ANALYSIS OF WATER YIELDS OF THE SOLOMON RIVER BASIN, KANSAS

by

JOSEPH WARREN MILLER

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Major Professor

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CHAPTER 1

INTRODUCTION

Water is a valuable and sometimes scarce resource in western Kansas. A major source of water supply for northwest and northcentral Kansas is the Solomon River and its reservoirs. Located in an area that is primarily agricultural and dependent on irrigation, the Solomon River has become an increasingly important asset to Kansas. The water supply to this river is highly dependent upon precipitation that is often erratic and unreliable. The problems in the Solomon River Basin have ranged from flood to drought. The major dams on the Solomon River have provided a more consistent water supply to the area; however, even in the last three decades changes have taken place in the Solomon River Basin that have severely affected the flow in the river. Some the changes can be attributed to nature's sometimes erratic precipitation, and other changes are due to man's intervention. The objective of this report is to investigate the relationship between precipitation and basin yield, and to use this relationship to demonstrate how man's changing use of the land has affected the Solomon River Basin's water yield.

Study Area

The Solomon River Basin is an area of approximately 6,770 square miles located in northwestern and northcentral Kansas. The river originates west of the city of Colby where it consists of a north and south fork. The two forks wind their way eastward toward Cawker City where they join into the main stem of the Solomon River. In the western part of the basin, the river flows above the water table and is almost entirely dependent on precipitation. In the eastern part, particularly between Beloit and Niles, the river has cut below the water table and groundwater flow helps to sustain the flow (KWRB, 1981). The river becomes perennial in Sheridan County (USBR, 1978). The Solomon River continues to flow east and southeast where it flows into the Smoky Hill River which subsequently flows into the Kansas River. The Solomon River Basin is considered part of the Kansas River Basin, which is part of the larger Missouri River Basin. This study includes both the north and south forks of the river and the main stem of the river.

Settlement of this area began in the late 1850's with the reports of excellent crop yields and access to railroads. Dryland farming was somewhat successful, but insufficient rainfall, severe winds, and floods made farming difficult. Farmers often dug deep wells and built windmills to pump water for irrigation. In 1902, the Bureau of

Reclamation was created by Congress; however, it was not until 1944 that the Bureau began extensive planning for Kansas water resource development. The Flood Control Act of 1944 authorized the Missouri River Basin Project. This was a project throughout a ten state region designed to regulate the rivers of the Missouri River Basin for irrigation, flood control, electric power, navigation, and fish and wildlife conservation. In 1951, one of the most destructive floods in the history of Kansas occurred. The destruction caused by this flood helped to expedite construction of two dams on the Solomon River: Kirwin Dam on the North Fork and Webster Dam on the South Fork. Construction on these dams was started within the next two years. The flood of 1951 also caused planners to reevaluate the original design storage capacity of the dams and to double their flood storage capacities. Kirwin Dam was completed in 1958, and Webster Dam was completed in 1961. The last Missouri River Basin project to be completed in the Solomon River Basin was the Glen Elder Dam on the Solomon River near the city of Beloit. The Glen Elder Dam forms Waconda Lake which has a storage capacity of almost one million acre-feet, of which three-fourths is devoted to flood control (USBR, 1979). In addition to being a key element in the flood control plans of the basin, it serves as the municipal water supply for the city of Beloit.

Although flooding expedited the construction of these dams, their primary purpose is for water supply. In the past two decades, low flows in the river have caused water supply problems that threaten the effectiveness of the existing reservoirs. Both Webster and Kirwin Dams have experienced declining inflows, although Webster has had the most severe problem. In fact, in 1972 the Webster Irrigation District did not release any water from the reservoir for irrigation, and since then, less than full releases for irrigation have become the norm. The flows have generally been declining since the mid 1960's. Figure 3 shows that the entire basin had an average yield of 471,000 acre-feet prior to 1964 and an average yield of 278,000 acre-feet after 1964. This is a decline of approximately 40 percent.

Much previous work and research relating to the Solomon River has been completed. In 1976, the Bureau of Reclamation created the Solomon River Basin Management Study to investigate the reasons for the declining yield of the basin. Since 1978, the Solomon River Basin Management Study has published periodic public information bulletins on research progress (USBR, Bulletins 1-7, 1978-1982). Additionally, it has published major studies on runoff and ground analysis of the basin. Zovne et al. (1978) completed part II of the working paper "Soil and Water Conservation Practices Effects on the Water Budget of the

Solomon River, 1978". This study, with the best data available, estimated the effects of conservation practices on the basin. Another report by Koelliker et al. (1981) evaluated the effects of agricultural soil and water yield on the South Fork of the Solomon River. This study utilized a hydrologic computer simulation model with which the annual yield of the basin could be closely predicted. All of the previos studies concluded that conservation practices and irrigation pumping have caused extreme changes in the yield of Solomon River Basin. The difficult and underlying question is determine how much effect each of these factors has had upon the basin.

CHAPTER 2

METHOD OF ANALYSIS

Concept

The flow in the Solomon River is primarily dependent on direct runoff, which is a result of precipitation in the basin. Baseflow is of lesser importance, particularly in the far west where the river only flows during wet periods. The overall objective of this study was to use estimates of direct runoff and baseflow to predict the yield of the basin, and subsequently to use this prediction to show how conservation practices have changed the yield. This was done by predicting the yields for a set of land use conditions prior to the widespread use of conservation practices and then holding these conditions constant in the prediction method through the period of study. It was expected that this procedure would give a good prediction of yield prior to the widespread use of conservation practices and would give high predictions afterwards. The period of study used was 1920 to 1980.

Two methods of analysis were used. The first method was an adaptation of the method used in the Republican River Study (Koelliker et al., 1983) in which relative annual inflow to its reservoirs was predicted. The second method was a statistical correlation of two variables, annual runoff and annual precipitation, to the annual yield. Major assumptions used in the analysis were:

(1)Direct runoff is the major contributor to the Solomon River flow.

(2)Variations in annual evapotranspiration could be neglected and relative annual yield could still be predicted.

(3)The Soil Conservation Service (SCS) runoff equation would give good estimates of runoff on a long-term basis.

(4)Storm intensity could be neglected by using the SCS equation over an annual period

(5)Land use conditions were relatively constant prior to the widespread use of conservation practices.

Determination of Runoff

Surface runoff occurs when the rainfall rate is greater than the infiltration rate. The method used in this study to determine runoff from the basin was developed by the Soil Conservation Service (SCS). Factors which this method considers are: the amount of rainfall, soil type or infiltration capacity of the soil, land use, conservation practices, and the antecedent moisture condition of the soil (SCS, 1972).

The SCS method uses the equation:

$$Q = \frac{(P-.2S)^2}{P+.8S} \qquad (1)$$

where

Q = runoff in inches.

P = amount of rainfall in inches.

S = maximum potential abstraction (or the amount of rainfall that does not runoff).

The .2S term is the initial abstraction which consists mainly of interception, infiltration, and surface storage. It has been empirically determined by the SCS that .2 of the maximum potential abstraction occurs before any runoff occurs. Precipitation must exceed .2S before any runoff is expected. It has been found that the maximum potential abstraction can estimated by the equation:

and $$S = \frac{1000}{CN} - 10 \qquad (2)$$

where

CN= curve number

The curve number represents the relative ability of a surface to produce runoff. It is a function of soil infiltration capacity, land use, conservation practices, and the antecedent moisture content of the soil.

From Equation 1 it can be seen that a threshold precipitation amount must be reached before a positive value for runoff is obtained. This mathematical equation is based on the assumption that runoff does not occur until a saturation limit of the soil has been reached and the infiltration rate no longer exceeds the precipitation rate (SCS, 1972).

Collection of Data

Precipitation data. Since the objective of this study was to analyze as large a time period as possible, representative stations had to be selected that would give long continuous records of rainfall data. All the stations selected had a continuous record for the period 1920-1980 (see Table 1). The eleven stations selected were: Colby, Hoxie, Norton, Hill City, Plainville, Phillipsburg, Alton, Smith Center, Beloit, Lincoln, and Minneapolis. The Thiessen polygon method (Linsley et al., 1981) was used to divide the basin into polygonal areas and then to weight the data for each station in proportion to its respective area. Figure 2 shows the Thiessen areas as they appear on a map of the basin. Table 2 shows the planimeter readings of areas and the determination of their weighting values.

Due to the hydrologic soil-cover complex of the basin, only rainfalls over one inch would produce appreciable runoff. For example, an area with a CN of 65 must have a rainfall of 1.08 inches before any runoff is predicted by the SCS runoff equation. For this reason, only daily rainfall events over 1.00 inch were collected for the eleven stations for the period 1920 - 1980. Daily rainfall records for the stations selected are maintained by National Oceanic and Atmospheric Administration (NOAA) and reported in Climatalogical Data, Kansas. These data were collected, and a micro-computer program was written which was able to file all the data and recall it for later calculations.

Basin yield. The gauging station that best represented the yield of the entire basin is at Niles, Kansas. The river flow data is measured by the U.S. Geological Survey and reported in Water Supply Papers (USGS, 1920-1980). The annual yield in acre-feet for the calendar year was recorded and filed on the micro-computer disk for later analysis.

Curve number data. The SCS curve number represents a surface's relative ability to produce runoff. With a curve number of 100 all rainfall would result in runoff. For a smaller curve number, the runoff would be less. The curve number is a function of the infiltration capacity of the soil or soil type, the use of the land (which includes conservation practices and land condition), and the antecedent moisture condition of the soil. All of these factors must be determined before the curve number can be estimated. The SCS has developed a table for determination of the curve number based on these factors (see Table 4). The methods used in this study to determine each factor of the curve number are described in the following paragraphs.

Soil types. Differences in the ability of soils to absorb rainfall or to produce runoff has led to the classification of soils into hydrologic groups. The classifications can be found in the National Engineering Handbook (SCS, 1972) and other hydrologic publications. The soil type throughout any of the Thiessen areas was not constant, nor did the Thiessen boundaries form good divisions for the different soil types. This presented the problem of determining the soil types that best represented the entire Thiessen area. This was done by estimating the percent of each soil type in the area and weighting each particular type of soil accordingly. The reference used for this determination was The Missouri River Basin Comprehensive Framework Study (1969). For example, in an area where the soil type was classified 50% group B and 50% group C, the runoff curve number was the mean of the the group B and group C curve number. The soil types for all the stations used are shown in Table 7.

