In: Proceedings of the 12th Symposium on Global Change and Climate Variations, 81st American meteorological Society Annual Meeting, p. 319-321, Albuquerque, New Mexico, January 14-19, 2001.

DECADE-SCALE PRECIPITATION AND STREAMFLOW VARIATIONS IN THE KANSAS-NEBRASKA REGION

J. Garbrecht[1], F. Rossel and J. Schneider
USDA, ARS, Grazinglands Research Laboratory, El Reno, Oklahoma

1. INTRODUCTION

Decade-long climate fluctuations are natural occurrences and impact sectors of the economy that depend on weather and water resources, such as agriculture, urban and industrial water supply, hydro-electric power generation, transportation, drought and flood preparedness, and ecosystem sustainability. In a previous study, above-average precipitation conditions were identified during the last two decades of the 20th century for many regions of the Great Plains (Garbrecht and Rossel, 2000). The increase in precipitation was particularly pronounced in the Nebraska-Kansas-Iowa-Missouri region as shown in Figure 1 in terms of standardized precipitation time series for all climate divisions in the four-state area. In this figure the dry period of the Dust Bowl years are clearly visible. Also visible are the wet years of the late 1940's and early 1950's, and the steady and continuous increase in precipitation that started in about 1955 and lasted through the end of the 20th century.

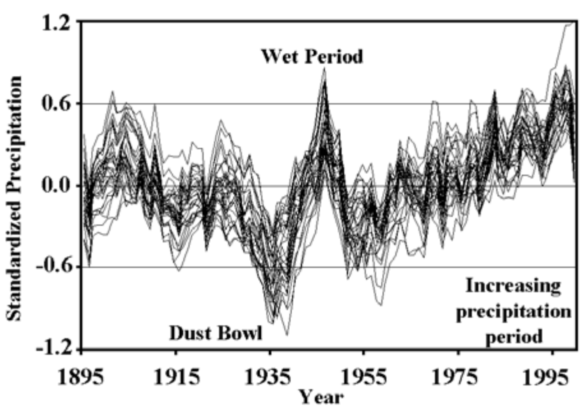

Figure 1. Decade-long precipitation fluctuations visualized by an 11-year moving average of standardized annual precipitation for climate divisions in Nebraska, Kansas, Iowa and Missouri (Garbrecht and Rossel, 2000).

[1] *Corresponding author address*: J. Garbrecht, Grazinglands Research Laboratory
7207 West Cheyenne St., El Reno, OK 73036

The object of this investigation is to identify changes in streamflow in Nebraska and Kansas associated with the observed above average precipitation conditions during the 1980-1999 period. This is a preliminary investigation in a larger effort aimed at identifying the dynamic behavior of the water budget components of river basins under changing climatic conditions. The findings of this study provide an indication of the sensitivity of long-term mean annual streamflow to decade-long fluctuations in mean annual precipitation.

2. DATA AND METHODOLOGY

The geographic region of this study is Nebraska and Kansas (Figure 2). Annual precipitation for each climate division in the region was computed by summation of the state divisional monthly precipitation data published by the National Climatic Data Center (NCDC, 1994). The period of precipitation data spans 105 years starting in 1895 and ending in 1999. Annual precipitation over a river basin was calculated as the area weighted average of the annual precipitation of the climate divisions within to the river basin. Area values used in the weighting represent only those portions of the climate divisions covering the river basin.

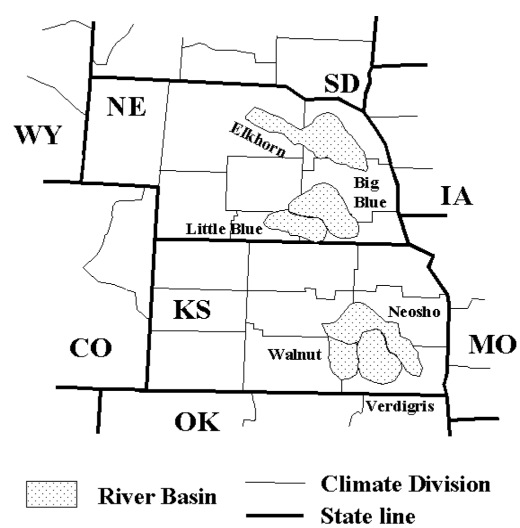

Figure 2. Locations of the river basins in the two-state region of this study.

