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Infiltration Characteristics of Forest Road Filter Windrows

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Abstract

A study to determine the infiltration parameters for filter windrows was undertaken. The study used a flow rate representing the runoff from a forest road of 100 m length during a storm of 50 mm/hr. Observations during the flow event suggested a hydrophobic-like condition existed for up to 10 minutes. The hydraulic conductivity required by the WEPP model to reproduce the field results ranged from 80 to 200 mm/hr in the filter windrow and from 60 to 1400 mm/hr in the forest floor. While the 1400 mm/hr value appeared to be due to macropores, hydraulic conductivity values of 400 mm/hr for the forest floor were required for proper WEPP simulation. These values will be incorporated in the U.S. Forest Service WEPP Road interface.
Keywords. Filter windrows, Hydrophobic conditions, Hydraulic conductivity, WEPP.

Introduction

Forest roads are frequently located on hill sides with slopes up to 60 percent. Many Forest Service roads have been constructed with filter windrows at the base of the fill slope. Filter windrows are barriers constructed of logging slash causing deposition of sediments. When placed during road construction the filter windrow provides immediate control of fill slope sediment. If left in place after construction, as most are, they provide sediment trapping capability for many years.

Burroughs and King (1989) reported an 88 percent reduction in sediment during a rainfall simulator test. The Washington Forest Practices Watershed Manual allows up to 82 percent reduction in sediment when filter windrows are used depending on how much of the fillslope is covered.

With process based erosion models there is a need for infiltration parameters in filter windrows. We undertook a simple study to determine the hydraulic conductivity of typical filter windrows and the forest floor below them.

Methodology

The site selected for this study was on the Boise National Forest located 25 km southeast of McCall, ID. The filter windrows were built in 1995 when the roads were constructed and were four years old. We selected only those sections of the filter windrows that were between 2.75 m and 3.5 m wide and had a "typical" number of small branches and woody debris. The habitat type was Lodgepole with mixed Ponderosa Pine. The geological parent material was decomposed granite.

The field test consisted of simulating the road generated runoff flowing through a filter windrow. To accomplish this a flow regulator was placed at the uphill edge of a filter windrow. The regulator was set at 36 l/min and placed in an open top diverging section with an outlet width of 0.254 m, comparable to the outlet from a moderate sized culvert. This flow rate represented the runoff from a section of forest road 100 m long and 4.2 m wide during a 50 mm/hr storm event. From the 0.254 m width the water spread out and flowed through the filter windrow. The flow event lasted for 30 minutes.

Once the wetting front exited the filter windrow, the distance of the wetting front from the outlet was measured at 5 minute intervals. At the end of the test the width of the wetted area beyond the filter windrow was measured at 2-meter intervals. Because we did not want to disturb the integrity of the filter windrow, no measurements inside the filter windrow were made.

Similar procedures were used for the forest floor plots. A total of 11 plots were tested. Five had no flow exiting the filter windrow at the end of the 30 minute test. Three plots had flow leaving the filter windrow and extending onto the forest floor. The remaining three were forest floor only plots. Slopes ranged from 13 to 41 percent.

The resulting data set was divided into three groups for subsequent analysis. One group contained those plots where the wetting front did not exit the filter windrow. The second group consisted of the forest floor

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plots. The last group contained the plots where the wetting front exited the filter windrow and flowed on the forest floor.

Modeling

We chose to use the Water Erosion Prediction Project model (WEPP) to determine the infiltration characteristics of the filter windrows and the forest floor. Since the WEPP model does not allow overland flow to be generated without precipitation, an extra OFE (OFE 1) was used for this purpose. The length of this OFE was arbitrarily set at 24 m and a hydraulic conductivity of 0.1 mm/hr was chosen.

The filter windrow or the forest floor was represented by a second OFE (OFE 2). The area of this OFE was equal to the actual infiltrated area at the end of the test. The model precipitation required to generate the volume of water placed on the plot during the 30 minute test was found by trial and error. This volume was calculated as shown below:

$$Vol = RO_{OFE1} * AREA_{OFE1} + (PRECIP - INT_{OFE2}) * AREA_{OFE2} \qquad (1)$$

where *RO* was the runoff, *AREA* was the area, *PRECIP* was the precipitation, and *INT* was the interception.

The hydraulic conductivity of OFE 2 (either the filter windrow or the forest floor) required to give the appropriate runoff from OFE 2 was found by trial and error. For the plots where the wetting front did not exit the filter windrow, the hydraulic conductivity was increased until a runoff of 0.5 mm was predicted. The conductivity of the forest floor plots was increased until a runoff of 1.0 mm was predicted.