Land use. Another factor that is considered in determination of the curve number for the SCS runoff equation is the land use. It is obvious that, for a given storm, runoff from a land surface used for pasture would be different from one used for row crops. The SCS method compensates for this by adjusting the SCS curve number for different types of land use. To determine the land use of each area, the U.S. Census of Agriculture was used as a reference (USDC, 1977). The land use in the basin is primarily pasture/range and croplands. The proportions are approximately equal and have not changed much with time. The percentages for each land use were calculated from the 1974 land use data. In determining the curve number, the non-terraced and non-contoured conditions were used to more closely approximate conditions prior to the advent of conservation practices. The county that dominated each Thiessen area was used to determine the predominant land uses. To simplify the immense task of determining specific land use, all of the land was considered to be one of four different uses. These uses were: fallow, row crops, grain crops, and pasture and others. Division of the land uses into these categories was modeled after the study of the Republican River Basin (Koelliker et al., 1983). All land that was not fallow, row crop, or grain crop was considered to have the same curve number as pasture. The land use data is shown on Table 5. The percentages of each type of land use were then used to weight and calculate the curve number.

Antecedent moisture condition. The final variable considered in determining the curve number was the antecedent moisture condition (AMC). AMC is the amount of water contained in the soil at the beginning of the rainfall. AMC I is dry, AMC II is moist, and AMC III is wet. Since determining the AMC before each rainfall event for the last 61 years would be an immense task, data was collected for the percentage of time in AMC I, II, and III for each Thiessen area. This data was obtained from the SCS in Salina, Kansas which had previously determined the percentages for the following stations: Colby, Hoxie, Hill City, Phillipsburg, Alton, Ellsworth, Belleville, Manhattan, Norton, and Hays. The variations in the percent of time in AMC I, II, and III were approximately linear with east-west distance; therefore, the values for the other stations that were needed were interpolated (see Table 4).

Determination of Curve Number

With the soil type, land use, and AMC determined, an average curve number for each station was determined. Table 4 is a reprint of the table of curve numbers for different hydrologic soil-complex covers as developed for the Republican River Study. These values were applied to the Solomon River and were used for determination of the curve number for each Thiessen area. Table 7 shows the the curve numbers determined by using a weighting technique. For example, the soil around Colby was determined to be primarily group B soil. The CN for AMC II in group B soil for the four different land uses was determined from Table 4. These values were then weighted by the appropriate percentages of land use (Columns c-f on Table 7). This resulted in an average AMC II curve number for the area. Finally, the percentage of overall time that an area was in AMC I, II, or III was used as a weighting factor to determine the final curve number. For example, Colby was in AMC I 95% of the time, AMC II 3.2%, and AMC III 1.8% of the time for a final weighted CN of 59.

Analysis of Data

The method of analysis that was first used on the data was a modification of the method used in the study of the Republican River Basin (Koelliker et al., 1983). In the Republican River Basin study, rainfall events were divided into daily rainfalls of 1.00 - 1.49 inches, 1.50 - 1.99 inches, and 2.00+ inches. The duration of each rainfall was collected so that each storm could then be classified according to its total rainfall and duration. Using historical data, each storm classification was assigned an average expected runoff. In the Republication River Basin, it was found that the relative amount of inflow could be approximated by the equation:

$$PINF = (1-A)P + A*IF^2 \qquad (3)$$

PINF is the predicted relative amount of average annual inflow. Relative amount is defined as the value for a particular period divided by the long-term average and expressed as a percentage. The P term is the relative annual rainfall and represents the effect that base flow had on the river yield. Specifically, it was determined by dividing the annual precipitation by the long-term average. The IF term in the PINF equation is the relative intensity factor and represents the effect of runoff on the basin yield. Specifically, it was determined by dividing the annual runoff by the average long-term average annual runoff. Annual runoff was determined by summing the runoff estimated for the daily storms as explained above. The A term is an estimate of the relative importance of the runoff factor in determining the relative yield of the basin. The IF term in the equation was squared to account for the wide variation in inflows that could not be accounted for by linear variations (Koelliker et al., 1983). Koelliker (1983) grouped the records into periods of five or more years which had either high or low flow amounts compared to the remainder of the record. A PINF equation was then derived to predict the relative inflow for these periods.

The method used in this study modified the previously described method by inputting each daily rainfall event over one inch into the SCS runoff equation to estimate the runoff produced. No storm duration time was used in the analysis of data for this method. Henceforth, in this report, the second term in the PINF equation will be referred to as the runoff factor (RO). The equation then becomes:

$$PINF = (1-A)P + A*RO^2 \qquad (4)$$

All other terms in the PINF equation were calculated the same as in the Republican River Study. Using this method, the PINF value represented a dimensionless relative value of basin yield. The reliability of the prediction was tested by dividing the actual basin yield by the PINF value and then plotting this value against time. A good PINF would show only small variations with time since the actual yield and PINF vary proportionally.

The second method of analysis used a regression analysis to relate the precipitation and runoff terms to the annual basin yield. In this approach, the yield of the basin would again be predicted by the baseflow and runoff. Annual precipitation was used to account for the base flow contribution. The runoff factor was, as in the previous method, determined by the amount of annual runoff calculated by the SCS equation. The annual runoff for each station was weighted according to its Thiessen percentage to determine the annual runoff for the entire basin.

With the determination of annual rainfall and annual runoff for the entire basin, these two factors were then used as independent variables in a regression analysis to determine their correlation to the annual yield. To determine the combined correlation of annual rainfall and annual runoff to basin yield, a multiple linear regression was conducted. Subsequently, to determine the separate correlations of annual runoff to basin yield and annual

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precipitation to basin yield, bivariate linear regressions were conducted. The linear regressions were tested on both the variables themselves and on their logarithmic scales. The correlation coefficient was determined in all cases. The results of these analyses are discussed in the next chapter.

Use of the Micro-Computer

Analysis of such a large data base required the use of a computer. The micro-computer proved to be economical, efficient, and capable of the task. Specifically, a TRS-80 Model II with 64K memory was used. A program was written that was capable of filing all the precipitation records for the eleven stations and the annual yield data. This information could then be recalled to compute the runoff for each rainfall event in the period of record and to use this information in the analysis methods previously described. The micro-computer was also used to conduct the statistical analyses of the data. This program was capable of conducting a multiple linear regression with two independent variables for the entire 61 years of records. With modifications, the program was also able to file data points and then compute linear regression analyses on the common logarithms of the variables. Since there was no evidence that the relationship would be linear, the options of computing the data in logs made it possible to determine if the data were linear on log-log or semi-log scales. A flow chart of the computer program is shown in Figure 4 with a listing of the program in the Appendix.

CHAPTER 3

RESULTS

Results of Analysis Using PINF Equation

The PINF equation, developed for an analysis of the Republican River Basin (Koelliker et al., 1983), was applied in this study to the Solomon River Basin due to the similarities of the basins. The equation as applied to the Republican River was able to predict relative annual yields of the basin. The value of A that best fit the Republican River was found to be .7 (Koelliker et al., 1983). It was not assumed that the same value of A would fit the Solomon River; however, it was a good starting value for a trial and error approach. As explained in the previous chapter, the test of the validity of the PINF was the amount of variation of its plotting value (actual yield divided by PINF). A small deviation from the mean plotting value indicated that PINF was a good relative predictor. A good predictor, when converted to a plotting value, would plot as an approximate horizontal line, with time on the abscissa and plotting value on the ordinate. Some variation could be removed by using the moving average of the plotting value. It was expected that this horizontal plot would show a sharp decrease when extensive conservation practices began to be used.

The first analysis of the data using the PINF equation was conducted using a value of .7 for A. The PINF was calculated for each year of record, and the three-year moving average was taken of the plotting value (Table 8). Figure 5 shows a graph of these plotting values. The graph does show an average decrease in the plotting value after the mid 1960's; however, it was judged that the PINF plotting values were too variable to consider PINF a good predictor. These values had a mean of 5,286 (acre-feet/PINF) and a standard deviation of 2,349. Various other values of A were tried with no significant improvement in the variability of the plotting value.

Results of Statistical Analysis

Since the modified application of the PINF equation did not appear to be valid for the Solomon River Basin, an attempt was made to find the relationship between annual precipitation, annual runoff, and annual yield by means of regression analyses. Bivariate and trivariate linear regressions were conducted to determine the correlation of the variables. Yield was considered to be the dependent variable while annual precipitation and annual runoff were considered independent variables. There was no reason to expect that any of the regressions would be arithmetically linear; however, mathematical methods could be used to make exponential relations plot as linear. To establish the correlation, only the first 30 years of data were used, so that the effect of increased conservation practices on the curve number would not be a variable.

Initially, a trivariate linear regression was conducted to determine the correlation of both independent variables to the basin yield. Subsequently, bivariate linear regressions (using only one independent variables) were conducted to determine which variable had the strongest effect on the yield.

The results of the trivariate linear regression showed that on a arithmetic scale the best fit relationship had a coefficient of determination, R^2, of .67. This was the best correlation that was achieved. The logarithmic and semi-logarithmic plots had R^2 values of .63 and .60, respectively (see Table 9). The best trivariate linear regression relation was found to be:

$$Y = .1002 \times P + .2258 \times RO - 1.2765 \qquad (6)$$

where:

Y= annual yield in inches

P= annual precipitation in inches

RO= annual runoff in inches

The standard error of estimate was .4021 inches. This standard error was 35% of the average yield and was too large to consider the equation to be a good predictor of yield.

To determine which independent variable had the strongest correlation to yield, two bivariate linear regressions were conducted. The first regression correlated annual precipitation to annual yield. This analysis gave the best correlation on an arithmetic scale. The coefficient of determination, R^2, was .67 (see Figure 6 and Table 10). While the correlation was not particularly strong, it was considered to be significant. The regressions on semi-logarithmic and full logarithmic scales had R^2 values of .64 and .60, respectively. The second bivariate linear regression correlated annual runoff to annual yield. The best correlation was achieved on an arithmetic scale. This R^2 value was .35, which was considered too low to be significant (see Table 11).

Since neither of the two methods of analysis appeared to be a good predictor of yield, a comparison of similar years was conducted to better understand the results of the analyses. For example, years were selected that had similar annual precipitation and annual runoff data; their yields were then compared. Believing that the period 1920-1950 had stable land use conditions, all the comparisons were done within these years.

Example:

Year	Annual Precip(in.)	Estimated Annual Runoff x 100(in.)	Yield (ac-ft)
1927	25.90	45	794,000
1948	24.64	47	495,000

In this case, the yield of 1927 was almost twice that of 1948, although they had almost equal precipitation and runoff statistics.

A comparison of two years of equal precipitation but different runoffs shows again that the yield is not consistent with what would be expected.

Example:

Year	Annual Precip(in.)	Estimated Annual Runoff x100(in.)	Yield (ac-ft)
1923	22.17	19	458,000
1938	21.14	40	267,000

In this case, it was expected that the yield of 1938 would be higher than 1923; however, the opposite was true.

