HYDROLOGIC INVESTIGATION OF THE NORTH CANADIAN RIVER BASIN

OKLAHOMA WATER RESOURCES BOARD

HYDROLOGIC INVESTIGATION

OF THE

NORTH CANADIAN RIVER BASIN

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By

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Page 14

1) 3rd Paragraph 2nd line "Figure 8" should read "Figure 9"

2) Equation 3 "P(X x)" should read "$P(X \geq x)$"

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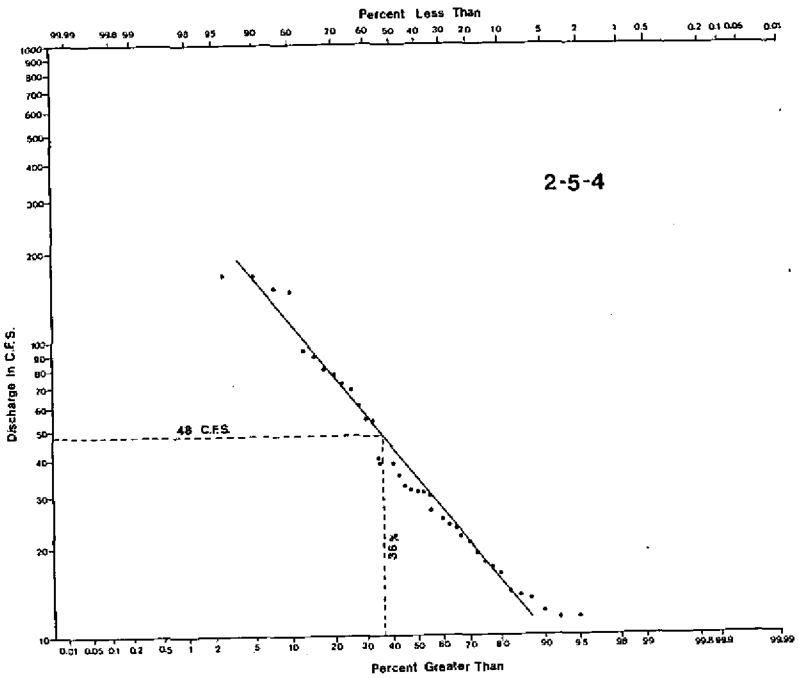
Figure 9 (continued) should be replaced by the following graph



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INTRODUCTION

This is a hydrologic investigation of the North Canadian stream system. Its main purpose is to search for answers to the questions that arise in the day-to-day management of stream water by the Oklahoma Water Resources Board.

The increasing demand for water by cities, towns, irrigators and industries requires a more efficient management of our water resources. To acquire this goal a great deal of attention must be devoted to more refined hydrologic studies. This study gives a hydrologic appraisal of surface water resources in the North Canadian River stream system. This study could be indicative of the basic requirement for planning, designing, constucting and operating reservoirs, but its main objective is to determine the source, extent and dependability of water supply for four different segments of the stream.

This study was based on existing data. For streamflow, gages of the U.S. Geological Survey were used. Precipitation and Class A pan evaporation were obtained from publications of climatological data, U. S. Department of Commerce. Other data was obtained from previous reports, water departments of cities and from records of the Oklahoma Water Resources Board.

The content of the study includes a general description of the North Canadian River basin and its sub-basins, climatological data, streamflow, appropriated and unappropriated water, monthly water consumption, and determination of the irrigation requirement for the four sub-basins of the North Canadian River.

BASIN DESCRIPTION

The North Canadian River stretches through the states of New Mexico, Texas and Oklahoma as shown in Figure 1. The total drainage area is 15,212 square miles, of which 4,899 square miles is noncontributing. Approximately 61.3% of the drainage area is situated in the State of Oklahoma, 33.2% in the State of Texas and 5.5% in New Mexico.

The topography of the North Canadian River Basin varies from gentle sloping plains to rough hills and high plains. In New Mexico it is composed of plateaus, mesas, and hills, and in Texas it is composed of High Plains. In Oklahoma it ranges from plains of gentle slope in the Panhandle area to rough and rolling hills in the eastern part of the basin.

Vegetation cover varies from grasses to oak forests. Vegetation cover in the States of New Mexico and Texas is essentially similar, primarily grasslands with trees like hackberry and cottonwood along watercourse banks. In Oklahoma, in the watershed area west of Oklahoma City, the prevailing vegetation cover consists of blackjack, postoak, plum, sage, skunk brush and grasses, while along the watercourses, hackberry, elm, cottonwood and chittamwood trees are plentiful. East of Oklahoma City the area is predominantly covered by oak forests and cleared cattle ranges.

The Oklahoma Water Resources Board recently divided some of the previously existing stream systems into sub-stream systems. The purpose of dividing the basins into sub-stream systems is an attempt to assist surface water resources management in general, and hydrologic investigations in particular. The North Canadian River Basin is one of the stream systems which was divided.

The four sub-basins of the North Canadian in Oklahoma are designated as 2-5-1, 2-5-2, 2-5-3 and 2-5-4 (Figure 1). Sub-basin 2-5-1 is the watershed of the North Canadian River that contributes runoff to the Eufaula Lake below Lake Overholser. Sub-basin 2-5-2 is the drainage area between Canton and Lake Overholser dams, 2-5-3 is the drainage area between Optima and Canton Dams, and sub-basin 2-5-4 is that part of the basin up stream from Optima Dam. Table 1 shows the respective drainage area data and the prominent tributaries of the North Canadian River in each sub-basin. In this same Table, the column of "Actual Area of Sub-basins" refers to the isolated area of each sub-basin, whereas "Drainage Area" includes all drainage areas that theoretically would be expected to contribute water to the outlet of each sub-basin.

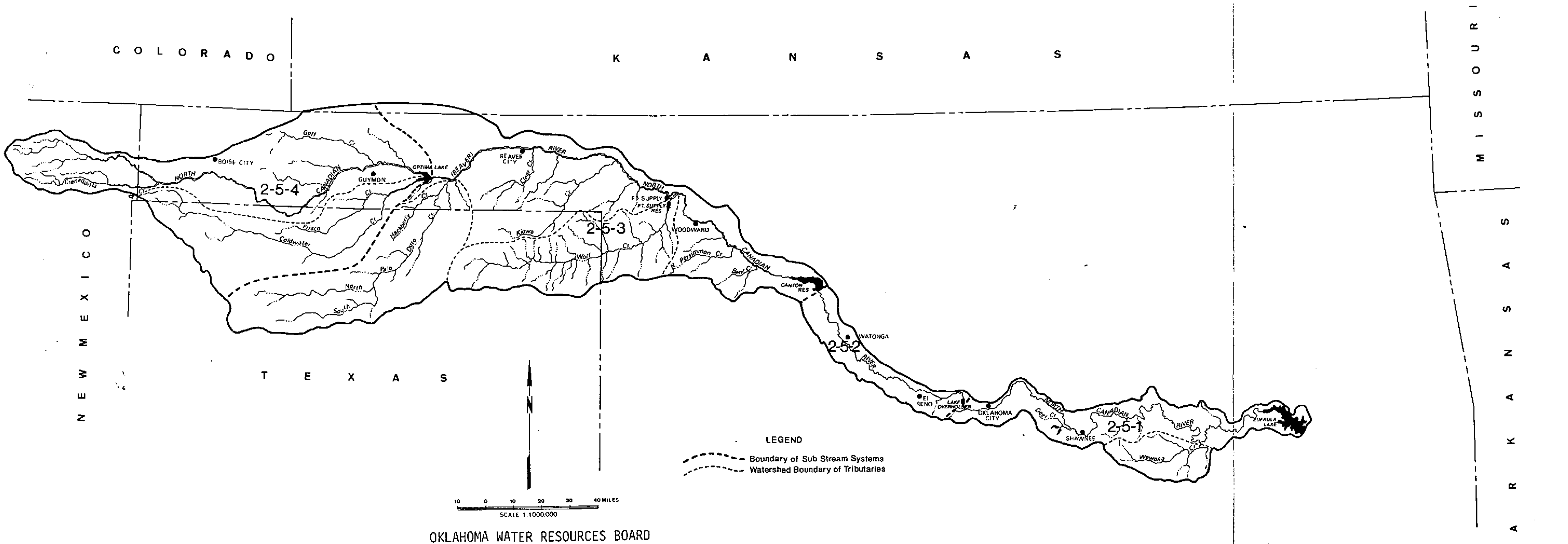


FIGURE 1 - North Canadian River Basin

TABLE 1

DRAINAGE AREA DATA FOR THE SUB-STREAM SYSTEMS, AND FOR THEIR PROMINENT TRIBUTARIES

SUB-STREAM SYSTEM	PROMINENT TRIBUTARIES	DRAINAGE AREA SQ. MI. CONTRIB.	NON.CONTRIB.	TOTAL	ACTUAL AREA OF SUB-BASINS SQ. MI.	RIVER MILE ABOVE MOUTH
2-5-1		10,313	4,899	15,212	1,990	
	Wewoka Creek	472	-	472		82.1
2-5-2		8,323	4,899	13,222	734	
2-5-3		7,605	4,883	12,488	7,459	
	Palo Duro Creek	849	931	1,780		611.8
	Kiowa Creek	463	73	536		528.1
	Wolf Creek	1,502	241	1,743		487.7
2-5-4		2,341	2,688	5,029	5,029	
	Coldwater Creek	781	1,200	1,981		623.0
	Cienequilla Creek	188	105	293		766.6

CLIMATOLOGICAL DATA

Apart from the physiographic factors, runoff from a drainage basin is primarily influenced by climatic factors. Such factors include precipitation, temperature, wind velocity (direction and duration), humidity, atmospheric pressure, and solar radiation. These factors could be combined into precipitation and evapotranspiration. In this report, however, precipitation, Class A pan evaporation and climatic zones are the only parameters considered.

CLIMATIC ZONES

The climatic zones of the North Canadian River Basin in the State of Oklahoma vary from semi-arid in the Panhandle to humid in the eastern tip of the Basin (Figure 2).

Sub-stream system 2-5-1 is predominantly in the moist sub-humid climatic zone except for its eastern most tip which is humid. The eastern part of 2-5-2 is in a moist sub-humid zone with the remainder in the dry sub-humid climatic zone. Sub-stream system 2-5-3 is essentially in a dry sub-humid climatic zone except for a small part of its western end which is in a semi-arid zone. 2-5-4 lies entirely in a semi-arid area.

PRECIPITATION

Precipitation varies significantly from east to west across the State of Oklahoma. Since the North Canadian River Basin stretches from beyond the westernmost tip of the state to the eastern one-quarter, precipitation varies tremendously in different parts of the Basin. This study attempts to provide precipitation data that could be considered representative to each of the four sub-basins. The term "representative" is used only in an indicative sense. Thus, it is basically for the purpose of general information. Therefore, precipitation representative of each watershed for the purpose of determining runoff, depending on the accuracy required, deserves more attention.