Streamflow data consists of mean annual streamflow for 6 river basins shown in Figure 2 for which at least 40 years of record are available (Table 1). These 6 river basins were selected from an initial set of 11 river basins because they display a hydrologically acceptable regression between annual precipitation and streamflow (about R^2 = 0.5 and higher). The basins are representative of rural environments, and little urbanization occurred over time. The data source was the US Geological Survey (USGS) Water Resources home page (http://water.usgs.gov), under historical NWIS-W data. The annual streamflow was calculated by simple arithmetic averaging of the historical USGS daily streamflow data.

Table 1. List of river basins considered in this study and their drainage areas.

River name	USGS gage number	Drainage area [sq. mi.]	Period of record	R^2 of precipitation versus streamflow
Elkhorn, NE	06800500	6900	1929-99	0.48
Big Blue, NE	06882000	4447	1933-99	0.59
Little Blue, NE	06884000	2350	1930-99	0.64
Neosho, KS	07183500	4905	1922-99	0.78
Walnut, KS	07147800	1880	1922-99	0.64
Verdigris, KS	07170500	2982	1921-99	0.77

For each river basin, the mean annual precipitation and streamflow for the 1980-1999 period and over the period prior to 1980 was calculated as a simple arithmetic mean. The 20-year and longer time span of analysis allowed the following simplifying assumptions to be made with respect to mean streamflow calculations. First, the amount of unaccounted water due to the first and last year's redistribution of water from snow-accumulation and groundwater storage is negligible. This assumption is reasonable because snow accumulation in the Nebraska-Kansas region is generally non-existent at the change of the year, and when is does exist, it is relatively small. Also, groundwater storage varies seasonally and to a lesser degree annually, and the effects of any difference in storage between the beginning and ending of the 20 year period is assumed to be small once the difference is averaged over the 20-year time span. Second, the difference in stored water in flood control reservoirs between the first and last year is negligible. This assumption is reasonable because flood control reservoirs are mostly constant volume reservoirs except during short flood periods (high stage) and during extended drought periods (low stage). Again, the effects of any difference in stored water are assumed to be small once the difference is averaged over the 20-year time span used in this analysis.

Land use was generally rural within each basin and conditions changed little over time. Artificial ground and surface water withdrawals within the basin for irrigation and municipal uses are considered to be an integral part of the basin water abstractions, similar to evapotranspiration and channel losses. Thus, for this study, the basin is considered to be a black box, and precipitation input and streamflow output are compared directly without explicit consideration of basin transformations. Nevertheless, it is recognized that artificial water withdrawals within the basin have increased over time and may effect the changes in mean annual streamflow identified by this analysis. Therefore, implications of this water withdrawal increase over time are considered in the interpretation of the results. Based on the above assumptions, the difference between the means of the 1980-1999 and the period prior to 1980 represents the increase in mean precipitation and streamflow over the last two decades of the 20th century. The increase is expressed in absolute precipitation and streamflow values, as well as in percent relative to the period prior to 1980. This relative representation highlights the sensitivity of long-term streamflow to changes in long-term precipitation.

3. RESULTS

The mean annual precipitation and stream flow for the two periods under consideration, and the increase in each for the last two decades of the 20th century are shown in Table 2. Column 4 shows that the 1980-1999 mean annual precipitation increased between 7% to 11% compared to the period prior to 1980. The increase is significant for all river basins except the Little Blue River, based on an one-tailed Student-t test at a 0.1 significance level. Column 7 shows that the corresponding 1980-1999 increase in mean annual streamflow increased 16% to 86% compared to the period prior to 1980. These differences are also significant for all river basins, except the Little Blue River, based on an one-tailed Student-t test at a 0.1 significant level.