The above comparisons are not isolated cases. What they do seem to indicate is that there may be one or more other variables that are affecting the yield, or possibly that the predictions of runoff used in this study are not representative of the actual runoff.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

Using only the variables annual precipitation and annual runoff, with runoff calculated by the SCS equation, it is not possible to accurately predict the relative annual yield of the Solomon River. The test of the PINF equations showed that their predictions were innaccurate, while the best statistical correlation of the variables to the annual yield showed only a moderately strong correlation. The best fit relationship had a R^2 value of .67 with a coefficient of variation of 35%.

The bivariate regression analysis of the runoff and yield data showed that runoff has a very weak correlation with the annual yield, while annual precipitation showed a much stronger correlation to the annual yield. It was expected that runoff would have a stronger correlation with yield, since it was believed that runoff is the predominant source of inflow into the Solomon River. For this reason, it appears that the runoff predictions for the basin may be inaccurate. As stated in the previous chapter, the SCS equation for predicting runoff does not consider the intensity of the rainfall. In an area that typically has intense and violent storms, this may be a significant source of error in runoff prediction.

Selection of the antecedent moisture conditions could have another source of error in determining runoff. The AMC values of the basin areas frequently change. In this analysis, the percentage of time in each AMC was used to weight the final curve number. This curve number was expected to account for changing AMC values over an annual term. However, it may be that this weighted curve number did not actually account for the effects that the actual changes in AMC had on the runoff.

As stated in the assumptions, evaporation and transpiration were not considered directly in the analysis. If evapotranspiration was a constant percentage of precipitation, then it would have little effect upon a relative yield prediction. However, due to the variation in temperatures, humidity, and number of sunny days, the effect of evapotranspiration may have had a significant effect on relative yield. Additionally, with the large impoundment of water in the three major reservoirs and an increase in the number of farm ponds, the effect of evaporation becomes increasingly important. During the fill-up periods of the three major reservoirs, the yield recordings at Niles are invalid for a representation of the entire basin yield. In this anaylsis, the tests of the PINF values and the statistical regressions were based on the years prior to the fill-up periods of the reservoirs, so this fact did not have a direct effect on the results of the analysis. However, this fact needs to be considered whenever analyzing the basin yield.

Although this study was not able to identify a good predictor of relative yield in the Solomon River Basin, it has shown that the basin yield and runoff, as predicted by the SCS equation, have a weak correlation. Under the premise that the flow of the Solomon River is primarily supported by runoff, one could conclude that the SCS runoff equation as used in this study did not give a valid representation of true runoff or that there are other factors that have a major effect on yield that were not considered in the analysis.

It is recommended that rainfall intensity should be considered when trying to determine runoff for an analysis of yield. Koelliker et al.(1983) presented a technique of determining average intensity factors for various amounts of precipitation from hourly precipitation records (see Koelliker, et al.,1983, Table 21). Using this method, any rainfall amount could be assigned an average runoff based on past hourly precipitation records. Because of the similarities between the two basins, there is a possibility that the same average intensity factor could be used for the Solomon River Basin and acheive better results. Furthermore, it is recommended that any further analysis of the basin be conducted on smaller elements of the basin such as the river reaches into and between the reservoirs. This would decrease the variability of almost all of the factors used in attempting to predict the yield.

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15. Zovne, J. J., J. K. Koelliker. 1978. Working paper on soil and water conservation practices effects on the water budget of the Solomon River Basin, Kansas, part II. USDI, Bureau of Reclamation, Lower Missouri Region, Denver, CO.