The precipitation data was obtained from Climatological Data published by the U. S. Department of Commerce. Precipitation data for the sub-stream systems was arrived at as follows: Arithmetic average precipitation data for Lake Overholser, and the cities of Wewoka and Eufaula was taken as representative of sub-stream system 2-5-1; that of Canton Dam and Lake Overholser as being representative of 2-5-2; and that of the cities of Beaver and Woodward and Canton Dam representative of 2-5-3. For sub-stream system 2-5-4 Boise City data was adopted as representative of the sub-system.

Precipitation data was presented on an annual basis and on a mean of the monthly values from 1938 to 1976. Monthly and annual means for the period are tabulated in Tables 2 and 3, and graphically presented in Figures 3 and 4, respectively.

The principal purpose for including the data in this report is for indicative information, however, such data could also be employed in some hydrologic estimations. It includes information such as long-term annual average, standard deviations and standard errors of annual precipitation and precipitation distributions based on a long-term average. All these factors could aid in the process of appropriating surface water, such as in determining irrigation requirements for different crops.

TABLE 2
ANNUAL PRECIPITATION FOR THE FOUR SUB-STREAM SYSTEMS

YEAR	PRECIPITATION IN INCHES FOR SUB-STREAM SYSTEM			
	2-5-1	2-5-2	2-5-3	2-5-4
1938	33.28	29.90	26.27	18.50
1939	28.06	22.40	17.97	14.03
1940	37.36	28.15	20.88	16.23
1941	48.07	40.45	40.10	35.98
1942	47.29	37.22	28.55	23.58
1943	31.09	22.91	18.86	11.28
1944	37.74	31.25	27.99	21.98
1945	46.08	34.20	23.13	11.62
1946	42.30	26.36	23.37	23.20
1947	37.90	28.80	23.26	17.06*
1948	33.19	26.55	25.12	23.86*
1949	40.36	28.11	27.25	19.25
1950	44.01	25.70	23.75	25.46
1951	35.93	29.71	25.21	20.32*
1952	28.49	16.15	13.09	16.72
1953	40.86	27.89	20.42	13.18
1954	24.53	15.58	13.38	11.47
1955	34.97	33.98	21.16	10.32
1956	24.03	16.09	12.20	6.95
1957	47.86	40.89	36.10	13.87*
1958	38.37	28.27	24.70	24.95*
1959	51.01	43.73	30.47	17.82
1960	38.47	35.32	27.68	21.12
1961	41.80	37.61	29.48	17.01
1962	30.99	26.23	23.01	19.48
1963	23.56	36.06	17.99	11.84
1964	38.05	29.25	21.80	12.86
1965	30.17	32.17	25.14	21.93
1966	28.75	18.52	16.06	13.78
1967	37.10	29.66	27.10	14.55
1968	46.17	27.45	27.51	12.64
1969	37.06	26.61	24.49	29.77
1970	39.31	26.37	14.88	9.60
1971	35.52	23.66	21.43	20.56
1972	31.56	24.71	22.58	17.52
1973	50.98	37.89	31.70	16.37
1974	40.46	37.28	25.55	12.41
1975	42.65	32.57	23.37	13.36
1976	26.63	20.16	17.99	13.63
MEAN	37.23	28.78	23.61	17.33
Sta. Dev.	7.44	8.28	5.93	5.95
Sta. Err.	1.19	1.33	0.95	0.95

*Missing Data Was Estimated

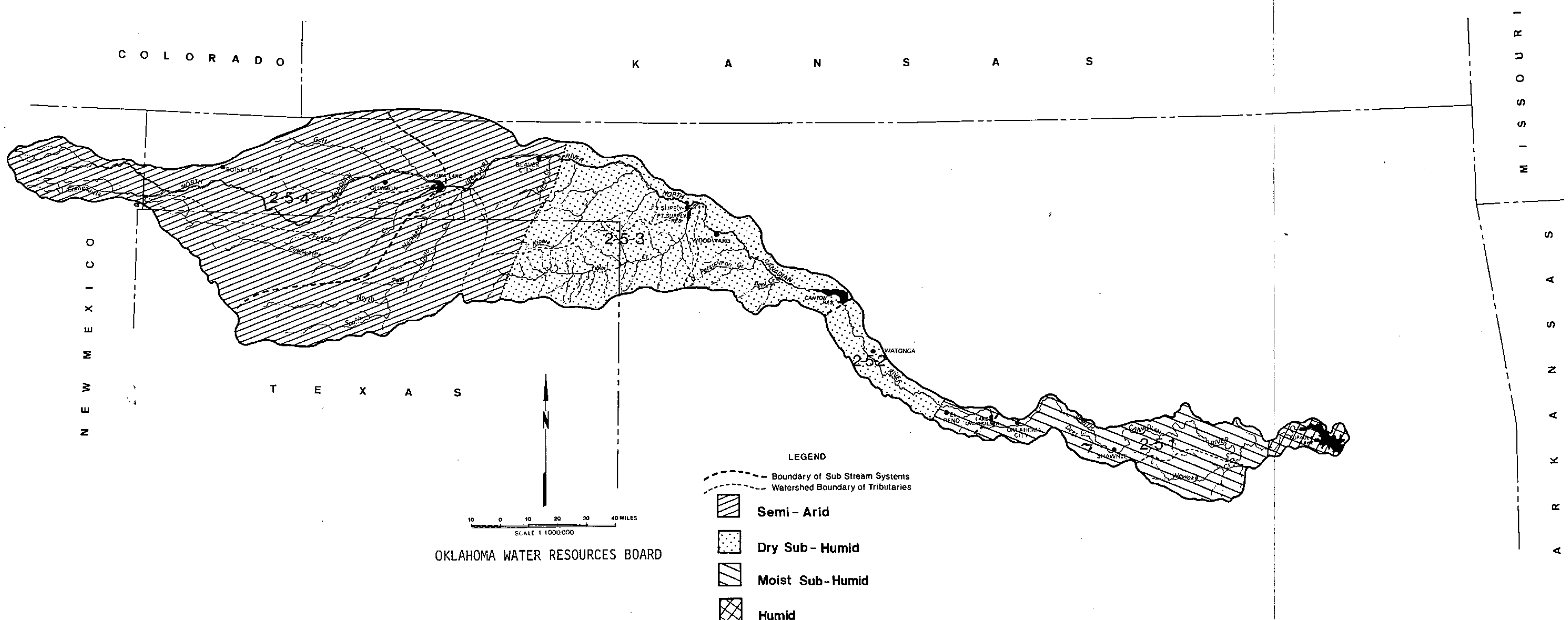


FIGURE 2 - Climatic Zones of the North Canadian River Basin.

TABLE 3

MONTHLY MEAN PRECIPITATION FOR THE FOUR SUB-STREAM SYSTEMS
FOR THE PERIOD OF 1938 - 1976

MONTH	PRECIPITATION IN INCHES FOR SUB-STREAM SYSTEM			
	2-5-1	2-5-2	2-5-3	2-5-4
JANUARY	1.40	0.85	0.53	0.44
FEBRUARY	1.87	1.19	0.80	0.50
MARCH	2.68	1.83	1.11	0.79
APRIL	3.96	2.91	1.80	1.57
MAY	5.42	4.51	3.11	2.56
JUNE	4.48	3.85	2.86	2.27
JULY	3.41	2.71	2.81	2.70
AUGUST	2.75	2.53	2.59	2.45
SEPTEMBER	3.98	3.39	1.78	1.75
OCTOBER	3.16	2.38	1.53	1.09
NOVEMBER	2.26	1.60	0.92	0.73
DECEMBER	1.86	1.09	0.64	0.47

