PROBLEMS ASSOCIATED WITH THE VARIABILITY OF SOUTHWEST PRECIPITATION AND SEASONAL SNOWPACKS

By

Ronald Jones [1/] and Anthony J. Brazel [2/]

INTRODUCTION

In a study of dry and wet periods in the contiguous United States, the climatologist Diaz (1983) showed that the Southwestern United States has a generally greater propensity for being in a situation where it is either "too wet" or "too dry" compared to other areas of the country. Diaz, et al (1985) indicates that precipitation fluctuations in the Lower Colorado Basin are characterized by few very wet years interspersed among several so-called "average" and below average years.

What are the effects of this variability in precipitation? How does it affect the general climate regime of Arizona? What specific problems are created in regard to runoff volumes, water management, and reporting of water conditions?

PRECIPITATION AND SNOWPACK

Since Arizona is generally regarded as an arid region, emphasis is usually placed on the lack of water. Paradoxically, it is the periodic extremely high events that cause many environmental problems.

Precipitation in Arizona comes from two primary mechanisms - frontal activity usually during the winter months and thunderstorm activity primarily during the summer. High pressure systems can and do block the intrusion of moisture and produce extended periods of little or no precipitation. The sources of moisture are the Pacific Ocean and Gulf of Mexico.

Snowpack development is directly related to the varibility of precipitation. The snowpack in turn can vary greatly in its contribution to the annual surface runoff. In the Salt River Basin, for example, over the 21 winters from 1965 to 1985 snowpack water equivalent (expressed as a percent of average February 1 and March 1 values) varies from a low of 13% in water year 1967 to a high of 270% in water year 1968 (see Fig. 1).

Explanations for equally high percentages are not necessarily the same, as illustrated by the highest "percent of average" figures for WY68 and 79. They are almost identical for the February 1 observation of the snowpack. However, the weather sequences that produced the same observed percentages of snow water equivalent on that date were quite different, as was the development of the snowpack prior to that date. Table 1 indicates the monthly progression during the winters of WY68 and 79. The WY68 was dominated by a single precipitation event between December 12th and 20th, 1967. During 1979, more frequent precipitation days occurred from November to the end of January, causing equally high "percent of average" snowpack values to prevail by February 1. However, the pattern of weather that explains high water equivalents of the seasonal snowpack for different years is quite variable spatially and temporarily during the Southwest winter period.

There is is no assured method of determining snowpack accumulation and ablation from one year to the next. Recent studies on long range weather forecasting for the Salt-Verde watershed has indicated only a modest level of success in predicting a winter season precipitation index (Eilbert, 1983). Lead times were a month to two months prior to the water year. Similar results are the norm for predictions by National Weather Service and others. Over long lead times (greater than a season and up to several years), there is very little persistence in a climatological estimate a year in advance (Brazel and Pisapio, 1980). This increases the difficulty of surface water management.

Presented at the Western Snow Conference, April 15-17, 1986, Phoenix, Arizona.
1/ Soil Conservation Service, 201 E. Indianola Avenue, Phoenix, AZ 85012.
2/ Laboratory of Climatology, Arizona State University, Tempe, AZ 85287.