APPENDIX

Listing of computer program used to calculate basin annual precipitation, annual runoff, and predicted inflows (PINF).

```
100 FC=0
200 INPUT "WHAT IS THE NAME OF THE STATION";S$
205 INPUT "DO YOU WANT TO USE AN EXISTING FILE OR UPDATE A F
ILE (Y/N)";A$
210 IF A$="Y" THEN 1400
215 INPUT "REM YOU ARE CREATING A NEW FILE & DESTROYING OLD,
PRESS Y TO CONTINUE OR N TO START OVER";C$
216 IF C$="Y" THEN 300
300 INPUT "WHAT IS ITS CN";CN
450 INPUT "WHAT IS THE START YEAR OF RECORD";B
455 INPUT "WHAT IS THE END YEAR OF REACORD?";E
456 YR=E-B+1
460 DIM AP(YR),I(YR),P(YR,20),J(YR)
468 OPEN "O",1,S$
469 PRINT #1,S$
470 PRINT #1,B
471 PRINT #1,E
472 PRINT #1,CN
475 LPRINT "        **** STATION:";S$,"****"
476 LPRINT " "
477 LPRINT "CN IS ";CN
490 FOR N=1 TO YR :PRINT
495 PRINT"FOR YEAR ";B+N-1
500 INPUT "WHAT IS THE ANNUAL PRECIP?";AP(N)
502 PRINT #1,AP(N)
600 INPUT"HOW MANY RAINFALL EVENTS WERE OVER 1.00 INCHES FOR
 THIS YEAR?";J(N)
605 PRINT #1,J(N)
610 S=1000/CN-10
700 FOR K=1TO J(N)
800 INPUT "INPUT VALUE OF RAINFALL OVER 1.00 INCH";P(N,K)
802 PRINT #1,P(N,K)
810 IF P(N,K)<.2*S THEN 900
815 Q=((P(N,K)-.2*S)^2/(P(N,K)+.8*S))*100
820 I(N)=I(N)+Q
900 NEXT K
950 PRINT #1,I(N)
1000 C=C+1 : IF C>1 THEN 1020
1009 LPRINT "           ANNUAL     INTENSITY    # OF RAINFALL
               RAINFALL EVENTS""
1010 LPRINT " YEAR      PRECIP       FACTOR     EVENTS OVER 1.0
0 "
1020 LPRINT USING"     ####     ##.##      ###          ##     ";
B+N-1,AP(N), I(N), J(N);
1022 FOR K=1 TO J(N)
1024 LPRINT USING "##.##";P(N,K);
1026 NEXT K
1028 LPRINT""
```

```
1300 NEXT N
1350 CLOSE #1
1355 GOTO 10000
1400 OPEN "I",1,S$
1500 INPUT #1,S$
1600 INPUT #1,B
1700 INPUT #1,E
1710 INPUT #1,CN
1800 YR =E-B+1
1850 DIM AP(YR),P(YR,20),J(YR),I(YR)
1900 FOR N=1 TO YR
2000 INPUT #1,AP(N)
2050 INPUT #1,J(N)
2100 FOR K=1 TO J(N)
2200 INPUT #1,P(N,K)
2300 NEXT K
2400 INPUT #1,I(N)
2450 NEXT N
2460 CLOSE #1
2500 IF FC=1 THEN 2700
2590 INPUT "DO YOU WANT TO MAKE ANY CORRECTIONS(Y/N)";CR$
2592 IF CR$="Y" THEN 7010
2600 INPUT "DO YOU WANT TO ADD DATA TO AN EXISTING FILE?(Y/N
)";AF$
2610 IF AF$="Y" THEN 3990
2620 IF AF$="N" THEN 2700
2700 LPRINT "          ****STATION:";S$,"****"
2800 LPRINT""
2900 LPRINT "CN IS";CN
2950 FOR N=1 TO YR
3000 C=C+1:IF C>1 THEN 3300
3100 LPRINT   "              ANNUAL      INTENSITY     # OF RAI
NFALL              RAINFALL EVENTS"
3200 LPRINT "   YEAR       PRECIP        FACTOR      EVENTS OVE
R 1.00 "
3300 LPRINT USING"   ####       ##.##           ###          ##
          ";B+N-1,AP(N),I(N),J(N);
3400 FOR K=1TO J(N)
3500 LPRINT USING"##.##";P(N,K);
3600 NEXT K
3700 LPRINT""
3800 NEXT N
3890 IF FC=1 THEN 8000
3900 IF AF$="N" THEN 8000 :IF FC=1 THEN 8000
3990 PRINT "THE PERIOD OF RECORD FOR THIS FILE IS";B;"TO";E
3995 DIM XAP(YR),XI(YR),XJ(YR),XP(YR,20)
4000 INPUT "HOWMANY ADDITIONAL YEARS DO YOU WANT TO ADD DATA
 FOR?";Y
4002 FOR N=1 TO YR
4004 XAP(N)=AP(N): XI(N)=I(N): XJ(N)=J(N)
```

```
4006 FOR K=1 TO J(N)
4007 XP(N,K)=P(N,K)
4008 NEXT K
4010 NEXT N
4012 YX=YR
4014 NY=YR+Y
4020 ERASE AP :ERASE I: ERASE J :ERASE P
4025 DIM AP(NY),I(NY),P(NY,20),J(NY)
4050 S=1000/CN-10
4100 FOR L=1 TO Y
4200 PRINT:PRINT"FOR THE YEAR ";E+L
4300 INPUT "WHAT IS THE ANNUAL PRECIP?";AP(YX+L)
4400 INPUT "HOW MANY RAINFALL EVENTS OVER 1.00 FOR THIS YEAR
?";J(YX+L)
4500 FOR K=1 TO J(YX+L)
4600 INPUT"INPUT THE VALUE OF THE RAINFALL EVENTS OVER 1.00"
;P(YX+L,K)
4601 IF P(YX+L,K)<.2*S THEN 4700
4602 Q=((P(YX+L,K)-.2*S)↑2/(P(YX+L,K)+.8*S))*100
4603 I(YX+L)=I(YX+L)+Q
4700 NEXT K
4800 NEXT L
4900 E=E+Y
4910 FOR N=1 TO YR
4920 AP(N)=XAP(N): I(N)=XI(N): J(N)=XJ(N)
4925 FOR K=1 TO J(N)
4930 P(N,K)=XP(N,K)
4935 NEXT K
4940 NEXT N
4949 PRINT""
4950 INPUT "ANY CORRECTIONS?(Y/N)";CR$
4951 IF CR$="Y" THEN 7010
5000 OPEN "O",1,S$
5100 PRINT #1 ,S$
5200 PRINT #1,B
5300 PRINT #1,E
5310 PRINT #1,CN
5315 S=1000/CN-10
5400 YR =E-B+1
5500 FOR N=1 TO YR
5550 I(N)=0 :REM ERASE OLD VALUES
5600 PRINT #1, AP(N)
5700 PRINT #1,J(N)
5750 FOR K=1 TO J(N)
5800 PRINT #1, P(N,K)
5810 IF P(N,K)<.2*S THEN 5900
5812 Q=((P(N,K)-.2*S)↑2/(P(N,K)+.8*S))*100
5814 I(N)=I(N)+Q
5900 NEXT K
6000 PRINT #1,I(N)
```

```
6100 NEXT N
6200 CLOSE #1
6300 FC=1
6400 GOTO 2500
7010 INPUT "WHAT IS THE YEAR YOU WANT TO CORRECT";CY
7020 N=CY-B+1
7022 INPUT "WHAT IS THE ANNUAL PRECIP";AP(N)
7030 INPUT "HOW MANY RAINFALL EVENTS OVER 1.00 INCHES FOR TH
IS YEAR";J(N)
7040 FOR K=1 TO J(N)
7050 INPUT "INPUT THE VALUE OF RAINFALL OVER 1.00 INCH";P(N,
K)
7060 NEXT K
7070 INPUT "DO YOU WANT TO MAKE ANY MORE CORRECTIONS(Y/N)";M
C$
7080 IF MC$="Y" THEN 7010
7090 GOTO 5000
8000 INPUT "DO YOU WANT TO COMPUTE YEARLY PRECIP % , IF % AN
D PINF (Y/N)";P$
8001 IF P$="N" THEN 10000
8002 INPUT "ASSIGN THE APPROPRIATE # TO THIS STATION :1-COLB
Y,2-HOXIE,3-NORTON,4-HILL CITY, 5-PLAINV, 6-PHILB, 7-ALTON,
8 SMTH CTR, 9-BELOIT, 10-LINCOLN, 11-MINNE";AN
8003 PRINT "THE PINF VALUES FOR EACH STATION WILL BE STORED
IN A 2 DIM ARRAY AS: PN(STATION #,YEAR)
8004 DIM PN(11,YR),PT(11,YR),IT(11,YR)
8006 LPRINT:LPRINT"***PRECIPITATION AND INTENSITY FACTOR PER
CENTAGES AND PINF FOR ";" "S$;"***":LPRINT
8007 LPRINT"   YEAR      % OF AVG PRECIP              % OF AVG I
F           PINF""
8008 SA=0 :SI=0
8010 FOR N=1 TO YR
8012 SA= SA+AP(N)
8014 SI= SI+I(N)
8016 NEXT N
8017 AP=SA/YR:AI=SI/YR
8018 FOR N= 1 TO YR
8020 PA =AP(N)/AP
8022 PI=I(N)/AI
8023 PN(AN,N)=(.7*PA+.3*PI↑2)*100
8024 PT(AN,N)=AP(N):REM STORING PRECIP AND IF TO GET THEISSE
NS
8025 IT(AN,N)=I(N)
8028 LPRINT USING "     ####           ###.##
  ####.##            ######.##";B+N-1,PA,PI,PN(AN,N)
8030 NEXT N
8032 LPRINT""
8036 LPRINT"TOTAL  PRECIP ";SA"     ";"AVERAGE PRECIP- ";AP:L
PRINT""
8038 LPRINT"TOTAL IF";SI"     ";"AVERAGE IF- ";AI:LPRINT""
```

```
8060 IF AN>1 THEN 8080
8065 OPEN "O",1,"PINF"
8070 FOR K=1 TO 11
8072 FOR N=1 TO YR
8074 PRINT #1, PN(K,N):PRINT#1,PT(K,N) :PRINT #1,IT(K,N)
8076 NEXT N: NEXT K
8077 CLOSE #1
8078 IF AN=1 GOTO 10000
8080 DIM DF(11,YR), DP(11,YR),DI(11,YR)
8085 FOR N= 1TO YR
8087 DF(AN,N)=PN(AN,N):DP(AN,N)=PT(AN,N):DI(AN,N)=IT(AN,N):R
EM STORE IN DUMMY
8089 NEXT N
9006 B=1920
9010 OPEN "I",1,"PINF"
9015 FOR K =1 TO 11
9016 FOR N=1 TO YR
9017 INPUT #1,PN(K,N)
9018 INPUT#1,PT(K,N)
9019 INPUT#1,IT(K,N)
9020 NEXT N: NEXT K
9025 CLOSE #1
9030 FOR N=1 TO YR
9035 PN(AN,N)=DF(AN,N):PT(AN,N)=DP(AN,N):IT(AN,N)=DI(AN,N)
9040 NEXT N
9045 OPEN "O",1,"PINF"
9050 FOR K=1 TO 11
9052 FOR N= 1TO YR
9054 PRINT#1, PN(K,N):PRINT#1,PT(K,N) :PRINT#1,IT(K,N)
9056 NEXT N:NEXT K
9065 CLOSE #1
9099 IF AN <11 THEN 10000
9100 REM THIS SECTION OF THE PROGRAM COMPUTES WEIGHTED PINF
FOR EACH YEAR
9105 DIM WP(YR),TP(YR),TI(YR):REM WEIGHTED PINF,THEISSEN PRE
CIP,THEISSEN IF
9108 LPRINT "WEIGHTED PINF FOR ENTIRE BASIN"
9109 LPRINT"   YEAR    WEIGHTED PINF   THEISSEN PRECIP       T
HEISSEN IF"
9110 FOR N=1 TO YR
9115 WP(N)=.013*PN(1,N)+.032*PN(2,N)+.044*PN(3,N)+.061*PN(4,
N)+.054*PN(5,N)+.104*PN(6,N)+.126*PN(7,N)+.090*PN(8,N)+.181*
PN(9,N)+.057*PN(10,N)+.238*PN(11,N)
9116 TP(N)=.056*PT(1,N)+.102*PT(2,N)+.085*PT(3,N)+.08*PT(4,N
)+.053*PT(5,N)         +.117*PT(6,N)+.124*PT(7,N)+.118*PT(8,N)
+.136*PT(9,N)+.03*PT(10,N)+.099*PT(11,N)
9117 TI(N)=.056*IT(1,N)+.102*IT(2,N)+.085*IT(3,N)+.08*IT(4,N
)+.053*IT(5,N)+     .117*IT(6,N)+.124*IT(7,N)+.118*IT(8,N)+.1
36*IT(9,N)+.03*IT(10,N)+.099*IT(11,N)
9120  LPRINT USING"      ####        ###.#        ###.##
```

```
 ####     ";B+N-1,WP(N),TP(N),TI(N)
9125 NEXT N
9300 REM CALCULATION OF PLOTTING VALUE: RUNOFF/PINF
9303 GOTO 9350 :REM PREVENTS DESTROYING FILE
9304  OPEN "O",1 ,"YIELD"
9306 DIM YD(YR)
9310 FOR N= 1TO YR
9315 PRINT "WHAT IS THE YIELD AT NILES FOR";B+N-1:INPUT;YD(N
)
9320 PRINT#1, YD(N)
9325 NEXT N
9330 CLOSE #1
9350 OPEN"I",1,"YIELD"
9355 DIM YD(YR)
9360 FOR N= 1TO YR
9365 INPUT #1, YD(N)
9370 NEXT N
9375 CLOSE #1
9380 INPUT "SIZE OF MOVING AVG";YA
9381 LPRINT YA;"YEAR MOVING AVGS OF THE YIELD AND PINF;AND P
LOTTING VALUE":LPRINT"
9382 LPRINT "   YEAR       M-AVG YIELD             M-AVG PINF
    PLOTTING VALUE  "
9384 FOR N=1 TO YR-(YA -1)
9386 MA=YD(N)
9388 FOR K=1 TO YA-1
9390 MA =MA+YD(K+N)
9392 NEXT K
9394 MA=MA/YA
9395 Y=(B+N-1)+(YA-1)/2
9560 MB=WP(N)
9570 FOR K =1 TO YA-1
9580 MB=MB+WP(K+N)
9590 NEXT K
9595 MB=MB/YA
9600 Y=(B+N-1)+(YA-1)/2
9605 PV=MA/MB
9610 LPRINT USING"  ####           #######.#       ######.#
      #####.#";Y,MA,MB,PV
9699 NEXT N
10000 END
```