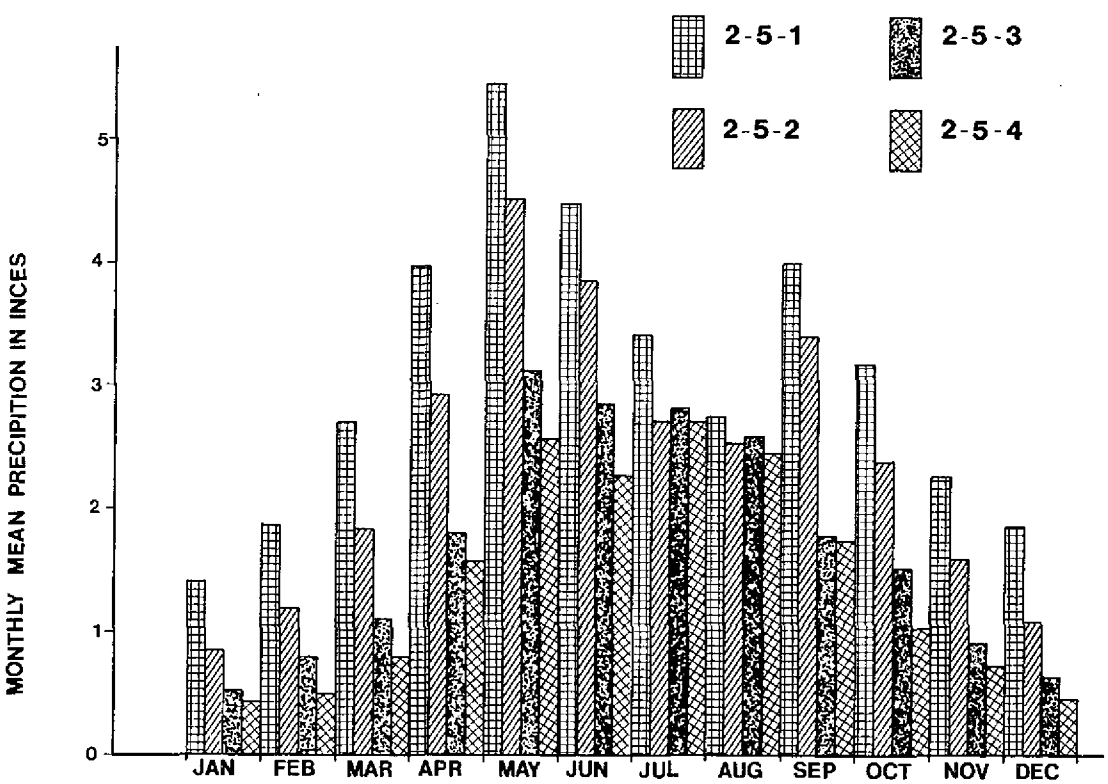


FIGURE 3 - Monthly Average Precipitation Over the 1938 - 1976 period

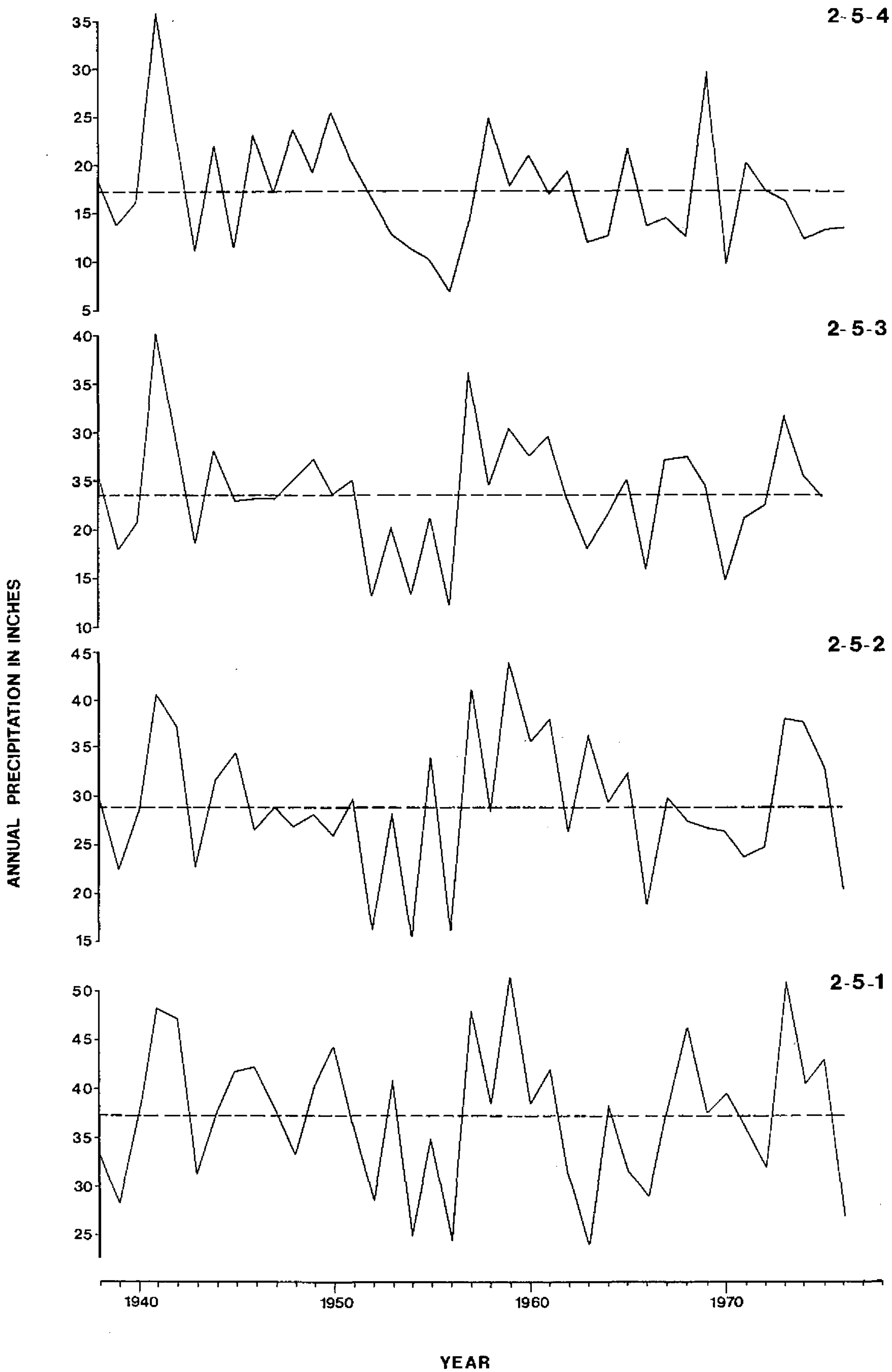


FIGURE 4 - Annual Precipitation for the Sub-Stream Systems for the Period of 1938 - 1976

PAN EVAPORATION

Pan evaporation data presented in this report is for the cities of Eufaula and Goodwell, Lake Overholser and Ft. Supply, i.e., one in each sub-system and was obtained from publications of Climatological Data, U.S. Department of Commerce. The data presented includes both annual values and mean monthly values over their respective periods. Table 4 and Figure 5 show the annual values, and Table 5 and Figure 6 show the monthly distribution of pan evaporation based on the mean of their respective periods.

Unlike the precipitation data, some monthly pan evaporation values were missing. The missing values were estimated in three different manners. The method of estimation and the relative quantity of missing data are discussed below.

The recorded period for Eufaula ran from 1961 to 1978. The months of December, January, and February of the recorded period had, on the average, 54% of the data missing. Data missing for other months was virtually insignificant. Nevertheless, missing values were estimated as the average value of the available data of the particular month for the recorded period, multiplied by the ratio of the annual total of the year of which the data is missing to the annual average of the recorded period.

Lake Overholser's pan evaporation recorded period was from 1952 to 1978. For December, January, February and March of the recorded period there was no data at all, whereas, for the combined November periods approximately 70% of the data was missing. The relatively small amount of missing data for each April through October, was estimated using the same method employed in the Eufaula case. For the November months the 8-year average was adopted as an estimate. Missing data for January, February, March and December were estimated using Equation 1.

$$Y = 0.01 + 0.83\,X \quad \text{. . . . . Equation 1}$$

Where Y = monthly mean pan evaporation for the record period for Lake Overholser.

X = corresponding average of the monthly mean pan evaporation for the record period for Eufaula and Ft. Supply.

The limitation of Equation 1 is the fact that it is arrived at using values of April through November to estimate values for the rest of the months.

Table 4 indicates that Lake Overholser's pan evaporation values are lower than expected. The National Weather Service was contacted and agreed that the recorded values do not appear accurate, but were not aware of the reason for such apparent inaccuracy.

Ft. Supply data (1941 - 1978) was the most complete of all. Missing data was substituted by data from the City of Woodward, Canton Dam, and such data as was not covered by these other locations was estimated as described in the case of Eufaula.

Pan evaporation for Goodwell is available for the period of 1948 to 1978. However, almost all of the values for the months of January, February, March, April, November and December were missing. For April and November, the mean of the available recorded data was adopted, and for May through October the method in the Eufaula case was used. Missing data for January, February, March, and December was computed using Equation 2.

$$Z = 0.07 + 1.08\,W \quad \text{. . . . . Equation 2}$$

Where Z = monthly mean pan evaporation for the record period for Goodwell.

W = corresponding monthly mean pan evaporation for the record period for Ft. Supply.

It should be noted that limitation previously described for Equation 1 also holds ture for Equation 2.

TABLE 4

ANNUAL CLASS "A" PAN EVAPORATION FOR

EUFAULA, LAKE OVERHOLSER, FT. SUPPLY AND GOODWELL

YEAR	PAN EVAPORATION IN INCHES			
	EUFAULA	LAKE* OVERHOLSER	FT. SUPPLY	GOODWELL*
1941	-	-	78.11	-
1942	-	-	83.02	-
1943	-	-	90.77	-
1944	-	-	87.60	-
1945	-	-	83.68	-
1946	-	-	89.25	-
1947	-	-	91.78	-
1948	-	-	89.64	80.75
1949	-	-	75.97	96.96
1950	-	-	83.03	90.59
1951	-	-	82.78	89.03
1952	-	75.76	98.95	108.40
1953	-	71.53	102.27	108.15
1954	-	76.71	112.74	118.07
1955	-	66.18	101.01	96.52
1956	-	76.40	115.52	118.49
1957	-	55.03	76.54	97.29
1958	-	59.68	75.77	93.23
1959	-	63.56	86.96	95.19
1960	-	64.61	84.26	89.94
1961	55.27	64.15	82.15	90.59
1962	66.46	75.52	91.04	90.79
1963	77.15	68.39	99.60	108.31
1964	65.34	71.65	100.15	109.77
1965	71.86	64.56	86.72	90.90
1966	70.50	65.73	94.48	93.30
1967	66.90	62.40	92.38	90.73
1968	66.45	65.53	92.26	97.67
1969	71.57	64.48	87.72	89.44
1970	68.72	71.80	100.04	98.67
1971	66.45	65.79	97.79	93.66
1972	68.22	68.50	94.05	90.16
1973	63.70	62.53	85.85	91.30
1974	72.87	63.24	91.23	99.55
1975	73.69	62.52	90.43	82.01
1976	65.95	63.74	92.88	101.41
1977	66.48	66.40	91.06	101.09
1978	74.76	66.40	99.25	109.90
MEAN	68.46	66.77	91.02	97.16