FIGURE 1
Snow Water Equivalent as Percent of Average

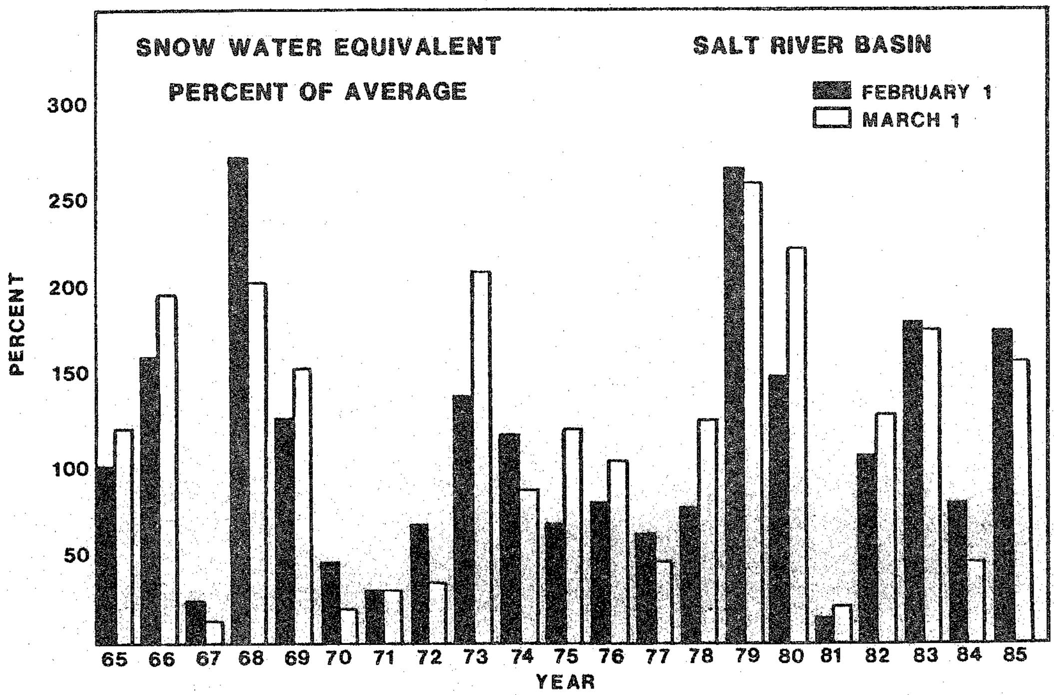


TABLE 1
Monthly Precipitation, Number of Precipitation Days and
Number of Storms By Winter Month for McNary, Arizona (WY68 and 79)

	O	N	D	J	F	M	A	TOTAL
Precip. (mm)								
WY 68	4	45	272	55	28	92	39	535
WY 79	44	211	235	178	29	129	14	840
Number of Precip Days								
WY 68	1	8	8	6	6	9	10	48
WY 79	5	11	12	16	9	10	3	66
Number of Storms								
WY 68	1	3	1	3	1	2	3	14
WY 79	1	3	3	4	2	3	2	18

MEDIAN VERSUS MEAN RUNOFF

Long term planning for surface water resources must still be on the premise that in most years runoff will be relatively small. In order to report on the water supply conditions or future outlook parameters must be chosen that convey the correct message to the reader. In many reports a computed average is still the standard parameter used for comparison of current conditions with the long term norm. In Arizona and other areas having arid climates, the use of a computed mean or average can be very misleading. The median value is a much better parameter for describing "normal" conditions, i.e., the most likely event, for most hydrologic data (Court, A., 1974).

Three streams are compared to illustrate the spatial changes in the ratio of median-to-mean runoff. These are the Clackamas River in the Cascades of Oregon, the Feather River in the Sierra Nevada of northern California, and the Salt River of Arizona. For the 20 year record of 1961 through 1980, the median and mean are nearly equal in the Clackamas River, more divergent on the Feather River in autumn and early winter, and quite divergent on the Salt River in most months (Table 2).

TABLE 2

RUNOFF CHARACTERISTICS OF THREE WESTERN STREAMS

	CLACKAMAS RIVER			FEATHER RIVER		
MONTH	MEAN	MEDIAN	RATIO %	MEAN	MEDIAN	RATIO%
OCT	98	87	89	161	128	79
NOV	224	209	93	256	177	69
DEC	366	314	86	467	251	54
JAN	380	371	98	846	435	51
FEB	278	253	91	644	647	100
MAR	268	236	88	770	731	95
APR	257	266	103	818	754	97
MAY	289	286	99	825	769	93
JUN	172	140	81	423	347	82
JUL	88	79	89	180	168	94
AUG	69	66	96	111	111	100
SEP	69	66	96	101	96	95

	SALT RIVER		
MONTH	MEAN	MEDIAN	RATIO %
OCT	42	17	41
NOV	31	17	56
DEC	76	17	22
JAN	65	22	34
FEB	102	48	47
MAR	155	76	49
APR	161	132	82
MAY	90	66	74
JUN	28	18	65
JUL	20	16	81
AUG	37	30	80
SEP	30	21	71