KANSAS RIVERS

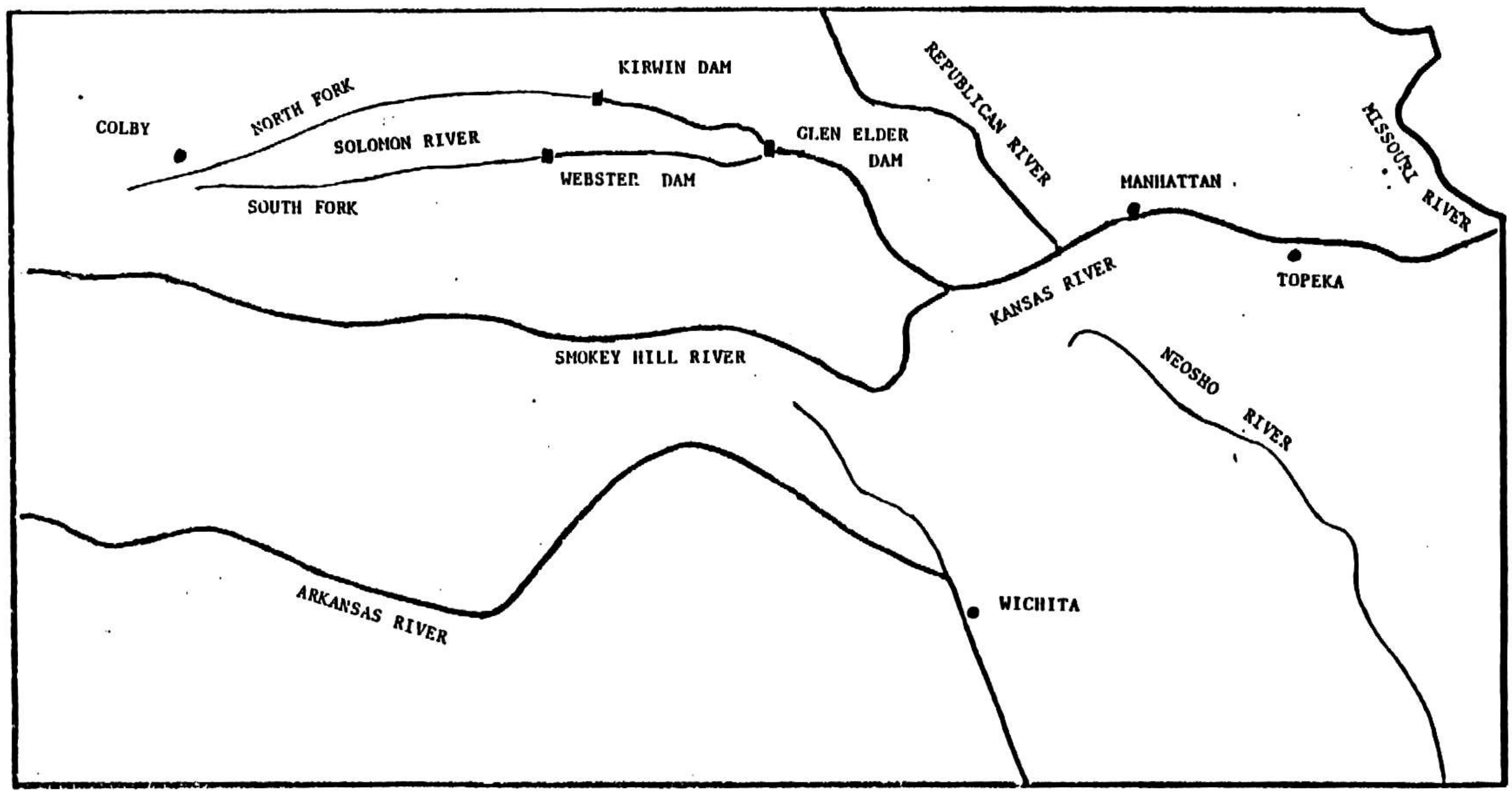

Figure 1. Major Rivers of Kansas

SOLOMON RIVER BASIN
and
THIESSEN WEIGHTED AREAS

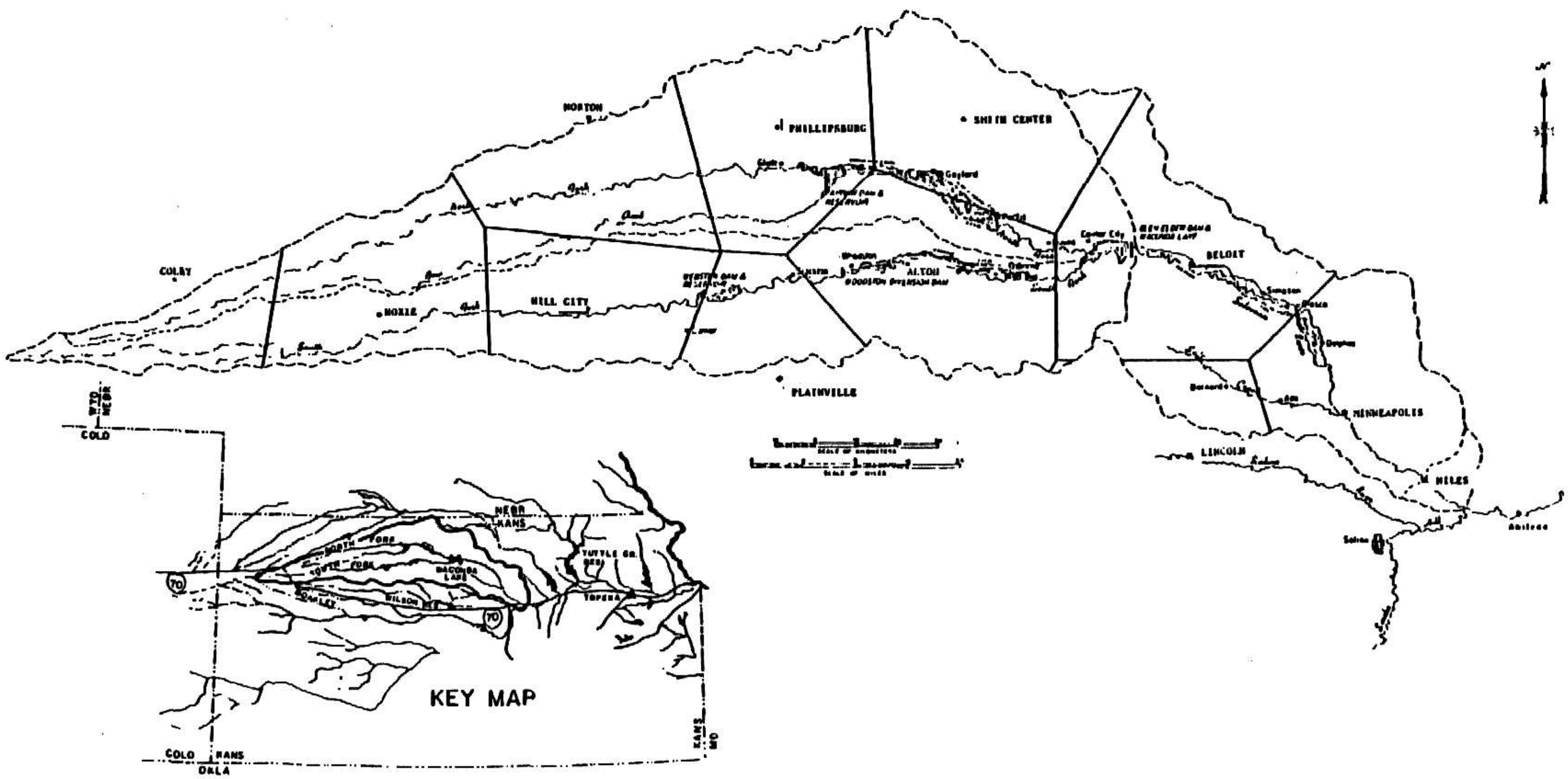

Figure 2. Solomon River Basin and Thiessen Areas

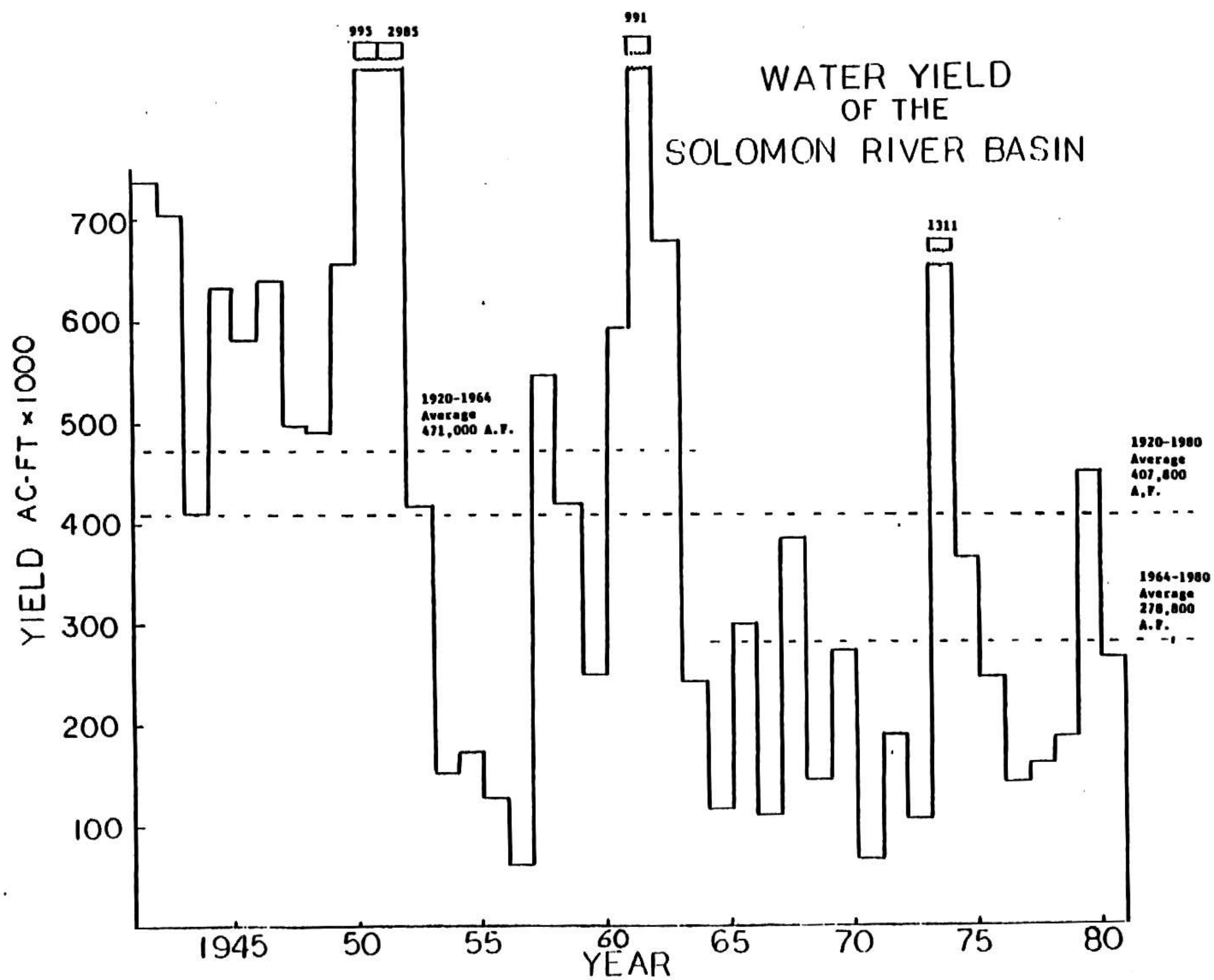

Figure 3. Annual water yields of the Solomon River Basin with average values for the period 1920-1980.