*Missing data for winter months were estimated using Eqs. 1 and 2

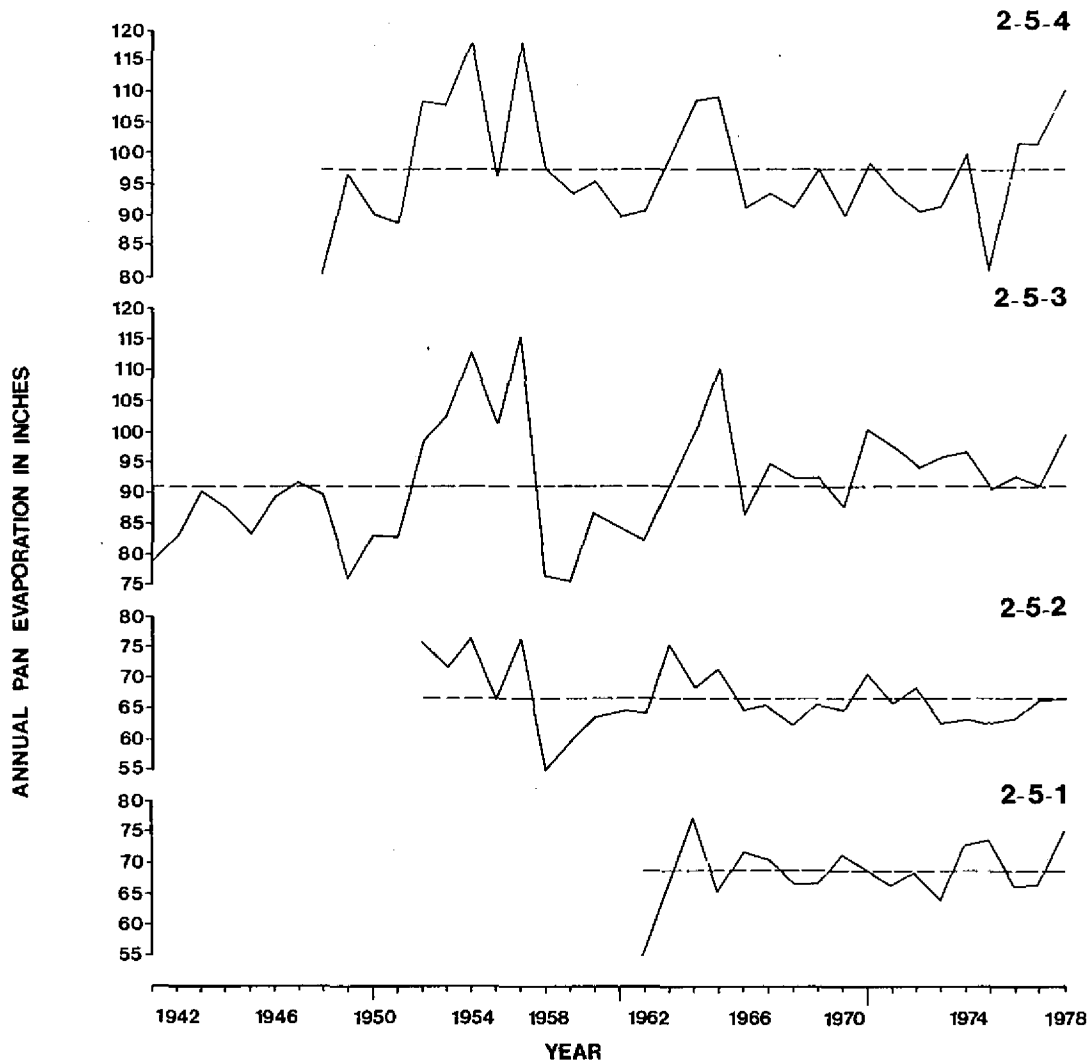


FIGURE 5 - Annual Pan Evaporation for Eufaula, Lake Overholser, Ft. Supply and Goodwell for the Indicated Period.

TABLE 5

MONTHLY MEAN CLASS "A" PAN EVAPORATION FOR EUFAULA, LAKE OVERHOLSER, FT. SUPPLY, AND GOODWELL FOR THE INDICATED PERIOD

MONTH	MEAN PAN EVAPORATION IN INCHES			
	EUFAULA (1961-1978)	LAKE OVERHOLSER (1952-1978)	FT. SUPPLY (1941-1978)	GOODWELL (1948-1978)
JANUARY	2.09	2.23#	3.26	3.45##
FEBRUARY	2.78	2.64#	3.56	3.77##
MARCH	5.22	4.83#	6.39	6.83##
APRIL	6.49	6.29	8.95	9.12**
MAY	7.35	7.58	9.91	11.47
JUNE	8.59	8.54	11.98	13.39
JULY	9.93	9.50	12.80	14.39
AUGUST	8.88	8.69	12.11	12.11
SEPTEMBER	6.14	6.35	8.99	9.18
OCTOBER	5.33	4.67	6.65	7.22
NOVEMBER	3.28	2.99*	3.94	3.56***
DECEMBER	2.33	2.01#	2.49	2.62##

* 8-Year Average
** 7-Year Average
*** 4-Year Average

\# Estimated by Equation 1
\## Estimated by Equation 2

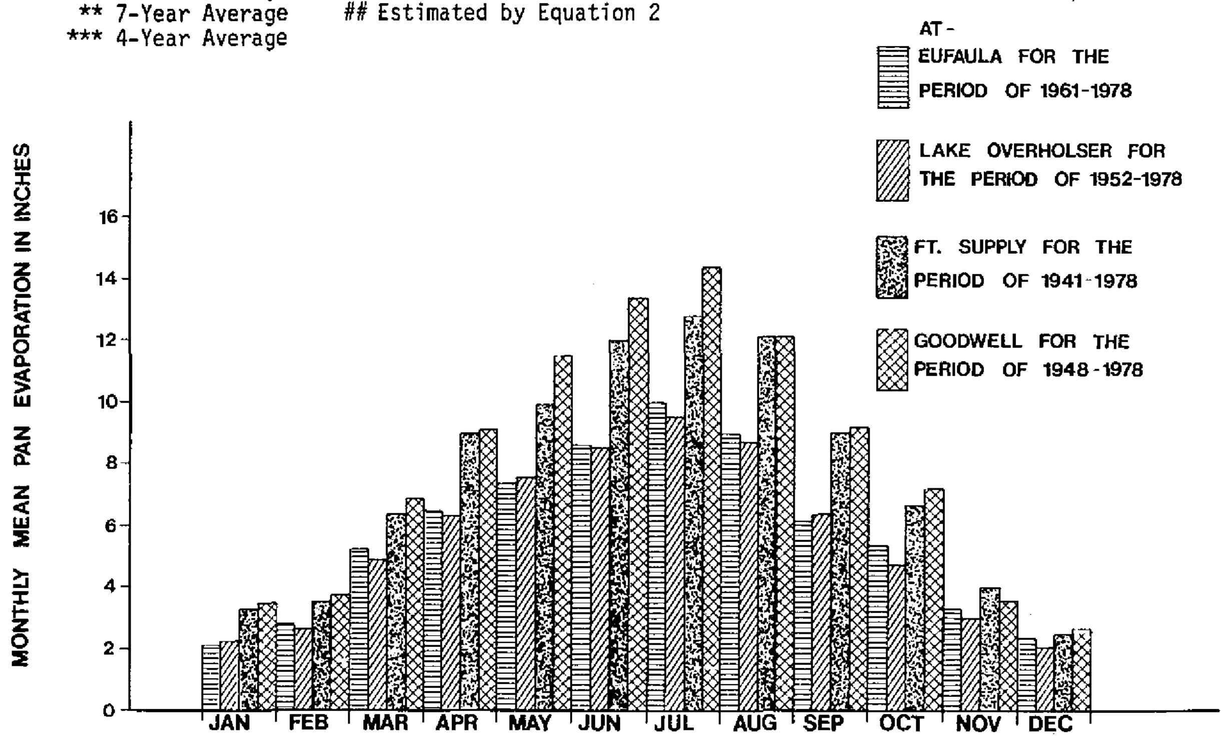


FIGURE 6 - Monthly Average Pan Evaporation over the Indicated Period for Eufaula, Lake Overholser, Ft. Supply, and Goodwell.

MUNICIPAL AND INDUSTRIAL USE DISTRIBUTION

The purpose of surveying water use distribution in the North Canadian River Basin is to determine if unappropriated water is available on a seasonal basis since most of the water is already appropriated. However, data for water used for the purpose of irrigation was not available on a monthly basis, thus, water use distribution was limited to municipal and industrial use. It is essential to note that data presented in this report is only indicative i.e., a more intensive study should be conducted in this regard.

Water use distribution data was obtained from water resources departments of four cities, one in each sub-stream system. The data was obtained from the cities of Eufaula, Oklahoma City, Woodward, and Guymon. Table 6 shows the monthly water use distribution and the monthly percent of the annual consumption.

Woodward water use seems unreasonably high, however, this is due to the 2½ MGD, water consumption on the average, by the Oklahoma Nitrogen Company. In general, use of water increased after January to a peak in July, August or September, and declined thereafter.

TABLE 6

MUNICIPAL AND INDUSTRIAL WATER CONSUMPTION FOR THE CITIES OF EUFAULA, OKLAHOMA CITY, WOODWARD AND GUYMON BY MONTH

MONTH	EUFAULA MGD		EUFAULA % OF ANNUAL	OKLAHOMA CITY MGD			OKLAHOMA CITY % OF ANNUAL	WOODWARD** MGD		WOODWARD** % OF ANNUAL	GUYMON MGD			GUYMON % OF ANNUAL	OVERALL AVERAGE % OF ANNUAL
	1978	1979		1976	1977	1978		1978	1979		1977	1978	1979		
JAN.	0.62	0.85	9	54.50	61.94	54.68	8	4.22*	4.05	7	1.35	1.83	1.20	5	7
FEB.	0.68	0.90	9	53.09	51.32	56.57	7	3.87*	3.72	6	1.59	2.39	1.95	7	7
MAR.	0.46	0.72	7	52.57	50.13	56.05	7	3.54	4.17	7	1.62	1.49	1.48	6	7
APR.	0.40	0.69	7	57.07	55.83	85.53	9	4.55	4.39	7	2.10	2.06	1.74	7	7
MAY	0.53	0.67	8	54.16	57.41	61.03	8	4.54	4.32	8	1.94	1.70	2.15	7	8
JUNE	0.67	0.81	9	67.54	78.82	69.77	9	5.83	4.23	8	2.26	2.59	2.14	8	9
JULY	0.89	0.87	11	77.42	83.47	90.18	11	7.62	5.73	11	3.17	2.54	2.48	10	11
AUG.	0.81	0.85	10	75.45	72.47	83.87	10	6.21	6.09	11	3.78	3.29	4.06	14	11
SEPT.	0.74	0.75	9	60.59	65.50	73.11	9	7.25	5.94	11	2.72	4.35	3.69	13	10
OCT.	0.68	0.48	7	58.07	57.84	60.56	8	4.99	6.03	10	2.34	3.21	2.54	10	9
NOV.	0.65	0.43	7	47.28	53.62	53.48	7	4.44	4.12	7	1.90	2.28	2.91	8	7
DEC.	0.56	0.63*	7	52.26	52.80	52.43	7	3.77	4.07	7	1.28	1.44	1.57	5	7

* Estimated
** About 2½ MGD is utilized by the Oklahoma Nitrogen Company

DETERMINATION OF IRRIGATION REQUIREMENT

A reasonably accurate determination of irrigation requirements is of great importance in the management of water resources. It aids in determining the amount of water that needs to be appropriated for specified numbers of acres, thus enhancing efficient water management.

The consumptive use, rainfall and irrigation requirement presented in this report is extracted from a study conducted by James E. Garton and Wayne D. Criddle.

Data (Table 7) from Shawnee, Oakwood, Beaver, and Goodwell was taken as representative for sub-stream systems 2-5-1, 2-5-2, 2-5-3 and 2-5-4, respectively. An attempt was made to take areas of lower precipitation within each sub-stream system so as not to under-appropriate water for irrigation. Currently irrigation water is appropriated on the basis of 2 acre-feet per acre per year throughout the State.

A survey was made of the two counties, containing the greatest area, in each sub-stream system, to determine prevailing crops. Crop statistics are available in publications of "Oklahoma County Statistics" published by the Oklahoma Department of Agriculture. The leading crop in all the surveyed counties was winter wheat with other crops like oats, barley, rye, corn, sorghum for grain, etc. also common.

As shown in Table 7, among the crops listed, alfalfa has the highest seasonal consumptive use coefficient. Thus, the irrigation requirement for each sub-stream system was determined based on the irrigation requirement for alfalfa. As shown in Table 7, irrigation requirements for alfalfa, rounded off to the unit, are 14, 18, 21 and 22 inches for sub-stream systems 2-5-1, 2-5-2, 2-5-3 and 2-5-4, respectively. Thus, irrigation requirement for the sub-streams in acre-feet per year would be 1.2, 1.5, 1.8 and 1.9 respectively.