The third group of plots, where flow exited the filter windrow and extended onto the forest floor, was used to test the hydraulic conductivity parameters. This was accomplished with a three OFE WEPP model. OFE 1 was used to generate runoff as before. OFE 2 was the filter windrow element, while OFE 3 represented the forest floor. These computer predictions were compared to the measured values.

Results and Discussion

Hydrophobic-Like Conditions

The wetting front where the flow exited the filter windrow and disappeared on the forest floor typically reached a maximum distance in 3 to 8 minutes then the wetting front began to retreat. It reached a steady state distance in 5 to 10 minutes and did not change after this period. During the retreat period and the steady state period, the width of the wetted surface did not widen. This resulted in the same amount of water infiltrating into a smaller area, implying an infiltration rate increasing with infiltrated volume.

Hydrophobic conditions in the forest soil are consistent with an infiltration rate increasing with infiltrated volume. Such conditions are often associated with forest soils following fire. However, Robichaud (1996) reported hydrophobic conditions on unburned soils using a water drop test. Robichaud (1996) was not able to report on the persistence of the hydrophobic conditions. Our data suggests that these conditions were short lived, less than 15 minutes, on unburned soils.

Spreading Angle Below Concentrated Flow Outlet

On seven of the eleven plots we were able to measure the dimensions of the wetted area on the forest floor. On all but one of these seven the wetting front diverged from the 0.254 m regulator outlet until the width was about 2 m then did not diverge further. There did not appear to be any micro-topographic controls on this lack of continued spreading. The average spreading angle was 20 degrees. There was no correlation between the spreading angle and the hillside gradient.

WEPP Model Hydraulic Conductivity

The results from the field tests where the flow was completely contained in the filter windrow were used to determine WEPP model parameters. There were five filter windrow plots. The hydraulic conductivity required by the model ranged from 80 mm/hr to 200 mm/hr. Since these values were from flows that did not exit the filter windrows, the area of infiltration was the maximum possible consistent with no flow out the filter windrow. This resulted in the infiltration estimates being the minimum possible.

The three forest floor only plots resulted in hydraulic conductivity values of 60, 65, and 1400 mm/hr. The 60 and 65 mm/hr values appear consistent with other reported forest floor rates. Elliot et al. (2000) suggest using 42 mm/hr, however, these values were not tied to field observations. Robichaud (1996) reported values ranging from 40 to 52 mm/hr. The 1400 mm/hr value appeared to be from a different population. Flow may have been going into macropores in the soil. The ratio of 1400 to 60 suggests a range of 20:1 for the spatial variability of hydraulic conductivity.

The results from the filter windrow and the forest floor plots were used in the WEPP model to compare to the plots where the water exited the filter windrow and flowed onto the forest floor. For the forest floor a hydraulic conductivity of 63 mm/hr was used and for the windrow values from 80 to 200 mm/hr were used. The computer simulation of one of the combined filter windrow and forest floor plots estimated no flow from the bottom of the forest floor. This was in agreement with the field test.

Two of the computer simulations estimated volumes of 22 to 24 L from the bottom of the forest floor. These depths were a substantial fraction of the 1080 L placed on the plots. This volume of water could not have been overlooked and we must conclude that the smaller range of model parameters were not sufficient to properly represent two of the three filter windrow and forest floor plots. In order to infiltrate the proper amount of water the hydraulic conductivity of the forest floor needed to be increased to about 400 mm/hr when the filter windrow conductivity was at its maximum value of 200 mm/hr.

While higher than 60 mm/hr, it was less than the maximum hydraulic conductivity estimated during these tests. We conclude that a range of at least 10:1 was needed to model the limited number of tests conducted. If we had tested more plots the 20:1 range would likely have been required.

Summary and Conclusions

This study found the forest floor required less area to infiltrate the runoff after it had been wetted for 8 to10 minutes. This observation implies a hydrophobic-like condition during the early time during a runoff event.

Runoff spread from the outlet of a culvert out at an angle of 20 degrees on the forest floor. There was no relationship between the hillside slope and the spreading angle.

We found the WEPP model required hydraulic conductivities in a forest filter windrow ranged from 80 to 200 mm/hr. The range on the forest floor was from 60 to 1400 mm/hr. The higher value of 1400 appeared to be due to infiltration into macropores.

The range of conductivities on the forest floor was 20:1 at a scale of 1 meter. This range has important implications for spatial variation in runoff. This full range of hydraulic conductivities was needed to simulate the observed runoff values measured in the field test.

We intend to use these hydraulic conductivity values for the filter windrows and the forest floor in future versions of our WEPP:Road interface.

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