ROLE OF SNOW IN THE HYDROLOGY OF THE MADREAN PROVINCE IN SOUTHEASTERN ARIZONA

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In characterizing the hydrology of the Madrean Province of the southwestern United States and northern Mexico, Baker et al. (1995) stated that winter precipitation in the region is generally rain, although snow occasionally falls and accumulates in the higher elevations. In theory, snowmelt from these intermittent accumulations could contribute to the surface runoff originating on these mountain tops. Therefore, snowpack measurements taken on two snow courses in the Santa Catalina Mountains, near Tucson, have been analyzed in terms of water equivalents at peak seasonal accumulations. Estimates of snowpack densities calculated from measurements of snow depth and water equivalents are also presented. Variations from long-term average conditions are described. Inferences on the role of snow in the hydrology of the Madrean Province are made in relation to forest management activities to increase snowmelt water yields.

Snow Courses

The two snow courses, Bear Wallow and Rose Canyon, were established in the winter of 1947–48 as part of the Arizona Cooperative Snow Survey, a joint effort of the USDA Soil Conservation Service (currently the Natural Resources Conservation Service), the USDA Forest Service, the Salt River Valley Users Association, the Arizona Agricultural Experiment Station, and others. The purpose of the cooperative snow survey, which is conducted throughout the western United States, is to provide an index of snowpack water equivalents to forecast future snowmelt-runoff volumes, not necessarily to report the average snowpack conditions of the watershed in question. Therefore, the survey snow courses are established on sites that have a deep snowpack even in the drier years. With the exception of two aerial markers in the Pinaleno Mountains, the two snow courses on the Santa Catalinas were the only representatives of the survey in southeastern Arizona.

The snow courses were located in old-growth ponderosa pine forest stands composed mainly of trees 20 inches in diameter and larger. The overstory on the Bear Wallow course averaged 100 square feet of basal area per acre, while that on the Rose Canyon course averaged about 50 square feet of basal area per acre. There were insignificant numbers of understory trees on the two sites. The Bear Wallow course was 8,100 feet in elevation, on a generally northeastwardly aspect of 30–40 percent slopes; the Rose Canyon course was 7,300 feet in elevation, on a northwestwardly aspect of 30–35 percent slopes.

Transects of 10-foot pipes located at 50-foot intervals marked the sampling points on the snow courses on both sites. Eight sampling points comprised the Bear Wallow course and there were seven sampling points on the Rose Canyon course.

Collection of Data

Measurements taken in the survey have been used to estimate water equivalents and the condition of snow throughout the winter period of snowpack accumulation and melt; therefore, measurements made in these periods normally included peak seasonal snowpack accumulations. Snow depth and water equivalents were measured at the sampling points on the Bear Wallow and Rose Canyon courses with a Federal snow sampler. Water equivalents were determined by weighing the tube and snow with a spring balance.

Measurements were generally taken at about two-week intervals throughout the period of late January to the first of April from 1947–48 to 1982–83, when the measurements were discontinued. Reported snow course data represented the averages for all sampling points on the course (USDA Soil Conservation Service 1981).

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Results and Discussion

Snow was measured on the two courses at least once in each of the 36 years of record with the exception of the Rose Canyon course in 1972. The two courses were also snow-free during parts of most winter sampling periods. Snowpack accumulations on the higher Bear Wallow course tended to melt more slowly than those at Rose Canyon; and, the accumulations at Bear Wallow were augmented more frequently by storms throughout the winter period. The snowpacks were more intermittent and discontinuous on the Rose Canyon course, where the entire accumulation often melted between measurement dates.

The time of peak seasonal snowpack accumulations on the courses was variable, although peak water equivalents were most frequently measured on the February 15 sampling date. The greatest water equivalents were measured on February 15, 1966, with 19.6 inches at Bear Wallow and 13.6 inches at Rose Canyon. The average water equivalent (with standard error) at peak seasonal accumulations for the years of record was 6.1 ± 0.8 inches at Bear Wallow and 3.2 ± 0.5 inches at Rose Canyon. However, there was considerable variation in the annual values of peak seasonal water equivalents on the two courses (Figure 1). Typical of many meteorological and hydrologic data in the southwestern United States, these values rarely approached the long-term average; a few values were indicative of extreme highs, and a relatively large number of values were below the long-term average.

Estimates of snowpack densities were obtained from the measurements of total snow depth and water equivalents at the sampling points. No attempt was made to differentiate newly fallen from the residual snowpack in these samples; therefore,

