate 2 of this report. Fields and Adams (1976, fig. 10) published values for normal air temperature, but the scale of their map makes comparisons with plate 2 impractical. At 39.5 degrees latitude, the equation used to prepare plate 2 defines a lapse rate of 3.5 degrees Fahrenheit per 1,000 feet, which compares favorably with an average decrease of 3.6 degrees Fahrenheit for most areas of the United States (Linsley and others, 1958, p. 11).

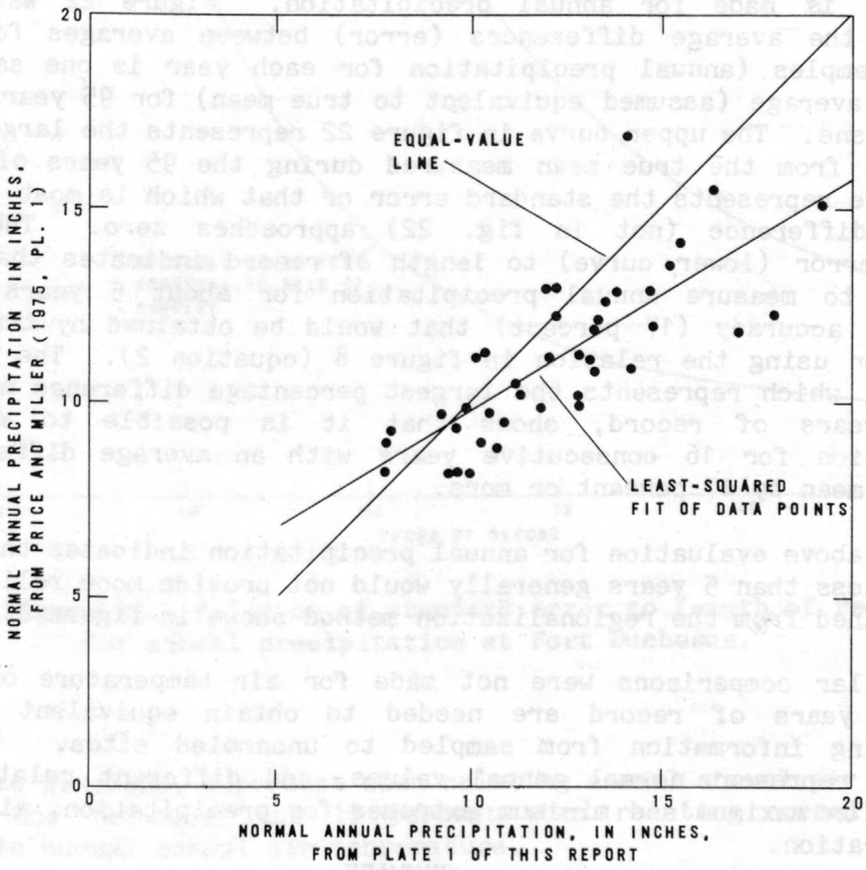

Figure 21.— Comparison of normal annual precipitation from plate 1 of this report and from Price and Miller (1975, pl. 1.)

Pan evaporation

The range in values for pan evaporation of 42-60 inches for 1941-70 from plate 3 compares to values of 50-55 inches for 1946-55 from the U.S. Department of Commerce (1959) and 50-57 inches (35-40 divided by 0.70) from Iorns, Hembree, and Oakland (1965, pl. 6). The data on plate 3 of this report show a general decrease of evaporation from north to south, whereas the other two smaller scale maps generally show an increase of evaporation from north to south which correlates with regional changes of air temperature with latitude. For the area covered by this report, however, the decrease in mean annual air temperature from north to south because of increase in altitude has greater effect on evaporation than does the normal increase of temperature from north to south due to latitude.

DATA NETWORK AND FUTURE MONITORING

Before considering an enlargement of the existing data network for future monitoring, it would be desirable to compare the accuracy associated with measuring a climatic characteristic at a site with transferring information by regionalization. The data in figure 22 illustrate how such a comparison is made for annual precipitation. Figure 22 was prepared by comparing the average differences (error) between averages for consecutive sets of samples (annual precipitation for each year is one sample) and the long-term average (assumed equivalent to true mean) for 95 years of record at Fort Duchesne. The upper curve in figure 22 represents the largest percentage difference from the true mean measured during the 95 years of record. The lower curve represents the standard error or that which is most probable. The smallest difference (not in fig. 22) approaches zero. The relation of standard error (lower curve) to length of record indicates that it would be necessary to measure annual precipitation for about 5 years to match the equivalent accuracy (17 percent) that would be obtained by transferring the information using the relation in figure 8 (equation 2). The upper curve in figure 22, which represents the largest percentage difference measured during the 95 years of record, shows that it is possible to measure annual precipitation for 16 consecutive years with an average differing from the long-term mean by 17 percent or more.

The above evaluation for annual precipitation indicates that operating a site for less than 5 years generally would not provide more reliable data than that obtained from the regionalization method shown in figure 8.

Similar comparisons were not made for air temperature or evaporation, but more years of record are needed to obtain equivalent accuracy when transferring information from sampled to unsampled sites. The curves in figure 22 represent normal annual values, and different relations would be expected for maximum and minimum extremes for precipitation, air temperature, and evaporation.