TABLE 7

CONSUMPTIVE USE, RAINFALL, AND IRRIGATION REQUIREMENT FOR SHAWNEE, OAKWOOD, BEAVER, AND GOODWELL (inches)

	SEASONAL CONSUMPTIVE	SHAWNEE			OAKWOOD			BEAVER			GOODWELL		
CROP	USE COEFFICIENT	CONS. USE	RAIN-FALL	IRRIG. REQUIR.	CONS. USE	RAIN-FALL	IRRIG. REQUIR.	CONS. USE	RAIN-FALL	IRRIG. REQUIR.	CONS. USE	RAIN-FALL	IRRIG. REQUIR.
ALFALFA	0.85	39.9	26.1	13.8	37.0	18.9	18.1	35.4	14.2	21.2	34.5	13.0	21.5
PASTURE	0.75	37.6	26.2	11.4	34.8	18.8	16.0	33.4	14.2	19.2	32.5	13.0	19.5
COTTON	0.70	28.9	21.6	7.3	27.7	16.3	11.4	27.4	13.2	14.2	26.9	12.4	14.5
SORGHUM	0.70	21.1	14.6	6.5	20.8	11.7	9.1	20.8	10.2	10.8	20.2	9.5	10.7
CORN	0.80	23.2	15.5	7.7	22.8	12.1	10.7	22.8	9.8	13.0	22.1	9.0	13.1

STREAM WATER FLOW

For surface water resources management, accurate streamflow measurements for each sub-stream system are of great importance. Streamflow data presented in this report is primarily measured by the U. S. Geological Survey, however, to determine flow from each sub-stream system it was necessary to estimate flow for parts of the sub-stream systems. The detailed procedure employed to determine streamflow for each sub-stream system is described below.

Tables 8 and 9 show the annual and the monthly distribution of streamflow for each sub-stream systems. The streamflows are shown graphically in Figures 7 and 8.

Plotting positions were computed for sub-stream systems of 2-5-1, 2-5-3 and 2-5-4 using Equation 3 and lognormal probability plots are shown in Figure 8. This was not done for sub-stream system 2-5-2 because there was not enough data to arrive at a definite pattern.

$$P\ (X\ \ x)100 = (M\ )\ 100\ /\ (n+1) \quad . . . . \text{Equation 3}$$

Where $P(X\ \ x)$ = probability that flow would be equal to or greater than x

M = rank, $M = 1$ for the largest $M=n$ for the smallest

n = number of observations

A primary purpose for the Board's conducting this study was to determine how much stream water is available for appropriation in each sub-stream system. As unappropriated water gets scarce, it appears inevitable that water will have to be appropriated on a seasonal basis, or not at all. Thus, the availability of monthly water use, precipitation, evaporation and streamflow distribution could facilitate the determination of water available on a seasonal basis. However, the effect of reservoir regulation on the monthly distribtuion of streamflow and lack of monthly irrigation use data presents an obstacle in determining available water on a seasonal basis. For instance, water is released from Canton Reservoir to be diverted downstream by Oklahoma City, thus greatly altering the natural distribution for subbasins 2-5-2 and 2-5-3.

The Rules and Regulations of the Oklahoma Water Resources Board state that "if it is determined that unappropriated water is available less than thirty-five (35) percent of the time, the Board may, in its discretion, issue a seasonal permit valid only during certain months of the year". Thus, if the amount applied for is available less than 35% of the time it is the Board's policy not to issue regular permits, but only seasonal ones. Conversely, the Board will issue regular permits if the amount applied for is available 35% of the time or more.

SUB-STREAM SYSTEM 2-5-1

Streamflow from sub-stream system 2-5-1 was measured at the U.S. Geological Survey Gage #07242000 at the North Canadian River near Wetumka which takes into account 94% of the total drainage area and 54% of the isolated drainage area of sub-stream system 2-5-1. Streamflow contributed by the downstream area (922 mi^2) from U.S.G.S. Gage #07242000 was estimated proportionately from the streamflow of Deep Fork River near Beggs, Oklahoma, as measured by U.S.G.S. Gage #07243500. The values were then added to that measured near Wetumka to represent inflow from the North Canadian River into Eufaula Lake. The annual average for the recorded period (1938-1976) is 1,067 cfs with a standard deviation of 709 cfs. The maximum yearly mean is 2,775 cfs and the minimum is 89 cfs.

SUB-STREAM SYSTEM 2-5-2

Streamflow designated as being from 2-5-2 is the flow that leaves the sub-stream system. It is measured by U.S.G.S. Gage #07241000 below Lake Overholser, near Oklahoma City. The recorded period ranged from 1953 to 1977 with data partially missing for the years of 1968, 1969, 1972 and 1973. The annual average flow for 21 years of the recorded period is 105 cfs with a standard deviation of 131 cfs. The maximum yearly mean is 498 cfs and the minimum is 0.25 cfs.

SUB-STREAM SYSTEM 2-5-3

Streamflow presented for 2-5-3 is the flow that leaves the sub-stream system measured at U.S.G.S. Gage #07239000 at the North Canadian River just below the Canton Dam. Annual average flow for the recorded period (1938-1976) is 198 cfs with standard deviation of 189 cfs. Annual average flow since the completion of Canton Dam has been 176 cfs (1949 - 1976). Maximum and minimum yearly mean flows for the recorded period of 1949-1976 are 666 and 29 cfs. Here, it should be noted 80,000 acre-feet per year of water is released from Canton for downstream diversion by Oklahoma City.

SUB-STREAM SYSTEM 2-5-4

Sub-stream system 2-5-4 is the part of the North Canadian River Basin upstream from Optima Dam. The streamflow presented in this report is the inflow to Optima Reservoir and not the flow that leaves the dam. The main streams are the North Canadian River and Coldwater Creek. Flow in the North Canadian River was primarily determined from the records from U.S.G.S. Gage #07232500 near Guymon, Oklahoma. The drainage area that theoretically contributes to the point where the above referenced gage is located comprises 43% of the sub-stream system. Coldwater Creek watershed comprises 39%, and the remaining 18% is the drainage area between the U.S.G.S. Gage #07232500 and Optima Dam (exclusive of the area that drains to Coldwater Creek). The latter 18% of the drainage area contributes approximately 16% of the average annual flow over the recorded period (1938-1976) and is estimated proportionally from the flow of Coldwater Creek watershed.

Flow from Coldwater Creek watershed was measured at U.S.G.S. Gage #07371000 near Hardesty, Oklahoma, from 1940 to October 1964. The rest of the study period was estimated from straight line equations developed for each separate month by treating the measured flow from Coldwater Creek watershed as a dependent variable, with the flow from the North Canadian River measured at U.S.G.S. Gage #07232500 as the independen variable. Inflow to Optima from the Coldwater Creek watershed comprises approximately 31% of the average annual flow over the recorded period.

Total annual average inflow into Optima Reservoir for the recorded period is 48 cfs with a standard deviation of 44 cfs. The maximum yearly mean is 168 cfs and the minimum is 8 cfs.

TABLE 8

ANNUAL STREAMFLOW FOR THE FOUR SUB-STREAM SYSTEMS

YEAR	ANNUAL DISCHARGE CFS			
	2-5-1	2-5-2	2-5-3	2-5-4
1938	1,000.67		290.52	89.68
1939	329.08		231.14	53.66
1940	371.34		92.46	60.87
1941	2,775.51		751.31	167.91
1942	1,917.20		337.98	68.78
1943	1,262.23		61.56	11.63
1944	722.09		183.10	23.67
1945	2,582.33		134.90	16.06
1946	1,300.36		271.49	153.11
1947	1,367.62		352.08	77.45
1948	1,321.60		98.82	38.41
1949	1,930.18		555.36	30.84
1950	1,809.67		705.84	149.26
1951	1,329.27		665.97	81.40
1952	540.92		107.35	13.45
1953	437.88	.86	46.97	17.22
1954	293.15	.25	63.83	7.91
1955	462.15	107.48	147.04	93.65
1956	89.46	.97	40.07	32.38
1957	2,374.53	497.50	470.88	54.40
1958	1,007.21	190.83	181.23	73.56
1959	1,333.57	194.88	113.55	29.98
1960	1,331.48	216.68	166.43	20.97
1961	922.85	176.07	121.67	12.25
1962	718.34	100.33	92.00	26.85
1963	238.56	6.24	102.12	11.79
1964	540.53	3.02	29.24	40.12
1965	386.09	73.09	98.95	160.64
1966	282.37	35.38	83.90	38.56
1967	384.67	4.95	48.15	31.85
1968	1,095.73	72.78*	145.94	30.90
1969	898.09	6.63*	206.79	24.98
1970	793.43	15.45	75.13	14.27
1971	667.36	3.59	58.07	35.00
1972	534.22	2.77*	80.59	23.21
1973	2,241.93	69.07*	160.26	19.22
1974	1,858.95	279.81	227.43	17.83
1975	1,708.98	266.14	58.93	13.66
1976	468.78	14.96	81.26	21.73
1977		21.74		
MEAN	1,067.45	105.25	198.47	48.44
Sta. Dev.	709.45	131.45	189.10	44.03
Sta. Err.	113.60	28.68	30.28	7.05

*DISCHARGE IS NOT FOR THE WHOLE YEAR

TABLE 9

MONTHLY MEAN DISCHARGE FOR THE INDICATED PERIODS FOR EACH SUB-STREAM SYSTEM

MONTH	MONTHLY MEAN DISCHARGE IN CFS 2-5-1 (1938-76)	2-5-2 (1938-76)	2-5-3 (1952-76)	2-5-4 (1938-76)
JANUARY	400	31	68	15
FEBRUARY	588	61	90	17
MARCH	918	68	130	19
APRIL	1,722	61	213	29
MAY	2,580	114	333	90
JUNE	2,329	263	486	103
JULY	997	148	295	94
AUGUST	450	76	172	55
SEPTEMBER	603	87	196	63
OCTOBER	889	148	244	67
NOVEMBER	865	103	91	17
DECEMBER	468	32	63	13

