# Overwinter Soil Water Recharge and Herbage Production as Influenced by Contour Furrowing on Eastern Montana Rangelands

EARL L. NEFF AND J. ROSS WIGHT

**Highlight: On fine-textured range sites in southeastern Montana, contour furrowing increased average overwinter soil water recharge 11 mm on a saline-upland range site and 39 mm on a panspot range site. Increased recharge resulted from decreased late fall and early spring runoff and increased snow accumulation. Overwinter recharge was a function of both antecedent soil water and the amount of water available for recharge. Herbage production was significantly ($r = 0.89$) related to spring soil water content.**

Soil water is limited in fine-textured range soils of eastern Montana and other areas because of low infiltration rates and low precipitation. Mechanical treatments, like ripping, pitting, and contour furrowing, have been used to increase rangeland soil water recharge by creating additional surface storage, decreasing runoff, and providing a longer time for infiltration (Branson et al. 1966; Wight and Siddoway 1972; Neff 1973; Soiseth et al. 1974; Wight 1976). Snowfall comprises about 20% of the average annual precipitation in eastern Montana while snowmelt accounts for about 50% of the average annual runoff and is a major source of water for filling stockponds and reservoirs (Wight et al. 1975). However, the role of overwinter precipitation in soil water recharge is not well understood.

The results and data presented in this paper are part of a cooperative study between the Agricultural Research Service, U.S. Department of Agriculture, and the Bureau of Land Management, U.S. Department of the Interior, conducted from 1967 through 1974 to evaluate the vegetational and hydrologic effects of contour furrowing on fine-textured rangeland soils in southeastern Montana.

## Study Area

This study was conducted about 29 km south of Ekalaka, Mont., on panspot and saline-upland range sites characterized by impervious, saline-sodic soils with low forage productivity. Soils in the panspot range sites were in the Bascovy and a phase of the Bickerdyne soil series with the taxonomic classification of fine, or very fine, montmorillonitic borollic vertic camborthids. Soils in the saline-upland range site were in the Dilt series with the taxonomic classification of clayey, montmorillonitic, acid, frigid, shallow ustic torriorthents. The climate at the research site is arid to semiarid continental with cold, relatively dry winters and warm summers with the long-time average annual precipitation estimated to be about 250 mm.

## Methods

Sixteen 0.8-ha watersheds were established in 1967, four on a saline-upland range site with an average slope of 3%, six on a panspot range site with an average slope of 5%, and six on a panspot range site with an average slope of 1%. Half of the watersheds at each site were left in their natural condition and half were contour furrowed using an Arcadia Model B furrower that constructed furrows about 50 cm wide, 15 cm deep, with 150 cm between furrows. Measurements taken on each watershed included: surface runoff by a continuous water-stage recorder on a precalibrated H-type flume; snow water content at two locations with a Federal Snow Sampler; soil water in the 120-cm profile at two locations by the neutron-scattering method; and annual forage production by clipping at ground level and oven drying vegetation in eight randomly located 0.25 × 2 m-quadrats. Precipitation was measured at each site by a recording raingage network with an average areal density of one raingage for each 4 ha.

The "overwinter" period was defined as the time between the last soil water measurement in the fall, about October 1, and the first the following spring, about May 1. For ease in partitioning precipitation and runoff, we divided this period into three subperiods with different problems associated with data collection and interpretation. "Fall (between the fall soil water measurement and December 1) precipitation occurred as rain, as snow, and as rain plus snow with most of the fall runoff resulting from rain events. "Winter" (between December 1 and the end of the initial snowmelt, usually between February 15 and

March 1) precipitation occurred only as snow, and winter runoff resulted entirely from snowmelt. "Spring" (between the end of the initial snowmelt and the first soil water measurement in the spring) precipitation occurred as rain, as snow, and as rain plus snow with runoff resulting from all three precipitation forms.