COMPUTER ANALYSIS

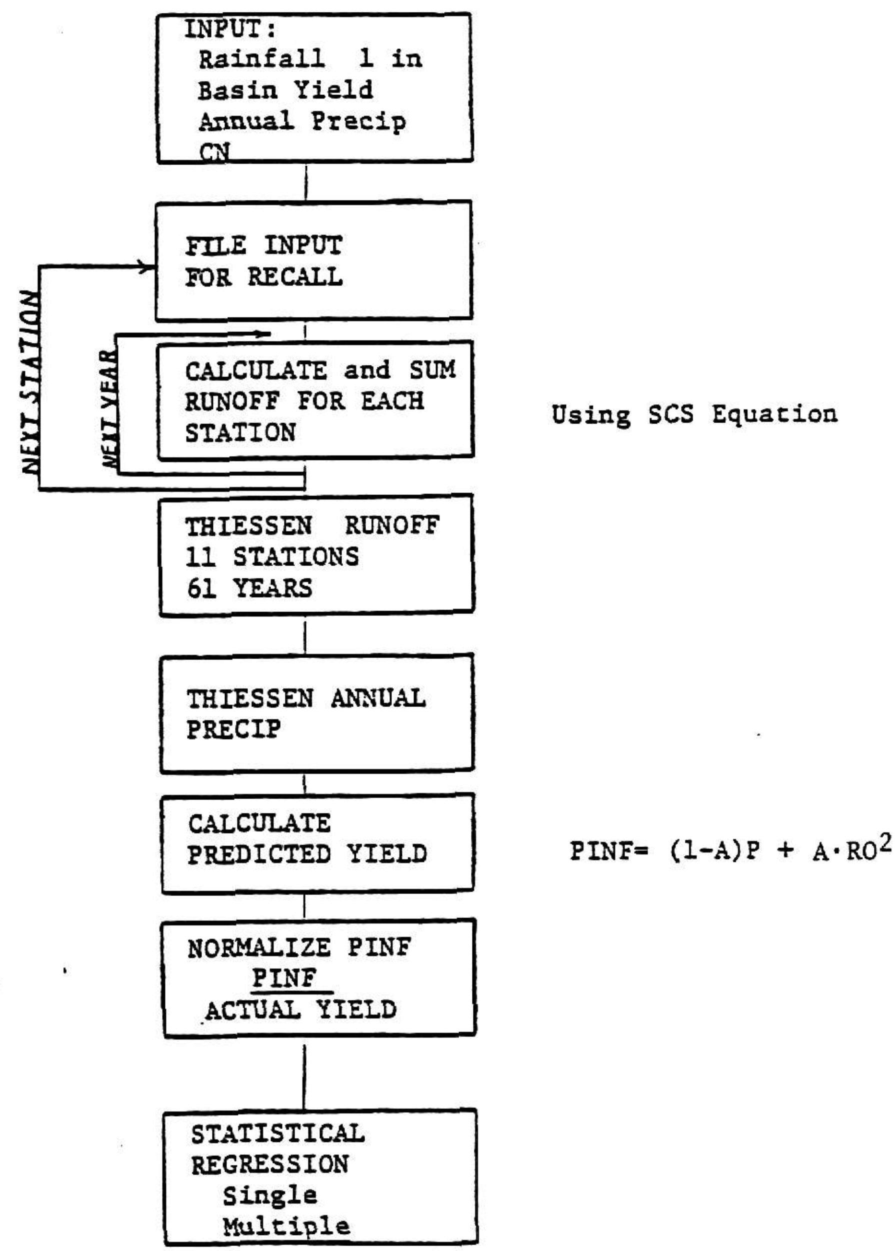

Figure 4. Flow chart for use of micro-computer in analysis

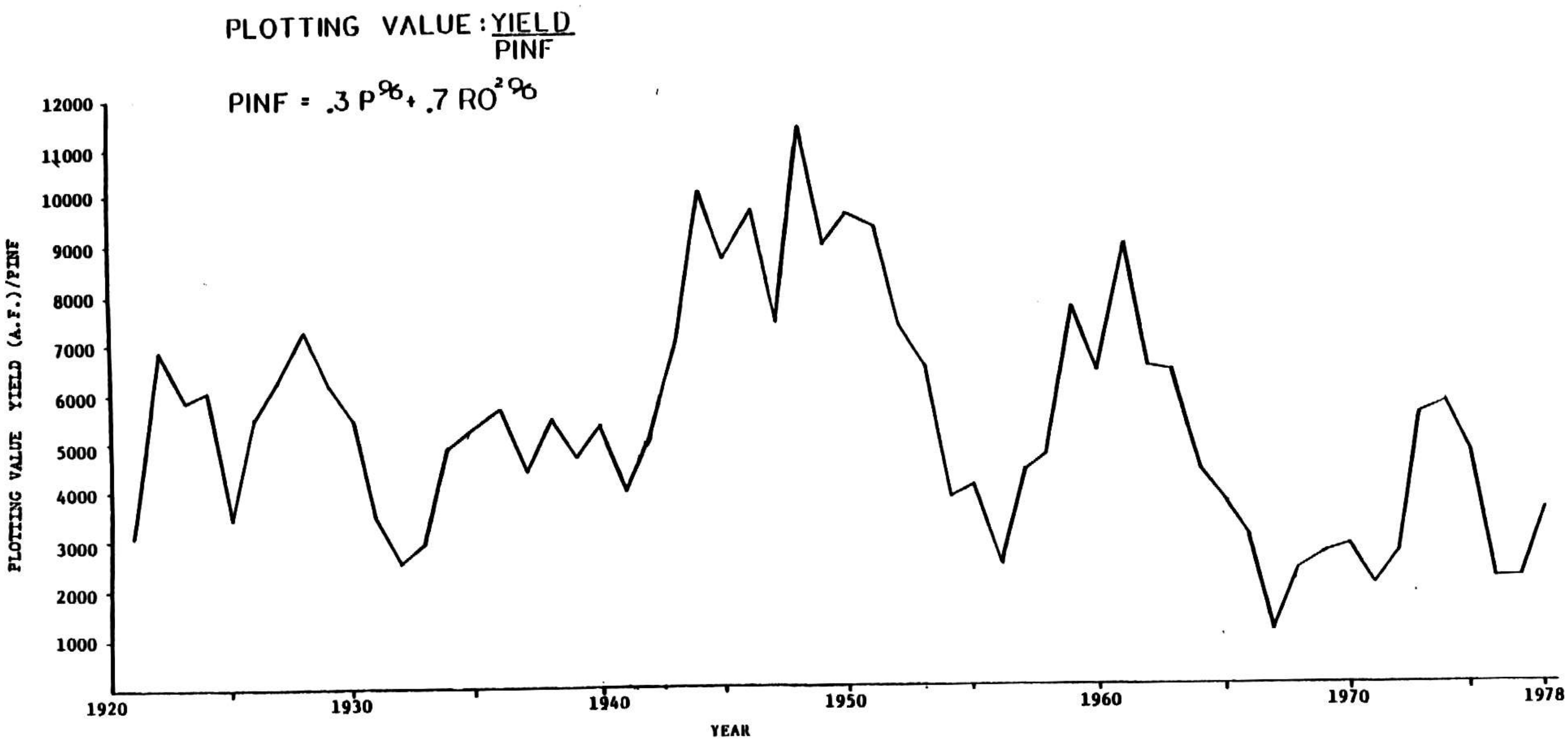

Figure 5. Plotting value of PINF for Solomon River Basin. Test of PINF.

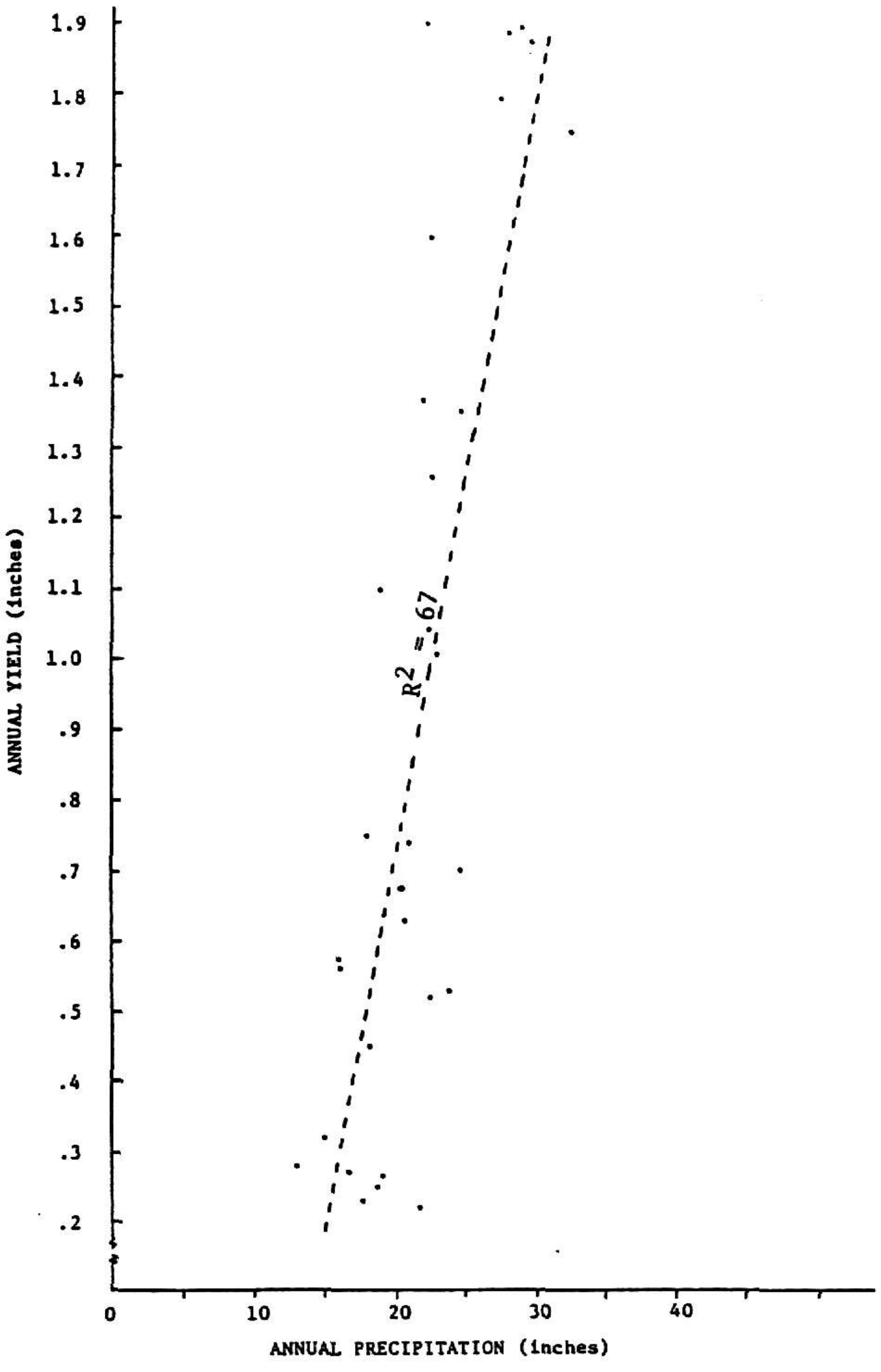

Figure 6. Linear Regression Line of annual precipitation and yield, Solomon River Basin, Kansas, 1920-50