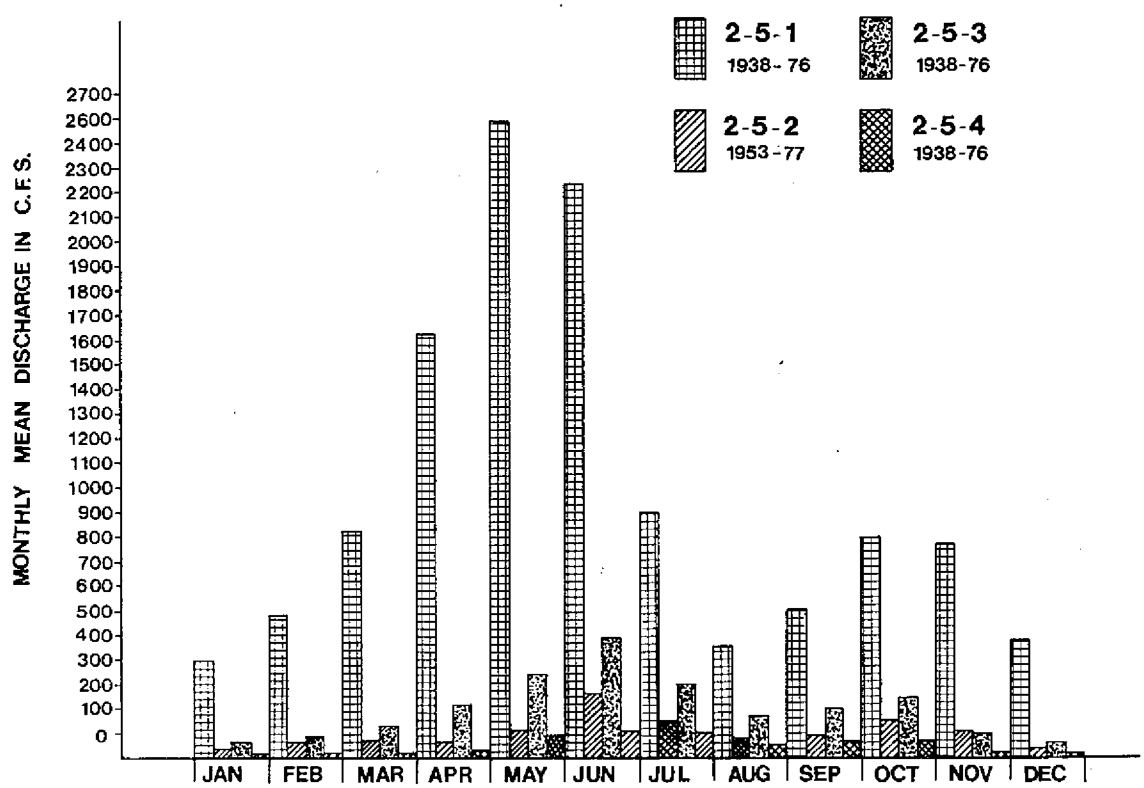
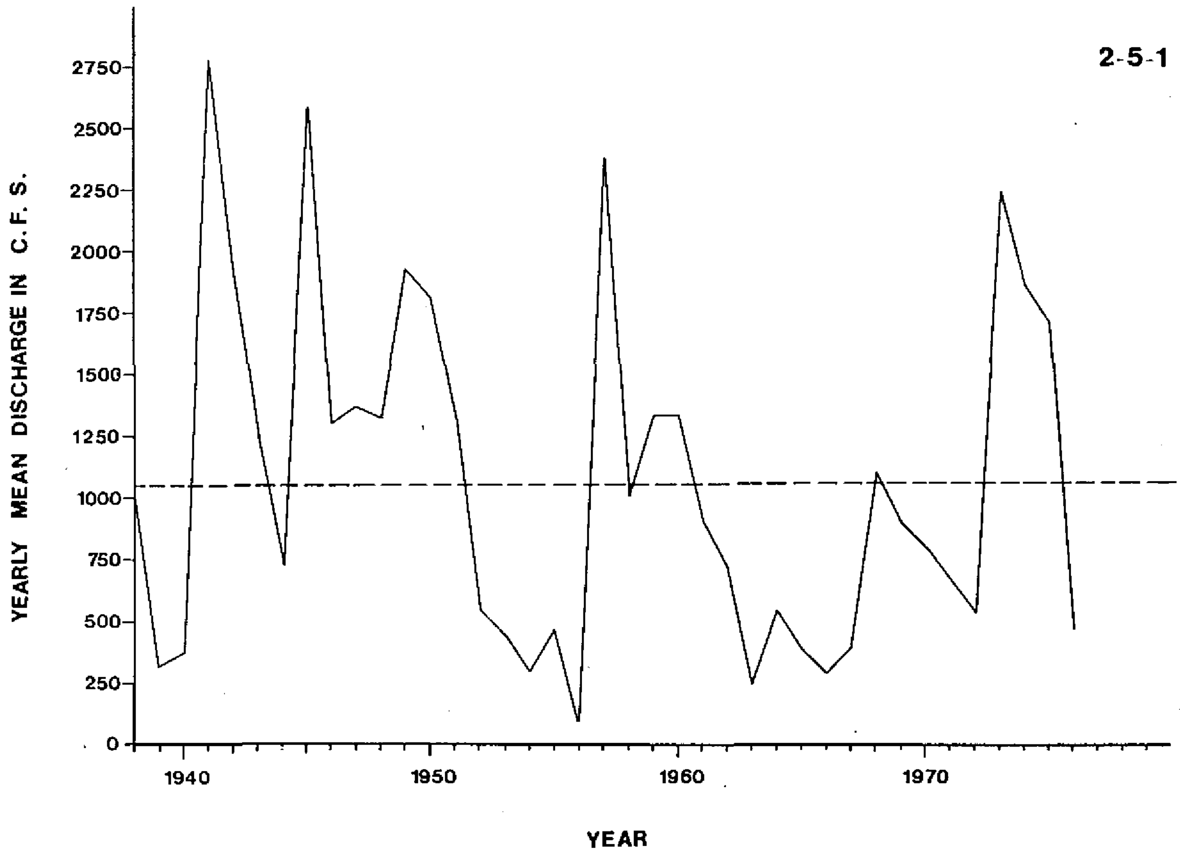


FIGURE 7 - Monthly Mean Discharge for the Indicated Record Period for all four Sub-Stream Systems.



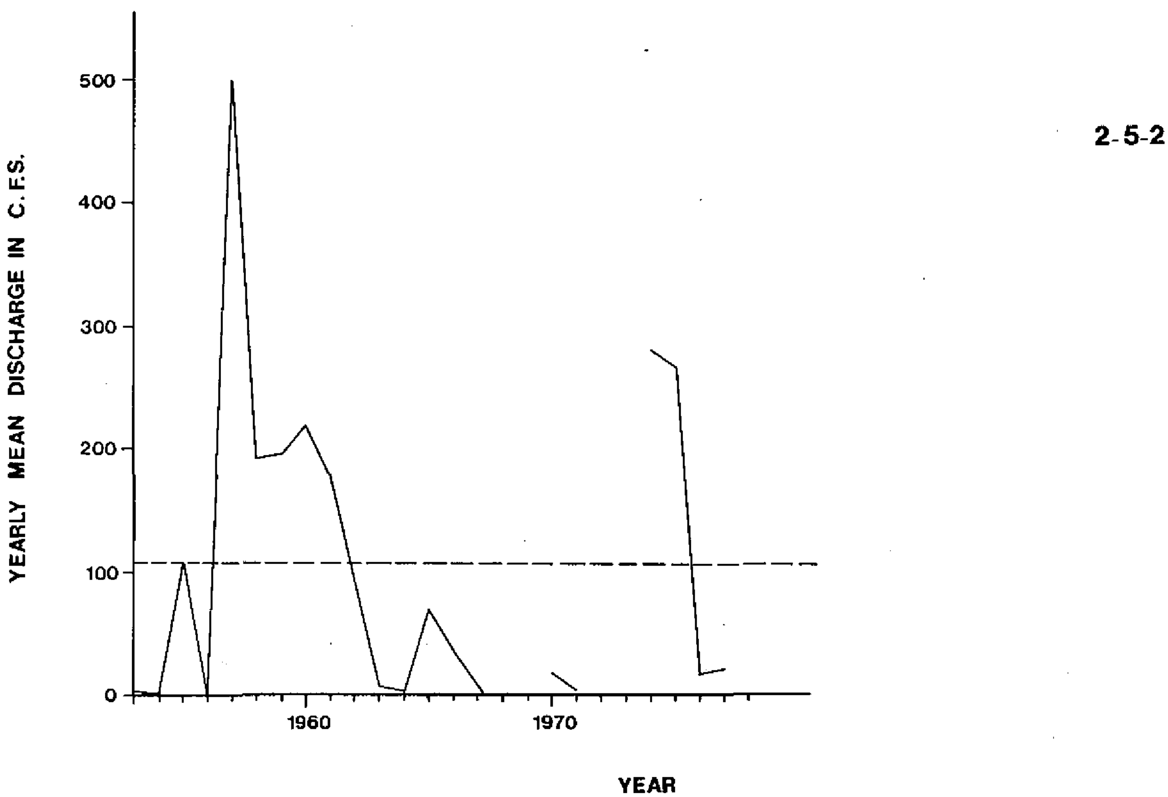
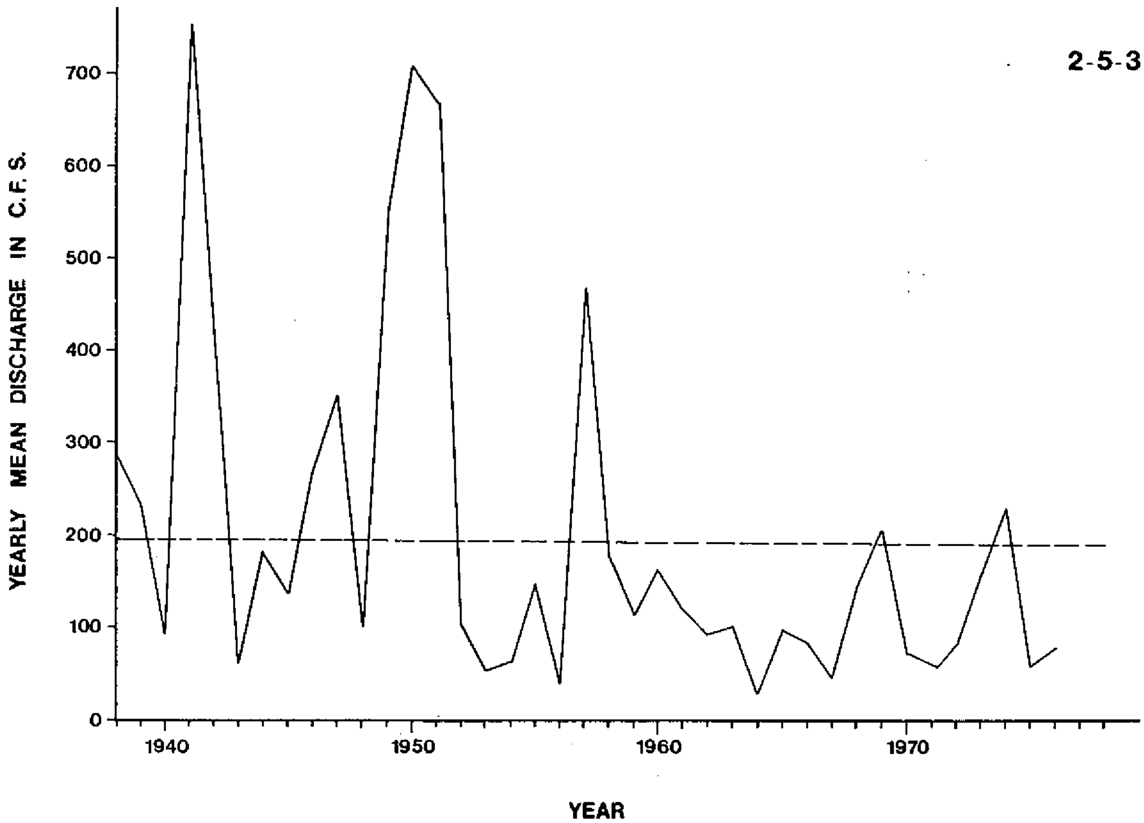