Snow drifting into the water-measuring flumes during the winter snow accumulation period and ice forming in and below the flumes and in the flume stilling wells during winter runoff prevented accurate measurement and made it necessary to estimate winter runoff. This estimate assumed no evaporation from the snowpack in the 7- to 14-day period between the date of measurement of the maximum snow accumulation and the date on which winter runoff began. For the untreated watersheds, it was assumed that winter runoff equalled the maximum snow water accumulation each year. This assumption was made because the soil was frozen during winter runoff each year, as evidenced by soil cores of concrete frost taken with the Federal Snow Sampler, and the infiltration rate of these soils, even when unfrozen, was about 5 mm/hour as measured by double-ring infiltrometers (Soiseth et al. 1974). Winter runoff from the contour furrowed watersheds each year was assumed equal to the difference between the maximum snow water accumulation and the water storage capacity of the furrows, which at this study location averaged about 25 mm (Neff 1973).

In Table 1, the water available for recharge is equal to the sum of the fall precipitation, the maximum snow accumulation, and the spring precipitation minus the sum of the fall, winter, and spring runoff. The available soil water is the difference between the soil water measurement and the minimum soil water measured at any time during the period of record. This definition assumed that the minimum soil water measured during the period of record approximated the soil water holding capacity at wilting point. Recharge is the difference between the available water in the fall and the available water in the spring. Recharge efficiency is equal to the recharge divided by the water available for recharge, expressed as a percentage.

Overwinter loss, or water not accounted for, was calculated by the water balance equation:

$$L = (TAW - RO) - SWC \qquad (1)$$

where **L** is overwinter loss; **TAW** is total available water (fall and spring precipitation + snow accumulation); **RO** is total runoff; (**TAW − RO**) is water available for recharge and **SWC** is soil water recharge. This loss represented evaporation from the soil, from the snow surface; and from the liquid water surface after snowmelt began, plus any transpiration that occurred between the last soil water measurement in the fall and the first soil water measurement the following spring.

## Results and Discussion

Contour furrowing affected the overwinter hydrology on both the saline-upland and panspot range sites, with greatest differences occurring on the panspot sites (Table 1). Contour furrowing increased average overwinter recharge 11 mm (157%) on the saline-upland site and 39 mm (162%) on the panspot site. Higher infiltration rates on the panspot site were the primary reason for the relative recharge differences between the two sites.

Over the 6-year period, contour furrowing increased the water available for recharge by decreasing fall and spring runoff about 17 mm and by increasing maximum snow water about 20 mm on both range sites. Although contour furrowing increased snow water by 60%, it had no significant effect on winter runoff because of the water storage capacity of the furrows.

Annual herbage production on both contour furrowed and natural watersheds was related ($r = 0.89$) to spring available water by the relationship:

$$Y = 6.96X - 9.07 \qquad (2)$$

Table 1. Average site, overwinter hydrologic characteristics, and herbage yields on saline-upland and panspot range sites when treated by contour furrowing and when in natural condition. Average of winter years 1968–69 to 1973–74, inclusive.)

| Site and hydrologic characteristics | Watershed averages[1] | |
|---|---|---|
| | Natural | Contour furrowed |
| **Saline-upland** | | |
| Fall precipitation (mm) | 55 | 55 |
| Fall runoff (mm) | 16 | 6* |
| Fall soil water (mm) | 475 | 480 |
| Max. snow water (mm) | 36 | 54* |
| Winter runoff (mm) | 36 | 30* |
| Spring precipitation (mm) | 61 | 61 |
| Spring runoff (mm) | 7 | 2* |
| Total runoff (mm) | 59 | 37* |
| Water available for recharge (mm) | 93 | 132* |
| Recharge (mm) | 7 | 18* |
| Recharge efficiency (%) | 5 | 12 |
| Loss (water not accounted for) (mm) | 86 | 115* |
| Available spring soil water (mm) | 33 | 48* |
| Herbage yield (kg/ha) | 180 | 327 |
| **Panspot** | | |
| Fall precipitation (mm) | 58 | 58 |
| Fall runoff (mm) | 16 | 1* |
| Fall soil water (mm) | 324 | 342 |
| Max. snow water (mm) | 35 | 57* |
| Winter runoff (mm) | 35 | 32 |
| Spring precipitation (mm) | 57 | 57 |
| Spring runoff (mm) | 6 | 1* |
| Total runoff (mm) | 57 | 34* |
| Water available for recharge (mm) | 93 | 137* |
| Recharge (mm) | 24 | 63* |
| Recharge efficiency (%) | 29 | 48* |
| Loss (water not accounted for) (mm) | 70 | 75 |
| Available spring soil water (mm) | 41 | 91* |
| Herbage yield (kg/ha) | 293 | 724* |