SUMMARY

Climatic data obtained from October 1974 to September 1978 by the Geological Survey, together with data available from other Federal agencies, were adjusted to the 1941-70 base period and selected climatic characteristics were related to altitude and latitude. The following average standard errors of estimate were obtained: 17 percent when relating normal annual precipitation to altitude, 34 percent when relating normal April 1 water content

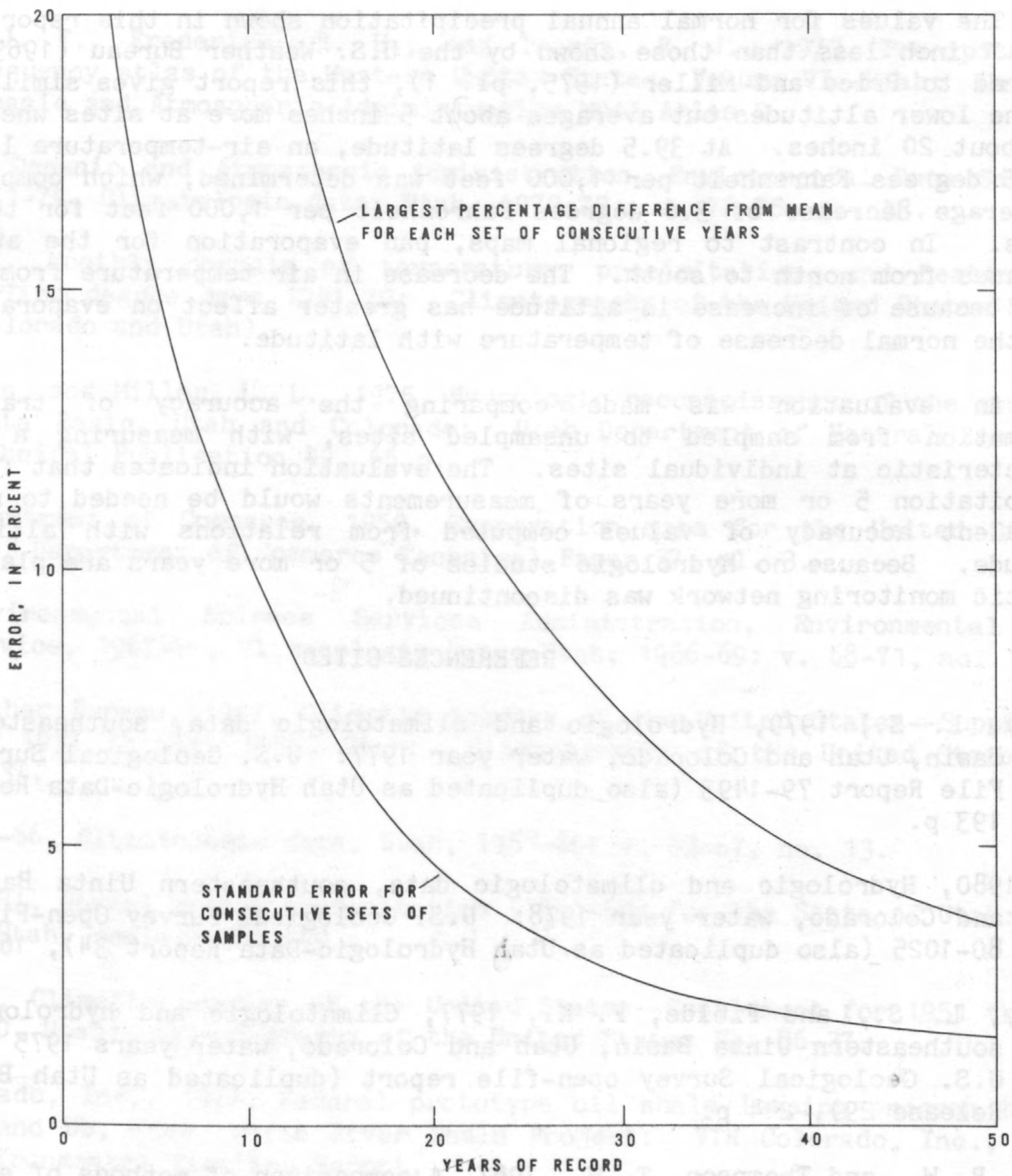

Figure 22.— Relation of standard error to length of record for annual precipitation at Fort Duchesne.

of snowpack to altitude, 4 percent when relating normal annual air temperature to altitude and latitude, and 10 percent when relating normal annual pan evaporation to normal annual air temperature.

The areal differences in normals for annual precipitation, air temperature, and pan evaporation are depicted on maps for the study area. For 1941-70, normal annual precipitation varies from less than 8 inches to more than 20 inches, normal air temperature from 37 to 47 degrees Fahrenheit, and normal pan evaporation from 42 to 60 inches.

The values for normal annual precipitation shown in this report average about 1 inch less than those shown by the U.S. Weather Bureau (1963). When compared to Price and Miller (1975, pl. 1), this report gives similar values for the lower altitudes but averages about 5 inches more at sites where values are about 20 inches. At 39.5 degrees latitude, an air-temperature lapse rate of 3.5 degrees Fahrenheit per 1,000 feet was determined, which compares with an average decrease of 3.6 degrees Fahrenheit per 1,000 feet for the United States. In contrast to regional maps, pan evaporation for the study area decreases from north to south. The decrease in air temperature from north to south because of increase in altitude has greater affect on evaporation than does the normal decrease of temperature with latitude.

An evaluation was made comparing the accuracy of transferring information from sampled to unsampled sites, with measuring a climatic characteristic at individual sites. The evaluation indicates that for annual precipitation 5 or more years of measurements would be needed to match the equivalent accuracy of values computed from relations with altitude and latitude. Because no hydrologic studies of 5 or more years are planned, the climatic monitoring network was discontinued.

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