A WATER BUDGET FOR EMORY OAK WOODLANDS OF SOUTHEASTERN ARIZONA: AN EXPANSION OF THE INITIAL APPROXIMATION

Peter F. Ffolliott[1]

An initial approximation of an annual water budget characterizing the Emory oak woodlands of southeastern Arizona (Ffolliott 1999) was presented in the Hydrology Section of the Arizona-Nevada Academy of Science at the 2000 meeting. Storage points and the flows of water within and between these storage points were examined in the context of the results of hydrologic investigations available at that time (Ffolliott 2000). Analysis of this water budget indicated that transpiration was the largest component, a finding that is generally expected (Brooks et al. 2003; Chang 2003). Estimates of transpiration rates of thinned coppice on the rootstocks of harvested Emory oak trees have been made since this initial approximation, allowing an expansion to be made of the water budget for these woodland ecosystems.

BACKGROUND PERSPECTIVE

Earlier investigations of the hydrologic characteristics of the Emory oak woodlands in southeastern Arizona allowed the initial approximation of an annual water budget by examining key water storage points and flows within and between these storage points. Components of the water budget cycle represented in this approximation included interception and stemflow, infiltration, stormflow, and transpiration.

Extrapolating results of a study of rainfall distribution in Emory oak woodlands by Haworth and McPherson (1991) to a stand-basis using known tree distributions and the estimated long-term frequency of large and small storms in a year led to an estimated canopy interception value of 10 percent of the annual gross precipitation. The magnitude of litter interception is unknown, but it was considered negligible because of the sparse buildups of litter on the soil surface. Stemflow was also considered insignificant. Net precipitation, therefore, was estimated to be 90 percent of the annual gross precipitation.

Infiltration was the most problematic of the budget components examined. Nevertheless, it was estimated from plot data presented by Beutner et al. (1940) that about 80–85 percent of the annual net precipitation infiltrates into the soil in the "average" year. However, the average year rarely occurs in the Emory oak woodlands. Fluctuations in rainfall regimes typically result in a few very wet years interspersed among several average years and below average years.

Transpiration of Emory oak trees had been estimated by the sapflow velocity method (Swanson and Witfield 1981; Swanson 1994) in an earlier study (Ffolliott et al. 2003). The estimate of transpiration by a stand of mature trees (60 years and older) was about 50 percent of the net annual precipitation. Mature trees and stump sprouts collectively stocking a partially (more than 75%) harvested stand transpired 85 percent of the net annual precipitation; the large number of post-harvest stump sprouts occupying the stand was the assumed reason for this finding. Transpiration rates for other woody plants, grasses, forbs, and succulents found in the Emory oak woodlands are unknown.

By applying a set of basic operating rules, and using the estimated long-term frequency of "large" storms in an "average year" in interpreting these rules (Ffolliott 2000), it was estimated that approximately 5–10 percent of the net annual precipitation is converted into stormflow in the average year. Most of this stormflow is generated by relatively few rainfall events. Snowmelt runoff (when it occurs) also flows into stream channels passing through the woodlands; however, this flow pathway was not considered in this water budget.

TRANSPIRATION OF THINNED COPPICE

Estimates of annual transpiration by thinned sprouts (coppice) on the rootstocks of harvested Emory oak trees have been made (Shipek et al. 2003, 2004) since the initial water budget approximation was presented. These latter estimates of

[1]School of Natural Resources, University of Arizona, Tucson.

transpiration were also obtained by the sapflow velocity method. This more recent information complements the findings from the earlier study of Emory oak transpiration (Ffolliott et al. 2003) and furnishes a basis to estimate the amount of water that js lost by the transpiration process after implementing selected coppice thinning practices. A summary of the transpiration rates for all of the Emory oak stand conditions studied to date is presented in Table 1. Parenthetically, the similarity of the transpiration estimates for the mature trees and the stump sprouts stocking the partially harvested stand and the stand of unthinned root-stocks averaging 4.5 dominant post-harvest stump sprouts is attributed largely to the overriding dominance of the post-harvest stump sprouts occupying the partially harvested stand.

It is apparent from Table 1 that the thinning of post-harvest Emory oak coppice has the potential to decrease the amount of water lost by transpiration in harvested stands and, therefore, increase the amount of water potentially available to recharge groundwater aquifers, produce overland flow, or increase the growth of other plants in comparison to the amount of water available in stands of unthinned rootstocks. Incorporating these latter estimates of transpiration into the initial approximation of the annual water budget provides expanded insight on the impacts of management practices.

ANNUAL WATER BUDGET

The annual water budget expansion presented in this paper was developed by partitioning an arbitrarily selected gross precipitation amount of 450 mm, a value between the reported ranges of annual precipitation values in the Emory oak woodlands and that used in illustrating the initial approximation (Ffolliott 2000), into the respective water budget components. The estimates of water storage points and flows of water within and between the storage points shown in Figure 1 are presented only to indicate the relative magnitudes of these water storage points in relation to the annual gross precipitation amount selected. The ranges of absolute values for these components are unknown.

Water losses not shown in Figure 1 include evaporation from water surfaces, soil evaporation, and watershed leakage. Evaporation from water surfaces is a minor loss in the Emory oak woodlands of southeastern Arizona because of the general absence of large water bodies. However, soil evaporation could be a significant part of the water budget in the interval between large rainstorm events when the relative humidity is low and wind velocities are high. Knowledge of the geology for the watershed in question provides the best evidence of losses to leakage.