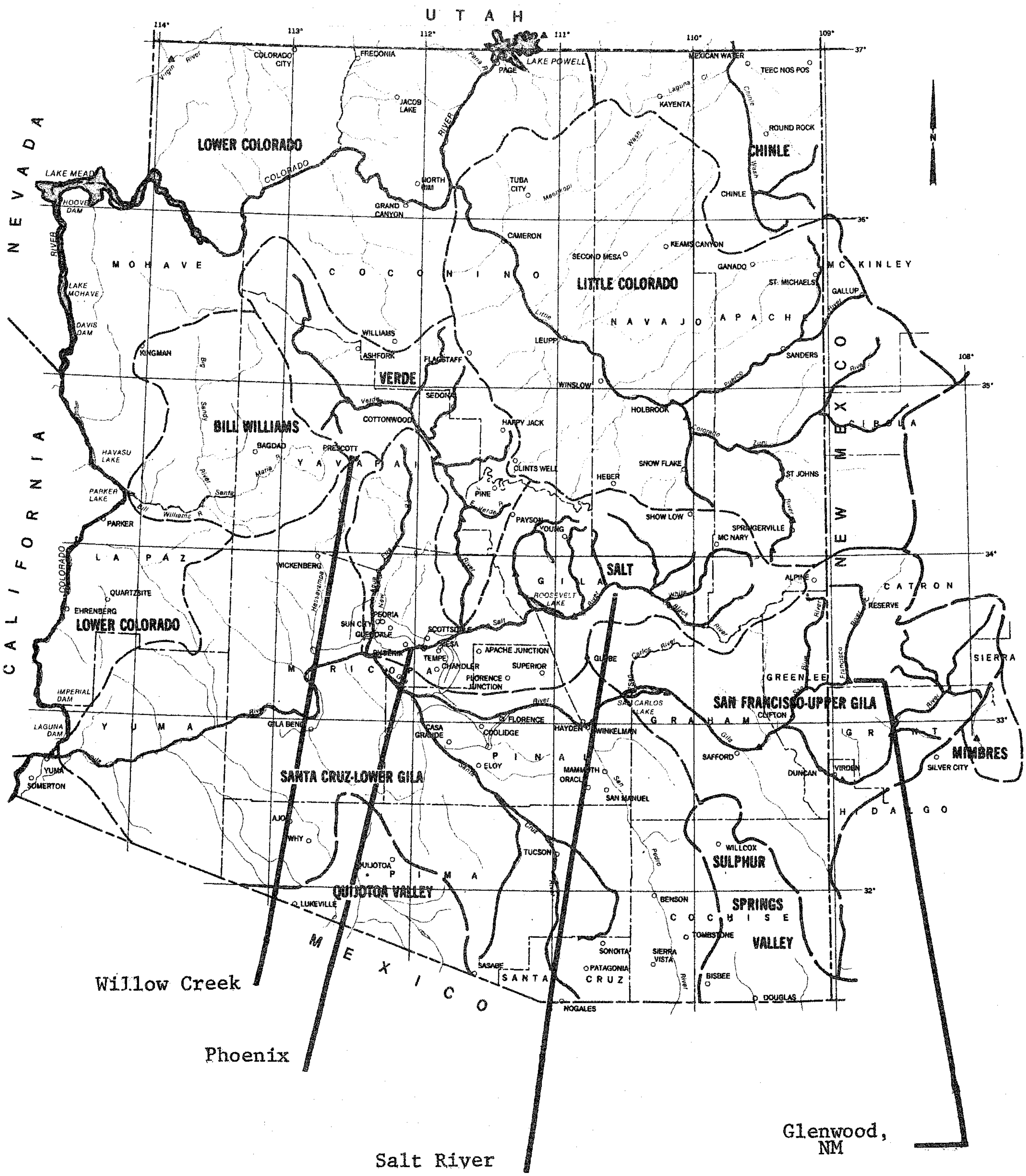
Runoff in Dam ^{3} based on 20 year period - water year 1961-1980.

The high divergence on the Salt River and other Arizona streams relates to a few extremely large precipitation events. They significantly raise the mean while having much less effect on the median value.

The surface runoff on the Salt River which results from rain or melting snow can occur as "feast or famine". The runoff of the Lower Salt River and its major tributary, the Verde River, is controlled to a large extent by a system of reservoirs upstream of the city of Phoenix (Fig. 2). Except for local storm drainage, the Salt River is usually dry through the Valley of the Sun. During the 25 year period 1940 to 1965, the Salt River

Figure 2

ARIZONA



channel was virtually empty of water by Phoenix. Since 1965, there have been a number of wet years when the reservoirs were filling and water had to be released. The resulting "floods" caused condsiderable damage and disrupted local transportation. For example, in February 1980 the flow measured close to 5,600 m^3/sec through Phoenix. This is a controlled river.

The floods of September and October, 1983, occurred on uncontrolled streams. In Mid-September Prescott, Arizona, received over 120 mm of precipitation in 36 hours while stations near Prescott recorded 300 to 330 mm in the same period. Willow Creek experienced record high discharges. Stream banks crumbled, houses were destroyed, and the city water and sewer systems were disrupted. A week later another storm hit, this time over southeastern Arizona and New Mexico. The Gila, San Francisco, and Santa Cruz River systems went into flood. In many areas, flows were so large they could only be estimated. Most of the low-lying section of Clifton, Arizona was destroyed. Numerous roads and bridges were washed out including Interstate 10 over the Gila River south of Phoenix. The Santa Cruz River near Marana, normally dry, was many kilometers wide.

