Technical Note

SEDIMENT GENERATION AND MANAGEMENT ON FOREST ROADS: MEASUREMENTS AND MODELING

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For much of a forest plantation rotation, forest roads represent the major area of bare soil, and therefore have potential to be significant long term sources of sediment. Control of sediment and runoff from roads is thus a major priority for sustainable management of forest plantations. This paper outlines results from field studies investigating the generation and management of runoff and sediment from forest roads in South East Queensland. Experiments included; a) rainfall simulation to determine erosion from road surfaces, b) overland flow experiments to investigate erosion in table drains, c) sediment laden overland flow to assess the effectiveness of vegetated filter strips, and, d) a range of modeling approaches to predict the infiltration of overland flows discharged onto hillslopes. A simple technique to predict the effectiveness of vegetated filter strips is also presented.

INTRODUCTION

In a review of impacts of timber harvesting on streams, Campbell and Doeg (1989) noted that roads in forested country, particularly those constructed during harvesting, were one of the major sources of suspended sediment. Reasons for this include their lack of vegetation cover and surface of loose, fine, material overlaying an impermeable compact layer. Because road networks in managed plantations remain in place throughout the cropping cycle, they can act as sources of sediment throughout a forest rotation.

The preferred method for controlling sediment movement from forest roads is to spread runoff water and avoid channelisation. However, where concentration of runoff cannot be avoided, standard design techniques include table drains that run along roads sides and turn-out drains at intervals to limit flows in drains to non erosive levels. In forest plantations, turnout drains typically discharge runoff into areas of vegetation or surface litter where entrained sediment will be deposited rather than being transported off-site. When roads occur in close proximity to watercourses, vegetated filter strips (VFS) can provide an additional barrier to the movement of sediment into waterways.

OBJECTIVES

The objective of this research is to improve the sustainability of forestry operations in South East Queensland. Specifically, field research was conducted to:

- determine the levels and characteristics of sediment generated from unsealed forest roads and table drains; and
- evaluate and predict the effectiveness of sediment trapping and water quality improvement measures, including hillslope discharge and vegetative filter strips.

Results from this research are reported in detail by Loch *et al.* (in press) and Costantini *et al.* (in press.)

SEDIMENT GENERATION ON ROADS

Simulated rainfall was applied at approximately 100 mm/h for 20 minutes to sections of unsealed road 4 m long and 1.5 m wide. Road surfaces included gravelled, ungraveled and partially grassed. Runoff samples were taken over the duration of the rainfall event and analysed for total sediment load (gravimetrically) and for sediment size distributions. Surface samples from the rainfall plot were also collected and analysed for size distribution. The effect of vehicles traversing the road when wet was also investigated.

The results showed a high level of enrichment of fines under rainfall and relatively little effect of road

slope on erosion rates. This is consistent with predominantly interill transport at low slopes. Gravel surfaces were found to reduce the generation of fine sediment (< 0.050 mm) by more than 500%. Roads with 50% grass reduced sediment generation by more than 400%. Wheel tracking the plot when wet increased sediment concentration in runoff by approximately 25%.

SEDIMENT GENERATION IN TABLE DRAINS

Ten metre lengths of two table drains were selected at each site to investigate sediment generation from table drains. Flow rates of 2, 4, 6, and 8 l/s were applied to the drains, each for four minutes. Runoff samples were collected and analysed for total sediment. The table drains tested were found to be largely resistant to scour; the only drain in this study to actively erode was both steep and in a highly erodible condition following re-forming maintenance activities. It was concluded that in the area studied, erosion of properly designed table drains is unlikely.

FILTER STRIP TRIALS

Sediment laden flows (2 and 4 l/s) produced using soils from two sites (Imbil and Toolara) were introduced to plots 0.3m wide at range of lengths, vegetation types (6) and slopes (from 6 to 29%). Samples of inlet and outlet flow were taken and sediment concentration and characteristics determined. Infiltration was not considered to be significant at these high flow rates and was not considered in calculations.

Results showed that most deposition occurred within the filter strip (in contrast to the limited deposition observed in the 'backwater' zone prior to the filter strip), with the sedimentation fan extending downslope as the run progressed. The effectiveness of VFS was found to be variable in terms of total sediment. However, the effectiveness was relatively consistent when the sediment was considered in terms of its constituent size fractions. The results showed:

- 95% of particles < 0.050 mm were not trapped in filter strips;
- most particles > 0.125 mm were trapped by filter strip;
- there was a high variation in the proportion of sediment trapped in the size class between 0.05 mm and 0.125 mm.

These results indicate that removing sediment < 0.050 mm will be difficult to achieve using VFS. To enable prediction of the effectiveness of VFS, a simple conceptual approach was used equating the filter strip to a sediment pond with variables of settling velocity, flow depth and residence time. Model predictions compared well with field observations, indicating that most of the sediment > 0.125 mm would be trapped by the filter strips, and most of particles < 0.05 mm would not be deposited under these conditions. For the 0.125 to 0.050 mm size class, predicted and observed sediment yields were compared using regression analysis, resulting in a significant r^2 of 0.62 and a slope close to 1.

These results suggest that this simple approach may provide an easy to use and effective method for practitioners to predict sediment movement through a filter strip.

HILLSLOPE DISCHARGE

Data from road rainfall simulation experiments and table drain flow studies were used to parameterize hydrology and erosion models to allow simulations of infiltration downslope of table drain discharge

Erosion researchers testing the effectiveness of vegetated filter strips for trapping sediment

points. The scenario modeled was a 60 m long & 2 m wide segment of road with 4% crossfall draining into a table drain with a longitudinal gradient of 7%. The table drain discharged to an area 6 m wide. Runoff from a 20 minute rainfall event with a recurrence interval of 10 years was simulated.

The KINCON model (Connolly and Barton 1990) was used to create a hydrology pass file to allow the CREAMS (Knisel 1980) model to predict sediment detachment and transport within the road/drain system. The ANSWERS model (Beasley *et al.* 1980), using a Green and Ampt representation of infiltration, was used to model flow and infiltration of runoff following discharge to the hillslope.

Predictions of hillslope runoff patterns for scenarios with and without flow spreading demonstrated the importance of this aspect of hillslope discharge. Results from simulations showed that appropriate flow spreading could reduce the distance surface flow moved downslope from 70 m to 20 m in some cases.

CONCLUSION

This study provides information to assist with the development of practices to improve the sustainability of the forestry sector in South East Queensland. Specific conclusions drawn from this study include:

- Hillslope infiltration provides the best option for the management of sediment laden road runoff.
- Only short lengths of road surface (and therefore low volumes of sediment-laden runoff water) approaching water courses should be directed to water course filter strips.
- Roads with table drains discharging in the vicinity of watercourses should be graveled.
- Table drains should discharge to areas with high infiltration rates and flow spreading should be maximised.
- Residue retention practices should be adopted during inter-rotational periods to maintain high roughness and infiltration rates.
- Graveling, grass cover and consolidation of road surfaces reduced sediment loads.
- Avoid pushing loose material generated from road maintenance into table drains as this material will be easily transported.
- Fine sediment will be very difficult to remove using VFS – need to reduce sediment generation, prevent flow concentration and discharge runoff as high as possible in the landscape instead.

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