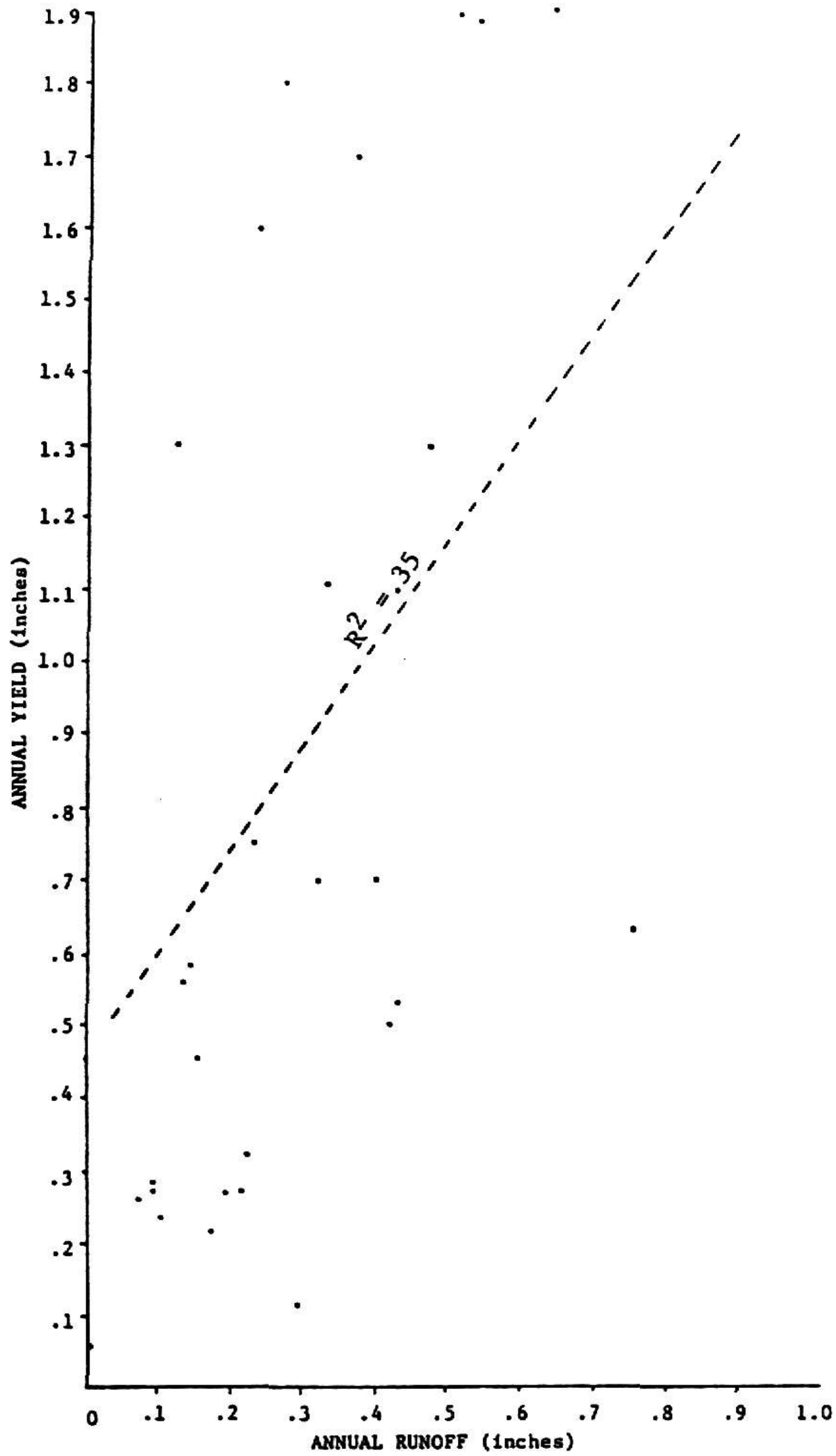

Figure 7. Linear regression line of annual runoff and yield, Solomon River Basin, Kansas, 1920-1950

Table 1. Station index of stations used for precipitation data collection in Solomon River Basin, Kansas.

Station	Latitude	Longitude	Years of Record
Colby 1 SW	3923	10104	89
Hoxie	3921	10027	61
Norton	3942	9950	89
Hill City	3923	9950	72
Plainville	3914	9418	74
Phillipsburg	3944	9919	89
Alton	3928	9856	78
Smith Center	3947	9847	61
Beloit	3929	9806	85
Lincoln	3902	9807	68
Minneapolis	3908	9743	90

Table 2. Thiessen area weightings for Solomon River Basin, Kansas.

Station	Planimeter Area Reading (mi^2)	Thiessen %
Colby	370	5.6
Hoxie	680	10.2
Norton	569	8.5
Phillipsburg	778	11.7
Plainville	356	5.3
Smith Center	789	11.8
Alton	829	12.4
Beloit	911	13.6
Lincoln	200	3.0
Minneapolis	658	9.9
Hill City	537	8.0
Total	6677	100.0

Table 3. Annual yield of Solomon River Basin as measured at Niles, Kansas, 1920-1980 (in acre feet).*

Year	Yield (ac-ft)	Year	Yield (ac-ft)	Year	Yield (ac-ft)
1920	243,000	1940	91,980	1960	588,400
1921	164,000	1941	739,900	1961	991,600
1922	83,000	1942	705,400	1962	675,800
1923	458,000	1943	409,800	1963	239,500
1924	77,400	1944	633,500	1964	115,100
1925	99,200	1945	579,000	1965	298,500
1926	270,000	1946	681,200	1966	111,200
1927	794,000	1947	495,000	1967	383,700
1928	702,000	1948	488,200	1968	143,400
1929	386,000	1949	655,600	1969	260,800
1930	259,000	1950	995,000	1970	63,260
1931	190,000	1951	2,985,000	1971	187,700
1932	193,000	1952	416,200	1972	105,600
1933	98,130	1953	151,500	1973	1,311,000
1934	100,900	1954	173,900	1974	362,400
1935	712,900	1955	126,200	1975	243,900
1936	117,300	1956	59,130	1976	139,100
1937	211,600	1957	543,600	1977	157,700
1938	267,800	1958	416,800	1978	180,400
1939	202,900	1959	246,400	1979	444,600
				1980	232,800

*Values from U.S. Geological Survey, Water Supply Papers, Missouri Basin, 1920-1980, Washington, D.C.

Table 4 Cultivation practices, crop types, and average runoff curve numbers for Antecedent Moisture Condition II on Groups A, B, and C soils.[a]

Description	Runoff Curve Number Group A	Group B	Group C
Pasture	55	70	80
wheat	62	74	82
wheat, graded terrace	*	70	77
wheat, level terrace with open ends	*	68	75
wheat, level terrace with closed ends	56	56	*
wheat, mulched	60	70	78
wheat, graded terrace, mulched	*	66	73
wheat, level terrace with open ends, mulched	*	64	71
wheat, level terrace with closed ends, mulched	52	52	*
row crop	70	78	85
row crop, graded terrace	*	71	78
row crop, level terrace with open ends	*	69	76
row crop, level terrace with closed ends	61	61	*
fallow	74	83	88
fallow, graded terrace	*	77	83
fallow, level terrace with open ends	*	75	81
fallow, level terrace with closed ends	64	64	*
fallow, mulched	69	79	84
fallow, graded terrace, mulched	*	73	79
fallow, level terrace with open ends, mulched	*	71	77
fallow, level terrace with closed ends, mulched	60	60	*

*This practice is not typically encountered on this soil type.

Sources: USDA, Soil Conservation Service. 1972. Hydrology. National Engineering Handbook, Section 4. Washington, D.C.

Holste, Authur H. 1980. Telephone interview by J. K. Koelliker. Soil Conservation Service, Hays, KS.

[a]Adapted from Koelliker et al. (1981) and values for Group A soils added.

[b]Reprinted from Koelliker et al. (1983). Group D CN values from (SCS,1972).

Table 5. Land use in the Solomon River Basin, Kansas (acres as of 1974).

County - City	Summer Fallow	Row Crops	Small Grains	Pasture & Other	Total
Thomas - Colby	224,156	57,969	246,038	156,357	684,520
Cheridan - Hoxie	96,265	54,871	105,542	314,778	571,456
Graham - Hill City	86,358	34,395	113,636	336,081	570,470
Norton	90,953	35,414	104,297	327,416	558,080
Phillipsburg	81,209	53,942	93,185	345,872	574,208
Rooks - Plainville	93,155	29,530	114,768	329,971	567,424
Smith - Smith Center	62,205	82,241	107,652	319,422	571,520
Osborne - Alton	66,238	50,839	127,470	322,235	566,782
Mitchell - Beloit	47,803	63,796	171,975	173,386	456,960
Lincoln	1,361	42,259	13,950	406,546	464,116
Ottowa - Minneapolis	8,998	33,387	151,259	268,694	462,338

Data from: U.S. Department of Commerce, 1977 U.S. Census of Agriculture, 1974. Kansas, Vol. 1, pt. 16, Washington, D.C.

Table 6. Percentages of antecedent moisture conditions (AMC) for selected stations of Solomon River Basin, Kansas.

	Percentage of in AMC Condition		
Station	I	II	III
Colby	95.0	3.2	1.8
Hoxie	93.4	4.2	2.3
Norton	92.7	4.3	3.0
Hill City	93.2	4.2	2.6
Phillipsburg	92.6	4.8	2.6
Plainville	92.6	4.8	2.6
Smith Center*	91.0	5.0	4.0
Alton	91.3	5.2	4.0
Beloit*	90.0	5.5	4.5
Lincoln*	90.0	5.5	4.5
Minneapolis*	89.5	6.0	4.5

*Interpolated values.
Data of all other stations from Kansas SCS, May 1983.

Table 7. Determination of curve numbers for Thiessen areas of Solomon River Basin, Kansas.

Area (a)	Soil Type (b)	% Land Use (CN_{II}) Pasture & Others (c)	Fallow (d)	Row (e)	Grain (f)	CN_{II} (g)	% AMC (CN_I) I	II (h)	III	Final Weighted CN (i)
Colby	B	23(70.0)	33(83.0)	08(78.0)	36(74.0)	76	95.0(58)	3.2(76)	1.8(89)	59.0
Hoxie	50%B 50%B-C	55(72.5)	17(84.5)	10(80.0)	18(76.0)	76	93.5(58)	4.2(76)	2.3(91)	59.5
Hill City	B-C	59(75.0)	15(86.0)	06(82.0)	20(78.0)	78	93.2(60)	4.2(78)	2.6(90)	61.5
Norton	B-C	59(75.0)	16(86.0)	06(82.0)	19(78.0)	78	92.7(60)	4.3(78)	3.0(90)	61.7
Phillipsburg	B-C	61(75.0)	14(86.0)	09(82.0)	16(78.0)	78	92.6(60)	4.8(78)	2.6(90)	61.6
Plainville	B-C	59(75.0)	16(86.0)	05(82.0)	20(78.0)	78	92.6(60)	4.8(78)	2.6(90)	61.6
Smith Center	B-C	56(75.0)	11(86.0)	14(82.0)	19(78.0)	78	91.0(60)	5.0(78)	4.0(90)	62.0
Alton	B-C	57(75.0)	12(86.0)	09(82.0)	22(78.0)	78	91.3(60)	5.2(78)	3.5(90)	62.0
Beloit	B-C	38(75.0)	10(86.0)	14(82.0)	38(78.0)	78	90.0(60)	5.5(78)	4.0(90)	62.0
Lincoln	C-D	88(81.5)	--(89.5)	09(86.5)	03(83.5)	82	90.0(66)	5.5(82)	4.0(92)	67.6
Minneapolis	75%C-D 25%B-C	58(79.8)	02(88.6)	07(85.3)	33(82.1)	81	89.5(64)	6.0(81)	4.5(92)	66.3

Table 8. Relative predicted inflows (PINF), normalized PINF, and three-year moving average of PINF for Solomon River Basin, Kansas 1920-1980.