SUMMARY

Estimates of annual transpiration by thinned Emory oak stump sprouts resulting from earlier harvests of fuelwood are available to complement the findings from the earlier investigation of Emory oak transpiration and, additionally, to furnish a basis to estimate the amount of water loss by transpiration after implementing coppice thinning practices. Incorporating these estimates of transpiration into an approximation of the annual water budget provides insight on the impacts of selected management scenarios on the hydrology of these woodlands.

Table 1. A summary of the transpiration rates for selected Emory oak stand conditions.

Stand Condition	Percent[1]
Mature trees	50
Partial (over 75%) harvest	85
Complete harvest	
Unthinned stump sprouts	85
Thinned to 3 residual stump sprouts	65
Thinned to 2 residual stump sprouts	55
Thinned to 1 residual stump sprout	40

[1]Percent of net annual precipitation.

GROSS PRECIPITATION
(450 mm)

↓

INTERCEPTION
(45 mm)

↓

NET PRECIPITATION
(405 mm)

↓

INFILTRATION   STORMFLOW   OTHER WATER LOSSES
(325-350 mm)   (20-45 mm)
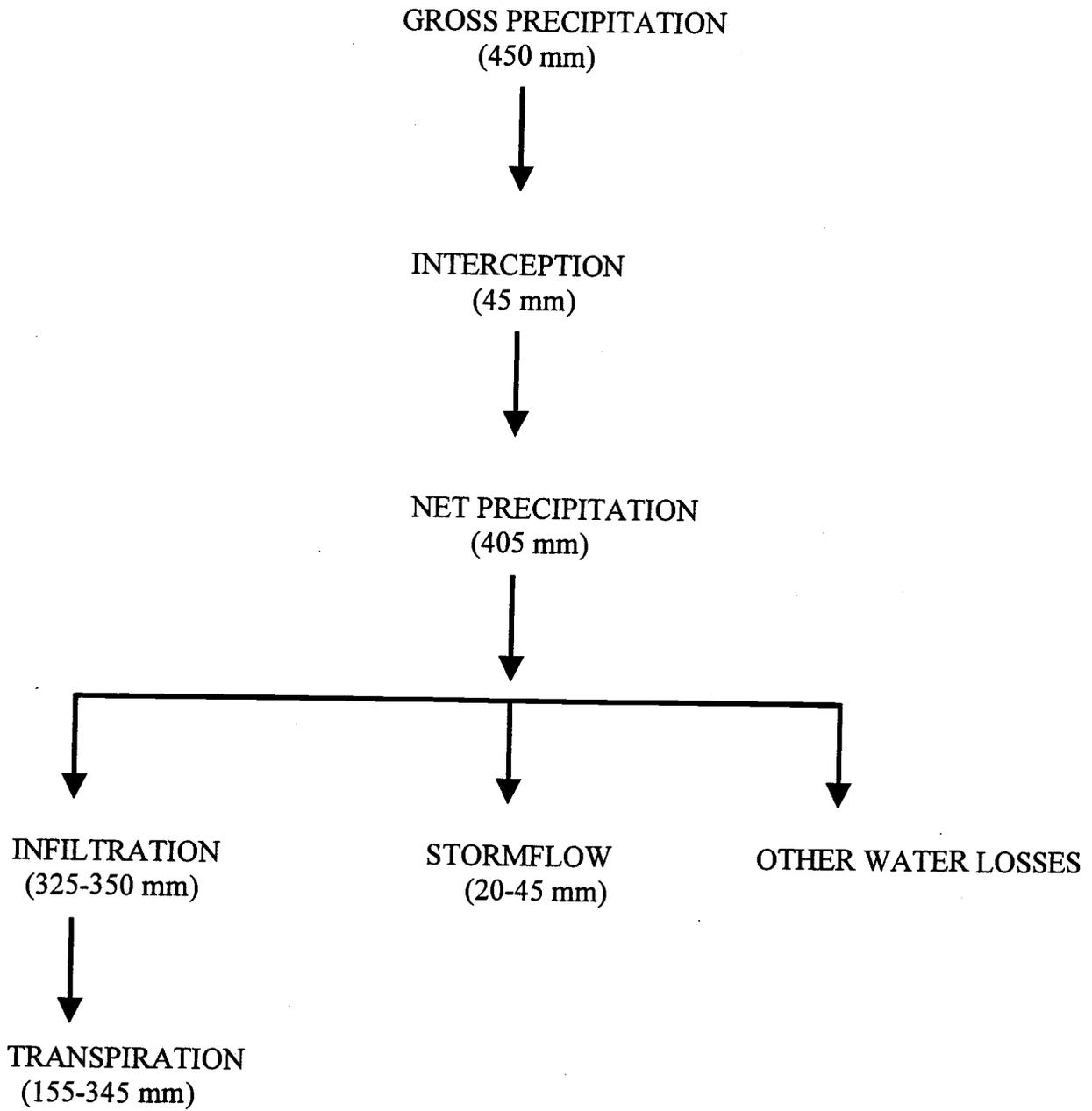
↓

TRANSPIRATION
(155-345 mm)

Figure 1. Annual water budget for selected management practices in the Emory oak
woodlands of southeastern Arizona.

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