[1] * = values are significantly different (p = 0.10) from the natural watershed data.

where **Y** is yield in kg/ha and **X** is spring available water in millimeters. Based on equation (2), the overwinter recharge accounted for about 50% of the increased herbage production due to contour furrowing on both the saline upland and the panspot sites.

There were significant year-treatment interactions as a result of variable precipitation patterns among years, with both runoff and water loss directly related to precipitation amounts. Overwinter recharge was related ($r = 0.81$) to antecedent soil water as expressed by the fall soil water content and to water available for recharge by the multiple regression equation:

$$Y = 80 - 0.22F + 0.32W \qquad (3)$$

where **Y** is recharge, **F** is fall soil water, and **W** is water available for recharge; all in millimeters. Equation (3) has a standard error of estimate of 17 mm and is significant at the 5% level of confidence. Contour furrowing increased the water available for recharge about 40 mm on both the saline-upland and the panspot sites. Of this increase, 25 mm, about 60%, was contributed by the increase in snow water accumulation during the winter period. The relative contribution to water available for recharge by snow trapped in furrowed areas is highly variable from year to year. For example, in 1968–1969 and again in 1972–1973, increased snow water in the furrowed areas accounted for 100% of the difference between the water available for recharge on furrowed and that on natural watersheds; whereas, on the panspot sites in 1971–1972 increased snow accumulation in furrows accounted for only 28% of the difference. From these data it can be concluded that snow

trapping characteristics of contour furrows is most important during years with low fall and spring precipitation and is less important during years of above-normal fall and spring precipitation.

For the 6-year period, contour furrowing significantly ($p = 0.10$) increased snow water accumulation, spring available soil water, and soil water recharge and significantly decreased total runoff. Herbage yield was significantly increased only on the panspot range site. More specific interpretations of some of these data should be made with caution. Average annual spring and fall runoff amounts for the study period may be biased because spring precipitation was 380% of the longtime average in 1970, fall precipitation was 320% of longtime average in 1970, and 420% of longtime average in 1971. These high precipitation periods resulted in above-normal runoff that may have biased the short-term 6-year records by indicating higher runoff from both contour and natural watersheds than would be expected under either more nearly normal precipitation conditions or a longer, more representative study.

## Literature Cited

Branson, F. A., R. F. Miller, and I. S. McQueen. 1966. Contour furrowing, pitting, and ripping on rangelands of the western United States. J. Range Manage. 19:182-190.

Neff, Earl L. 1973. Water storage capacity of contour furrows in Montana. J. Range Manage. 26:298-301.

Soiseth, R. J., J. R. Wight, and J. K. Aase. 1974. Improvement of panspot (solonetzic) range sites by contour furrowing. J. Range Manage. 27:107-110.

Wight, J. Ross. 1976. Land surface modifications and their effects on range and forest watersheds. Proc. of Fifth Workshop of the United States/Australia Rangelands Panel. (Ed.) Harold F. Heady, Donna H. Falkenborg, J. Paul Riley. Utah Water Res. Lab., Coll. of Engineer., Utah State Univ., Logan. p. 165-173.

Wight, J. Ross, E. L. Neff, and F. H. Siddoway. 1975. Snow management on eastern Montana rangelands. Proc. of Symposium on Snow Management on the Great Plains, Bismarck, N.D., July 29, 1975. Pub. No. 73, Res. Comm. Great Plains Agr. Counc. p. 138-143.

Wight, J. Ross, and F. H. Siddoway. 1972. Improving precipitation-use efficiency on rangeland by surface modification. J. Soil and Water Conserv. 27:170-174.