FIGURE 8 - Yearly Mean Discharge for Sub-Stream Systems 2-5-1, 2-5-2



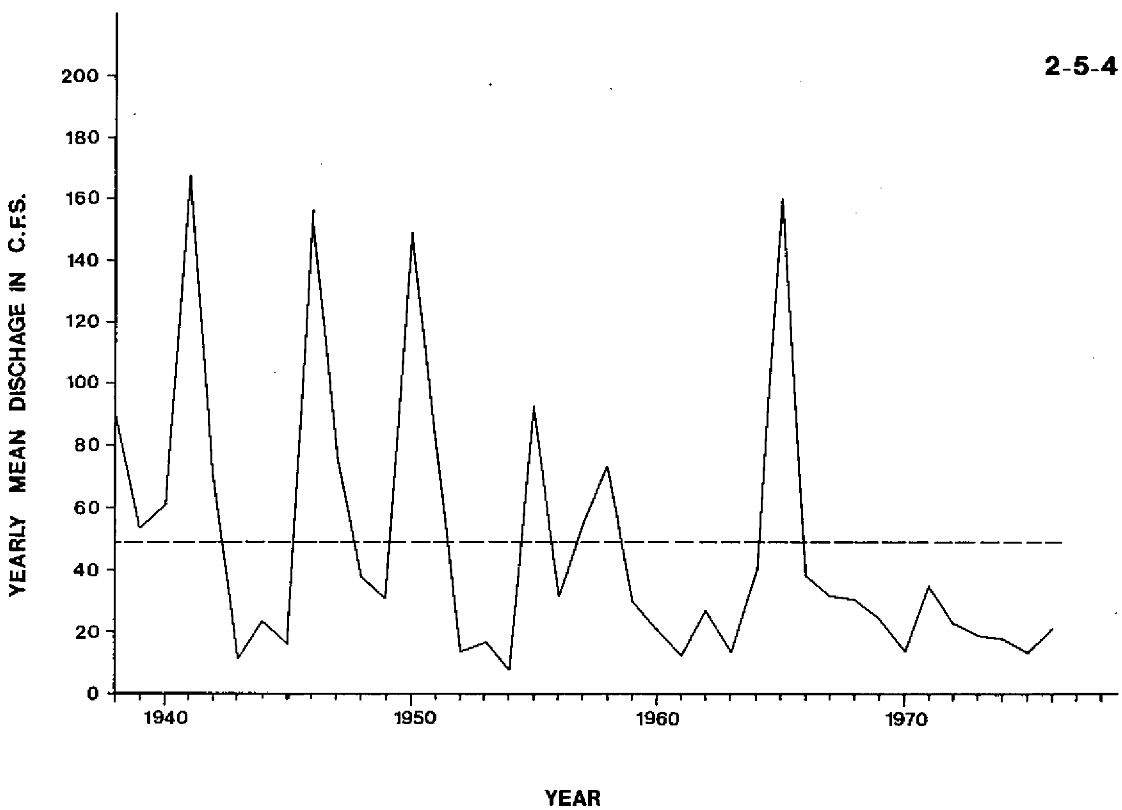
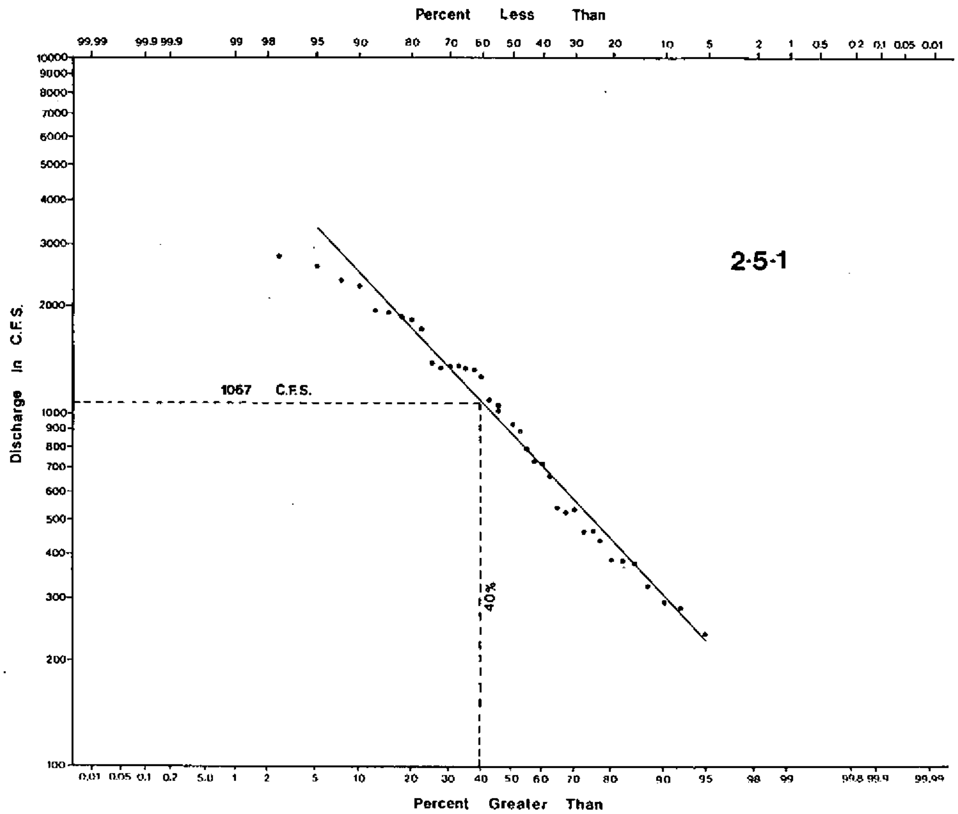


FIGURE 8 - (continued) Yearly Mean Discharge for Sub-Stream Systems 2-5-3, 2-5-4



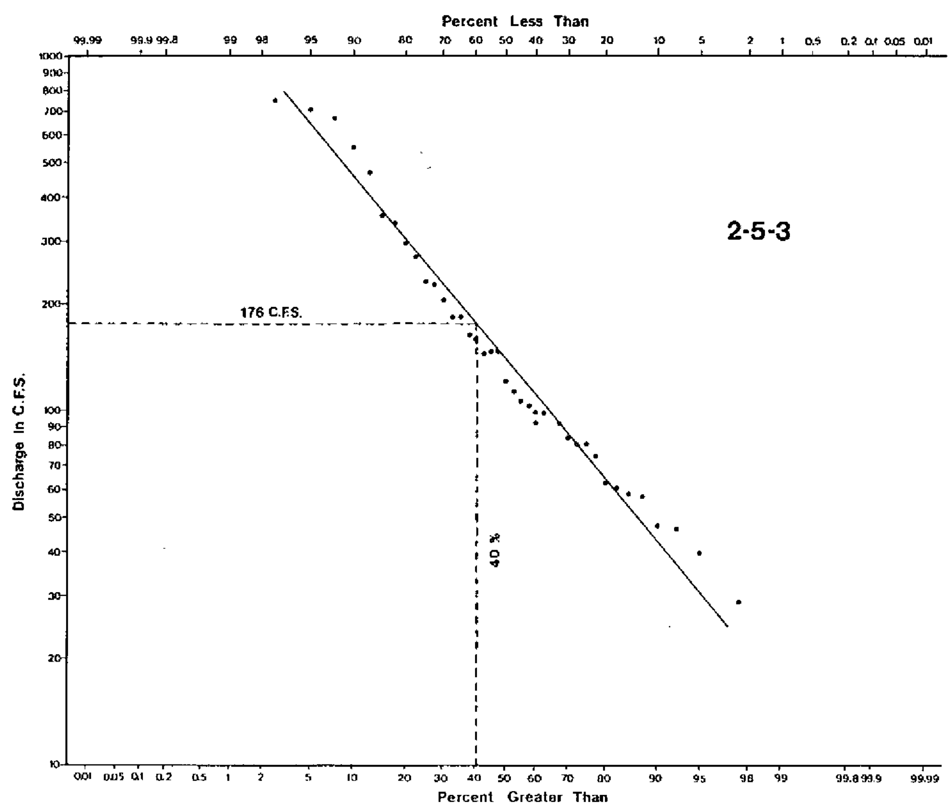


FIGURE 9 - Lognormal Probability Plot for Sub-Stream Systems 2-5-1, 2-5-3

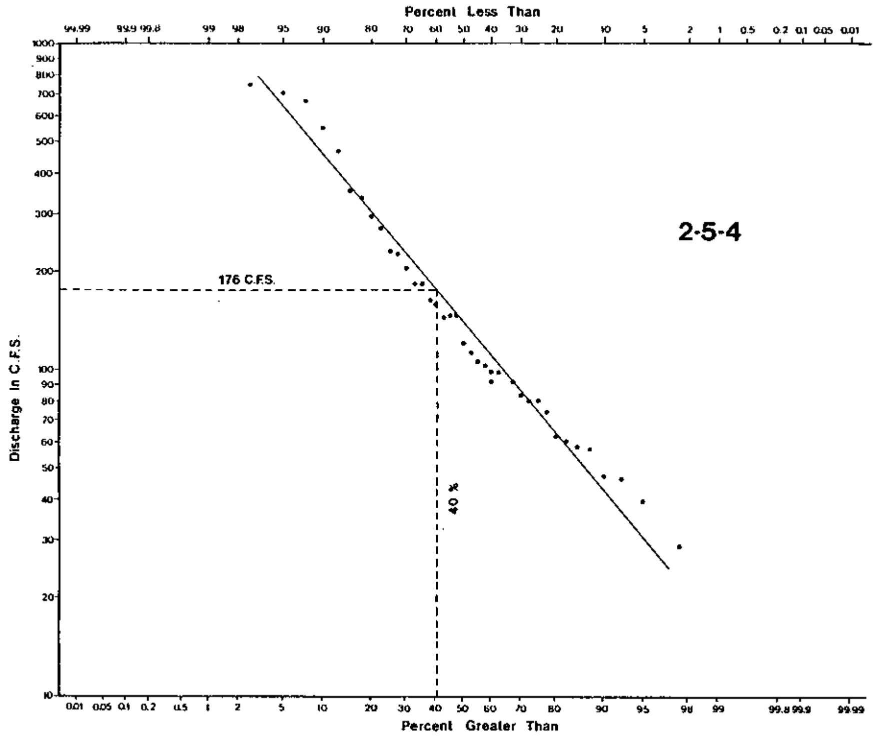


FIGURE 9 (continued) - Lognormal Probability Plot for Sub-Stream System 2-5-4

APPROPRIATED WATERS

Table 10 shows the total amount of water which has been appropriated for the categories of 1) irrigation, 2) municipal and industrial and 3) recreation, fish and wildlife for each sub-stream system. The amount under irrigation also includes water rights that have a combined purpose of recreation and irrigation.