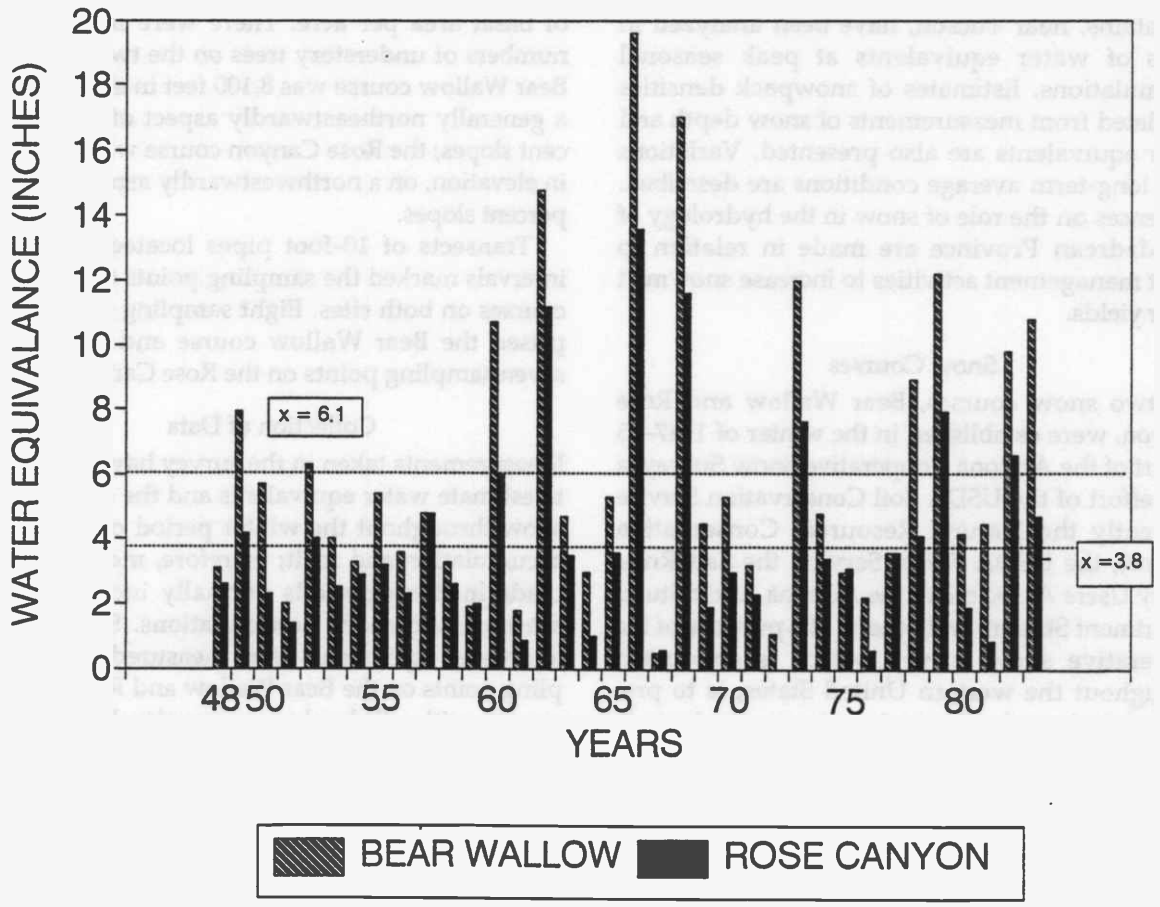

Figure 1. Annual values of peak seasonal water equivalents on the Bear Wallow and Rose Canyon snow courses. The respective average water equivalents at peak seasonal accumulations for the 36 years of record are indicated by the broken line.

the estimates of snow densities reflect values for the integrated snowpack at the time of measurement. Snowpack densities ranged from 0.15 to 0.47 gm cm^{-3} at Bear Wallow, and from 0.10 to 0.49 gm cm^{-3} at Rose Canyon for the period of record. The lower values generally represented newly fallen snow with little residual snowpack, and the higher values indicated a snowpack that probably was melting. The snowpack densities observed on the two courses and the temporal variations in the snowpack density values were similar to those reported for snow conditions of northern Arizona (Ffolliott 1985).

Snowpack densities at the time of peak seasonal accumulation were also variable, ranging from lows of about 0.15 to highs of almost 0.60 gm cm^{-3} throughout the 36 years of record. It was concluded, therefore, that the condition (ripeness) of the snowpacks at peak seasonal accumulation was variable in terms of ripeness or readiness to melt.

Management Inferences

Snow falling on high-elevation forests is a source of water throughout much of the southwestern United States. It might follow, therefore, that snowmelt water yields could be increased by modifying the structure of the forests through thinning, clearing, or combinations thereof. While these possibilities do occur elsewhere in the mountains of the southwestern United States (Ffolliott et al. 1989), they are essentially nonexistent in southeastern Arizona.

Snowpacks in the Madrean Province are largely intermittent, relatively shallow, and limited in their aerial extent; as a consequence, they do not represent a significant water supply potential in the region. Furthermore, high transmission losses in the stream channels suggest that only a fraction of any increases in water flows occurring as a result of modifying the structure of the forests would reach downstream places of use.

Discontinuities in forest cover on the mountain tops in the Madrean Province preclude implementation of management activities on a scale large enough to have a significant influence on the hydrologic regimes. It must be inferred, therefore, that the importance of snow as a source of water, and its role in the hydrology of the Madrean Province, is largely insignificant.

References Cited

Baker, M.B., Jr., L.F. DeBano and P.F. Ffolliott. 1995. Hydrology and watershed management in the Madrean Archipelago. Pages 329–337 in L.F. DeBano, P.F. Ffolliott, A. Ortega-Rubio, G.J. Gottfried, R.H. Hamre and C.B. Edminster, technical coordinators. Biodiversity and management of the Madrean Archipelago: The Sky Islands of southwestern United States and northern Mexico. USDA Forest Service, General Technical Report RM-GRT-264.

Ffolliott, P.F. 1985. Snowpack density: An index of snowpack conditions. Hydrology and Water Resources in Arizona and the Southwest 15:1–6.

Ffolliott, P.F., G.J. Gottfried and M.B. Baker, Jr. 1989. Water yield from forest snowpack management: Research findings in Arizona and New Mexico. Water Resources Research 25:1999–2007.

USDA Soil Conservation Service. 1981. Summary of snow measurements for Arizona and pertinent portions of New Mexico: 1938–1980. USDA Soil Conservation Service, Washington, D.C.