Year	PINF*	Plotting Value	3-Year Moving Average
1920	236.5	1027.6	------
1921	30.0	5472.2	3108.1
1922	29.4	2824.5	6829.0
1923	37.6	12190.2	5815.2
1924	31.8	2431.0	6022.4
1925	28.8	3445.9	3330.8
1926	65.6	4115.6	5394.8
1927	92.1	8622.9	6191.9
1928	120.3	5837.1	7296.4
1929	52.0	7429.2	6057.1
1930	52.8	4905.1	5305.4
1931	53.0	3581.8	3372.8
1932	118.3	1631.5	2466.8
1933	44.9	2187.0	3023.9
1934	19.2	5253.3	4779.8
1935	103.3	6899.2	5387.6
1936	29.2	4010.4	5584.0
1937	36.2	5842.5	4196.1
1938	97.9	2735.3	5357.7
1939	27.1	7495.4	4528.7
1940	27.4	3355.4	5348.0
1941	142.5	5193.3	3777.0
1942	253.5	2782.2	5123.8
1943	55.4	7396.0	7136.6
1944	56.4	11231.5	10331.3
1945	46.8	12366.6	8385.2
1946	437.4	1557.6	9692.1
1947	32.7	15152.1	7005.5
1948	113.4	4307.0	11302.4
1949	45.4	14448.2	8768.0
1950	131.8	7548.8	9528.4

Table 8. Continued

Year	PINF*	Plotting Value	3-Year Moving Average
1951	453.1	6588.2	9253.1
1952	30.6	13622.3	7164.4
1953	118.1	1282.7	7364.0
1954	24.2	7187.0	3599.3
1955	54.2	2328.3	4006.3
1956	23.6	2503.5	2224.4
1957	295.2	1841.6	4027.1
1958	53.9	7736.2	4656.6
1959	56.1	4392.0	7635.4
1960	54.6	10778.0	6064.6
1961	327.9	3023.9	8936.7
1962	52.0	13008.3	6344.0
1963	79.8	2999.7	6409.6
1964	35.7	3220.9	4270.7
1965	45.3	6591.6	3698.5
1966	86.7	1282.9	2922.5
1967	429.8	892.8	974.4
1968	191.9	747.5	2201.0
1969	52.6	4962.6	2635.0
1970	28.8	2195.1	2782.7
1971	157.7	1190.4	1899.8
1972	45.6	2313.8	2659.9
1973	292.9	4475.6	5440.5
1974	38.0	9532.1	5641.5
1975	83.6	2916.7	4644.5
1976	93.7	1484.6	2065.9
1977	87.8	1796.4	2198.3
1978	54.4	3313.8	3550.8
1979	80.2	5542.1	6248.2
1980	23.5	9888.8	------

*PINF = .3 P + .7 RO^2

**Plotting value = $\frac{\text{Actual Yield}}{\text{PINF}}$

Table 9. Data for linear regression of annual runoff and annual yield, Solomon River Basin, 1920-1950.

Independent variable - annual runoff (inches)
Dependent variable - annual yield (inches)
Point - year beginning with 1920

THIS IS YOUR DATA FOR MULTIPLE LINEAR REGRESSION:

POINT	INDEPENDENT VARIABLE(S)		DEPENDENT VARIABLE
1	20.80	0.75	0.67
2	18.10	0.15	0.45
3	17.72	0.10	0.23
4	22.17	0.19	1.27
5	21.71	0.17	0.21
6	19.22	0.09	0.27
7	18.13	0.23	0.75
8	25.90	0.45	2.20
9	29.72	0.54	1.94
10	23.64	0.29	1.07
11	24.79	0.32	0.72
12	22.95	0.42	0.53
13	20.44	0.43	0.53
14	16.60	0.21	0.27
15	13.21	0.09	0.28
16	22.73	0.51	1.97
17	15.21	0.22	0.32
18	16.23	0.14	0.59
19	21.44	0.40	0.74
20	16.35	0.13	0.56
21	18.68	0.07	0.25
22	33.20	0.85	2.05
23	28.27	0.64	1.95
24	19.60	0.33	1.14
25	32.50	0.37	1.75
26	22.29	0.23	1.60
27	29.84	1.25	1.89
28	22.23	0.12	1.37
29	24.64	0.47	1.35
30	27.69	0.27	1.82

****

THE COEFFICIENTS OF THE LINE ARE:
CONSTANT =-1.27645
INDEPENDENT VARIABLE (1) = .100154
INDEPENDENT VARIABLE (2) = .225774

THE EQUATION OF THE LINE IS:
Y = (.100154)(X1) + (.225774)(X2) + (-1.27645)

COEFFICIENT OF DETERMINATION (R↑2) = .670314
COEFFICIENT OF MULTIPLE LINEAR REGRESSION = .818727
THE STANDARD ERROR OF ESTIMATE (SEE) = .402004

Table 10. Data for linear regression of annual precipitation and annual yield, Solomon River Basin, Kansas, 1920-1950.

Independent variable - annual precipitation (inches)
Dependent variable - annual yield (inches)
Point - year beginning with 1920

THIS IS YOUR DATA FOR MULTIPLE LINEAR REGRESSION:

POINT	INDEPENDENT VARIABLE(S)	DEPENDENT VARIABLE
1	20.80	0.67
2	18.10	0.45
3	17.72	0.23
4	22.17	1.27
5	21.71	0.21
6	19.22	0.27
7	18.13	0.75
8	25.90	2.20
9	29.72	1.94
10	23.64	1.07
11	24.79	0.72
12	22.95	0.53
13	20.44	0.53
14	16.60	0.27
15	13.21	0.28
16	22.73	1.97
17	15.21	0.32
18	16.23	0.59
19	21.44	0.74
20	16.35	0.56
21	18.68	0.25
22	33.20	2.05
23	28.27	1.95
24	19.60	1.14
25	32.50	1.75
26	22.59	1.60
27	29.84	1.89
28	22.23	1.37
29	24.64	1.35
30	27.69	1.82

****

THE COEFFICIENTS OF THE LINE ARE:
CONSTANT =-1.37615
INDEPENDENT VARIABLE (1) = .108139

THE EQUATION OF THE LINE IS:
Y = (.108139)(X1) + (-1.37615)

COEFFICIENT OF DETERMINATION (R↑2) = .668932
COEFFICIENT OF MULTIPLE LINEAR REGRESSION = .817882
THE STANDARD ERROR OF ESTIMATE (SEE) = .395481

Table 11. Data for multiple linear regression of annual precipitation annual runoff, and annual yield, Solomon River Basin, 1920-1950.

First independent variable - precipitation
Second independent variable - runoff
Point - year beginning with 1920

THIS IS YOUR DATA FOR MULTIPLE LINEAR REGRESSION:

POINT	INDEPENDENT VARIABLE(S)	DEPENDENT VARIABLE
1	0.75	0.67
2	0.15	0.45
3	0.10	0.23
4	0.19	1.27
5	0.17	0.21
6	0.09	0.27
7	0.23	0.75
8	0.45	2.20
9	0.54	1.94
10	0.29	1.07
11	0.32	0.72
12	0.42	0.53
13	0.43	0.53
14	0.21	0.27
15	0.09	0.28
16	0.51	1.97
17	0.22	0.32
18	0.14	0.59
19	0.40	0.74
20	0.13	0.56
21	0.07	0.25
22	0.85	2.05
23	0.64	1.95
24	0.33	1.14
25	0.37	1.75
26	0.23	1.60
27	1.25	1.89
28	0.12	1.37
29	0.47	1.35
30	0.27	1.82

****

THE COEFFICIENTS OF THE LINE ARE:
CONSTANT = .492365
INDEPENDENT VARIABLE (1) = 1.53336

THE EQUATION OF THE LINE IS:
Y = (1.53336)(X1) + (.492365)

COEFFICIENT OF DETERMINATION (R↑2) = .355359
COEFFICIENT OF MULTIPLE LINEAR REGRESSION = .59612
THE STANDARD ERROR OF ESTIMATE (SEE) = .552004

ANALYSIS OF WATER YIELDS
OF THE SOLOMON RIVER BASIN, KANSAS

by

JOSEPH WARREN MILLER

B. S., United States Military Academy, 1973

AN ABSTRACT OF A MASTER'S REPORT

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MASTER OF SCIENCE

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ABSTRACT

Water yield in the Solomon River Basin, Kansas, has been steadily declining since the mid 1960's. Prior to 1964 the average annual yield was 471,000 acre-feet, while after 1964 the average annual yield dropped to 278,000 acre-feet. This unexpected decline presents a critical threat to the water supply of northwest and northcentral Kansas, as well as an analysis problem for engineers and planners. The purpose of this report was to investigate the relationship between precipitation, runoff, and the annual yield of the Solomon River Basin, and to subsequently use this relationship to demonstrate how the changing land uses have caused a decrease in the yield. Understanding how land use changes affect a basin yield is critical to designers of large water resource projects such as those of the U.S. Army Corps of Engineers or the U.S. Bureau of Reclamation.

This report analyzed the entire Solomon River Basin for the period 1920-1980. Daily rainfall data and annual yield data were collected for the entire period of analysis. Basin runoff was estimated by using the Soil Conservation Service runoff equation. The Thiessen method was used to estimate the entire basin annual precitation and annual runoff from the values of eleven precipitation collection stations.

The analysis of the data was conducted by using a modification of a method developed for a similar basin, the

Republican River Basin. This modified method used relative annual precitation and relative annual runoff to predict the relative annual yield. A statistical analysis was also conducted to determine the correlation between the same variables.

The statistical analysis showed that the two variables, annual precipitation and annual runoff, correlated to yield with a coefficient of determination, R^2=.67. Precipitation showed the strongest correlation to yield, while the correlation of runoff to yield was very weak. The fact that the correlation of runoff to yield was weaker than that of precipitation to yield, indicated that the runoff values were not representative of the actual runoff, or that other factors that were affecting the yield were not considered in the analysis.

The report concluded that yield was unable to be predicted from annual runoff, as calculated by the SCS equation, and the annual precipitation. Intensity needs to be considered when estimating the runoff over a any basin. The SCS runoff equation does not consider intensity. With a good estimate of runoff, relative annual yield could perhaps be predicted for the basin. This prediction could then be used to show how land use changes such as increased conservation practices have caused declines in the basin yield.