The social effects of these large events are obvious--injury and loss of life, property damage, disrupted transportation and communication, and contaminated water supplies, to name few. Surface water managers are at the mercy of these events. Managers have a difficult time planning for them since their degree of impact is hard to predict. Managers can only react.

Table 3
October Streamflow Ascending Values
San Francisco River, Glenwood, New Mexico
(Thousands of Cubic Dekameters)

Water Year 1961-1980		Water Year 1961-1985	
0.73		0.73	
1.39		1.39	
1.42		1.42	
1.63		1.44 *	
1.89		1.63	
1.91		1.76 *	
1.91		1.89	
1.92		1.91	
2.17		1.91	
2.24	Median	1.92	
2.31		2.15 *	
2.43		2.17	
2.76		2.24	- Median
3.07		2.30	
3.17		2.42	
3.38		2.76	
3.51		3.07	
4.02		3.17	
32.74		3.38	
81.14		3.51	
		4.01	
		4.93 *	
		32.74	
		81.14	
		152.89 *	
155.74	Sum	318.87	Sum
7.79	Mean	12.75	Mean
2.27	Median	2.24	Median

A further case in point is the San Francisco River at Glenwood, New Mexico, just north of where it flows into Arizona. Table 3 shows the measured streamflow in cubic dekameters for the month of October, in ascending value, for the 20 water year period 1961 through 1980 and the 25 water year period 1961 through 1985. In the 25 year data set, the values indicated with astericks are the newest five years added to the record.

The month of October is chosen simply as an example. Usually October is a quiescent month in the Southwest, experiencing only the odd precipitation event. Every so often an early winter cold, closed low pressure system of a cut-off low becomes positioned within the vicinity of the desert region. Perhaps once in 25 years, development of a mid-to-upper latitude trough along the west coast occurs at the same time that an intense tropical storm system migrates toward the southwestern desert latitudes. The resultant interaction of these events can be devastating. For the 20 year period 1961-1980 the average streamflow at Glenwood was 7,792 dam^3 and the median was 2,269 dam^3. By extending the period of record by five years, the average has increased to 12,749 dam^3 while the median has remained essentially the same at 2,244 dam^3. The sum of all of the Octobers in the 20 year record is 155,740 dam^3. The official measured flow of October, 1983 was 152,892 dam^3. This one month had almost as much streamflow as the sum of all the Octobers in water years 1961 through 1980.

The 25 year period is soon to become the averaging period used for reporting runoff on Arizona and New Mexico streams. If October, 1986, were to have a runoff of 6,165 cubic dekameters, well within the realm of reality, it would be difficult to report this using a percent of average and still maintain credibility. The 6,165 would be the fourth largest October runoff in 26 years. It would be 275% of median, but only 48% of average.

CONCLUSION

Arizona's mountainous region is affected by a variable weather pattern. The weather results from mid-latitude to upper-latitude atmospheric flows, but can also be influenced by frequent tropical air masses. The variability of weather produces a temporal precipitation distribution characterized by high variability. Low frequency, high magnitude precipitation events skew the frequency distribution of moisture inputs and runoff and cause large influences on the long-term average of mean snowpack and runoff statistics. The median value offers a more meaningful measure of "normal" for interannual comparison purposes, especially for hydrologic data such as precipitation and runoff.

REFERENCES

Brazel, A. J. and L. Pisapio, 1980: "Climatic Prediction of Winter Precipitation in Arizona", Climatological Publications, Scientfic Paper No. 15, Laboratory of Climatology, Arizona State University, Tempe, Arizona, 33 pp.

Court,A., 1978: "The Climate of the Conterminous United States", pp 193 to 343 in Climates of North America, World Survey of Climatology Vol. 11, Bayson, R. A. and F. K. Hare (ecls.)

Diaz, H. F., 1983: "Some Aspects of Major Dry and Wet Periods in the Contiguous United States, 1895-1981", Journal of Climate and Applied Meteorology, 22: 3-16.

Diaz, H. F., R. L. Holle, and J. W. Thom, Jr., 1985: "Precipitation Trends and Water Comsumption Related to Population in the southwestern United States, 1930-83", Journal of Climate and Applied Meteorology. 24:145-153.

Eilbert, R. F., 1983: Long Range Weather Forecasting Study for Central Arizona, Entropy Limited, Phoenix, Arizona, 91 pp.

Kangeiser, P. C., 1967: "Arizona-December, 1967, Special Weather Summary", Climatological Data, U S Dept. of Commerce, 71(12): 208 - 209.