Sensitivity of the streamflow to precipitation was calculated as the ratio between the relative increase in mean annual streamflow in the last two decades of the 20th century and the corresponding relative increase in mean annual precipitation over the same period (Table 2, Column 8). Thus, the sensitivity is a multiplicative factor reflecting the relative increase in streamflow relative to the increase in precipitation. The multiplicative factors for the river basins are between 2 and 7, indicating that the long-term mean annual streamflow is sensitive to changes in long-term mean annual precipitation. At the time of this analysis, the specific reasons for the range of multiplicative factors have not been identified. However, the results suggest that the multiplicative factor is specific to each basin and reflects the effect of geologic, topographic, land use/cover and water use on the streamflow of the river basin. Thus, a generic, basin independent, precipitation-streamflow relationship is unlikely, and each basin must be individually analyzed. It is also recognized that the relationship between precipitation and streamflow is likely to be dependent on basin size, land use and climate regime. Further studies are underway to investigate these aspects of the precipitation-streamflow relationship.

Table 2. Mean annual precipitation and streamflow for the 1980-1999 period and the period prior to 1980, and increase during the last two decades of the 20th century.

River name	Mean annual precipitation		Increase %	Mean annual streamflow		Increase %	
	prior-1980 [in]	1980-1999 [in]	ΔP	prior-1980 [cfs]	1980-1999 [cfs]	ΔQ	$\Delta Q / \Delta P$
1	2	3	4	5	6	7	8
Elkhorn, NE	24.0	26.7	11	1098	2046	86	7.8
Big Blue, NE	27.8	30.4	9	787	1095	39	4.3
Little Blue, NE	27.6	29.6	7	369	428	16	2.3
Neosho, KS	34.6	37.8	9	2560	3494	36	4.0
Walnut, KS	36.2	34.9	10	801	1081	35	3.5
Verdigris, KS	37.2	40.1	8	1685	2283	35	4.4

4. CONCLUSIONS

The increase in mean annual precipitation during the 1980-1999 period resulted in an increase in mean annual streamflow over the same period for all river basins considered in this study. The proportionality between the change in mean annual streamflow and precipitation in the eastern Nebraska-Kansas area is between 2 and 7, with a mean value of about 4. Thus, changes in mean annual streamflow in the eastern Nebraska-Kansas area are sensitive to changes in mean annual precipitation. However, no common multiplicative factor among all river basins could be identified from this data. Further analysis based on additional river basins is required to address this question. The increase and the sensitivity of mean annual streamflow are believed to represent conservative estimates because water withdrawals have generally increased over the last two decades of the 20th century and have reduced mean annual streamflow values. Without the water withdrawal the streamflow and the sensitivity to precipitation would have been higher. These findings point to the vulnerability of surface water supply during extended periods of below average precipitation in the Nebraska-Kansas region, and to large increases in runoff during extended periods of above average precipitation. The findings also demonstrate the highly dynamic behavior of the streamflow component of the water budget to decade-long changes in precipitation. Further studies are underway to investigate the role of basin size, land use and climate regime in water budget dynamics associated with changing climate conditions.

5. REFERENCES

Garbrecht, J., and F. E. Rossel. 2000. Decade-Scale Precipitation Increase in the Great Plains at the End of the 20th Century.
Journal of Hydrologic Engineering. Submitted for Publication August 2000.

NCDC. 1994. Time Bias Corrected Divisional Temperature-Precipitation-Drought Index. Documentation for Data Set TD-9640. Available from DBMB, NCDC, NOAA, Federal Building, 37 Battery Park Avenue, Asheville, NC 28801-2733. 12 pp.