Appropriated water for the entire North Canadian River Basin allocated for the purposes of irrigation is 14.7%, municipal and industrial 84.7%, and 0.6% for recreation, fish and wildlife. Over 62% of the total appropriated water is from sub-stream system 2-5-1 and 33% is from sub-stream system 2-5-2, leaving 5% from the other two sub-stream systems combined. The values in Table 10 were prepared after a recent (1979) reduction or cancellation of unused water rights, which should make them reasonably representative of actual present use.

TABLE 10

APPROPRIATED WATER FROM EACH SUB-STREAM SYSTEM

SUB-STREAM SYSTEM	APPROPRIATED ACRE-FEET OF WATER			
	IRRIGATION	MUNICIPAL & INDUSTRIAL	RECREATION, FISH & WILDLIFE	TOTAL
2-5-1	29,972	128,215	396	158,583
2-5-2	3,377	80,000	4	83,381
2-5-3	3,209.2	7,051	1,070	11,330.2
2-5-4	723	0	0	723
TOTAL	37,281.2	215,266	1,470	254,017.2

MAJOR LAKES AND AMOUNT OF WATER APPROPRIATED FROM THEM

Pertinent data concerning major lakes in the system is tabulated in Table 11. All were constructed by the Corps of Engineers, except for the Shawnee Lakes and Lake Overholser, which are owned by the Cities of Shawnee and Oklahoma City, respectively. As indicated by the water supply yield and the amount appropriated from each lake (Table 11), Lake Eufaula and Lake Optima are the only ones which presently have water available for appropriation. However, pending applications on Optima far exceed the lakes dependable yield and the conservation storage in Canton is presently under contract to Oklahoma City to satisfy their downstream right.

Other lakes like Lake Chambers, Lake Weleetka, Tecumseh Lake, Sportsman Lake, and Wewoka Lake are also found in the North Canadian River Basin. Most of them are located in sub-stream system 2-5-1 and are municipally owned.

TABLE 11

INFORMATION ON MAJOR LAKES IN THE NORTH CANADIAN RIVER BASIN

ITEM	LAKE* EUFAULA	SHAWNEE LAKES	LAKE OVERHOLSER	CANTON LAKE	FT. SUPPLY LAKE	LAKE** OPTIMA
Sub-Stream System	2-5-1	2-5-1	2-5-2	2-5-3	2-5-3	2-5-4
Drainage Area, mi.	47,522(1)	34	13,222(2)	12,483(3)	1,735(4)	5,029(5)
Flood Control Storage, AC-FT	1,470,000	0	0	267,800	86,800	71,800
Water Supply Storage, AC-FT	56,000	34,000	17,000	107,000	400	76,200
Water Supply Yield, AC-FT/YR	56,000	4,400	5,000	13,440	220	5,400
Date of Completion	Feb.1964	1935	1919	July 1948	May 1942	Sept.1978
Amount of Appropriated Water, AC-FT/YR	47,908	8,000	80,000(6)	0	7,051	0

*Lake Eufaula stretches over 4 Stream Systems

(1) 9,700 mi^2 Non-contributing
(2) 4,899 mi^2 Non-contributing
(3) 4,899 mi^2 Non-contributing
(4) 241 mi^2 Non-contributing
(5) 2,688 mi^2 Non-contributing
(6) Stored in Canton Reservoir

** Pending Applications Amounts to 24,617 AC-FT/YR

UNAPPROPRIATED WATER

In determining unappropriated water it was assumed that all the appropriated water was being utilized inasmuch as under Oklahoma law that portion not being used becomes available to other prospective users. This assumption is quite reasonable when determining unappropriated water on a long period average and when all non-used water rights have either been reduced or cancelled recently as they were in this system (1979). In some of the sub-stream systems the streamflow incorporated in this report is the unappropriated amount and in others it is not, as is described below for each sub-stream system.

SUB-STREAM SYSTEM 2-5-1

Average annual streamflow for the period of 1938-1976 was computed to be 1,067 cfs (772,508 acre-feet per year). Because of the above assumption on unappropriated water, and since the above streamflow figure is the flow into Eufaula Lake, the unappropriated water is 772,508 acre-feet per year less the amount appropriated from Lake Eufaula within the North Canadian River Basin (773 acre-feet per year) and less the annual average discharge from sub-stream system 2-5-2 which is equal to 105 cfs (76,020 acre-feet per year). Therefore, total unappropriated water entering Lake Eufaula is 695,715 acre-feet per year.

However, it is appropriate to account for evaporation loss from Lake Eufaula. The major contributing streams are the Deep Fork and the North and South Canadian Rivers. Evaporation loss from the lake was proportioned by the amount of water that each stream contributes to the lake, as measured by U.S.G.S. Gage Nos. 07243500, 07242000 and 07231500. Assuming a water surface area at the elevation of the top of the gates, evaporation loss that needs to be compensated by the North Canadian River amounted to 124,700 acre-feet per year. Thus, available unappropriated water is 571,015 acre-feet annually.

SUB-STREAM SYSTEM 2-5-2

The streamflow for sub-stream system 2-5-2 represents the amount that leaves the sub-stream. The annual average discharge for the period considered is 105 cfs (76,020 acre-feet per year). The annual average discharge from sub-stream system 2-5-3 is 176 cfs, of which 110 cfs is a release for use by Oklahoma City. Hence, the discharge to sub-stream system 2-5-2 from 2-5-3 is only 66 cfs (47,784 acre-feet per year), and the total unappropriated water available for appropriation is 39 cfs (28,236 acre-feet per year). Unlike Eufaula Lake, since the streamflow gage is located downstream from the Overholser Dam, evaporation from Lake Overholser is already accounted for.

SUB-STREAM SYSTEM 2-5-3

The sub-stream system flow given in this report is measured below the Canton Dam. However, Oklahoma City uses Canton Reservoir for storage of its water right of 80,000 acre-feet per year to be diverted at Lake Overholser. Therefore, the total available unappropriated water from this sub-stream system, on the average, should equal the streamflow average, less the release for use by Oklahoma City (110 cfs) and less the discharge from sub-system 2-5-4 (48 cfs).

It was stated earlier that the annual average flow for the recorded period of 1938-1976 is 198 cfs and for the recorded period of 1949-1976 it is 176 cfs. The difference between the two averages, among other things, is primarily due to the water retained in the reservoir and evaporation losses from the reservoir since its completion in July, 1948.

Thus, it appears appropriate to adopt the 176 cfs (127,424 acre-feet per year) as the average flow from this sub-stream. Total unappropriated water would then be equal to 176 cfs less 158 cfs (114,392 acre-feet per year) equaling 18 cfs (13,032 acre-feet per year). Evaporation loss from Ft. Supply and Canton Reservoirs is automatically accounted for.

SUB-STREAM SYSTEM 2-5-4

The question of whether existing appropriate water rights have been utilized or not has no significant meaning concerning this particular sub-stream system because of the small number of stream water rights. The unappropriated water is equal to the streamflow minus the evaporation loss from Optima Lake. The annual average flow at the Optima Dam is computed to be 48 cfs (34,752 acre-feet per year). Annual evaporation loss was computed as 0.7 times the average annual pan evaporation of Goodwell times 5,340 acres which is the surface area of the top conservation pool. Its value is 30,265 acre-feet per year. Therefore, unappropriated water from Optima Reservoir is approximately 6 cfs (4,344 acre-feet per year). It should be noted that surface area of the reservoir is not always going to be 5,340 acres.

SUMMARY AND CONCLUSIONS

As stated earlier, the purpose of this investigation is to utilize available data and information to efficiently manage water resources in the North Canadian River Basin. The basin was divided into four sub-stream systems to provide as much actual streamflow measurements as possible for each system. However, runoff from some parts of the basin was estimated due to lack of gages ample to monitor streamflows in each sub-stream system. Table 12 shows a summary of the results.

Monthly water use distribution for municipal and industrial needs increased from January and peaked in July, August or September and declined thereafter. On the overall, average consumption peaked in July. However, no data was available to assess irrigation use distribution on a monthly basis.

It is concluded that unappropriated water is available in the amounts tabulated in Table 12 and that any new appropriations from sub-stream system 2-5-4 should be limited to Optima Reservoir.

For sub-stream systems 2-5-1, 2-5-3, and 2-5-4 the probability that the flow would be equal or greater than the recorded average of the respective sub-streams is 40%, 40% and 36%, respectively. This indicates that appropriating stream water based on the annual average flow is in agreement with Section 654.1 of the Rules and Regulations of the Oklahoma Water Resources Board previously set forth.

RECOMMENDATIONS

Water yield from watersheds, among other factors, is dependent on land uses and farming practices which change with time. Thus, to assess the concurrent and future water needs of the State, it is imperative that appraisal level watershed hydrology studies be conducted from time to time. Furthermore, monthly water use distribution data, especially for the purpose of irrigation, is scarce and deserving of additional attention.

TABLE 12

SUMMARY OF RESULTS

SUB-STREAM SYSTEM	AREA SQ. MI.	ANNUAL AVERAGE PRECIPITATION (IN)	ANNUAL AVERAGE PAN EVAPORATION (IN)	ANNUAL AVERAGE STREAMFLOW CFS	IRRIGATION REQUIREMENT FOR ALFALFA AC-FT/AC	APPROPRIATED WATER AC-FT/YR	UNAPPROPRIATED WATER AC-FT/YR
2-5-1	1,990	37.23	68.46	1,067	1.2	158,583	571,015
2-5-2	734	28.78	66.77	105	1.5	83,381	28,236
2-5-3	7,459	23.61	91.02	176	1.8	11,330	13,032
2-5-4	5,029	17.33	97.16	48	1.9	723	4,344

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