POTENTIAL EFFECTS OF FOREST MANAGEMENT PRACTICES ON STORMFLOW SOURCES AND WATER QUALITY

by

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INTRODUCTION

Forest management practices may adversely affect water, sediment, and nutrient yields in areas where permeable soils overlie an impermeable layer on steep slopes. Such sites are sensitive to management activities because they produce rapid subsurface flow on the upper slopes and overland flow near stream channels. Logging, intensive site preparation, or sewage disposal on such areas can alter the normal flow processes and pollute streams. Environmental damage, however, can be minimized if we understand the basic soil-water processes within the forest ecosystem and the potential impact of management practices on flow, and if we can use criteria for evaluating the sensitivity of forest sites to damage.

FLOW IN UNDISTURBED FORESTS

Under favorable soil conditions, litter on floors of undisturbed forests dissipates rainfall energy and promotes infiltration of water. Overland flow and surface erosion, except from saturated zones near stream channels, are rare in these forests (Kirkby and Chorley 1967, Megahan 1972). On areas with deep permeable soils, water infiltrates and moves vertically to the water table; in sloping areas with impermeable strata, water will move laterally through the soil as subsurface flow. Subsurface flow is an important factor in expanding the source areas of stormflow (Hewlett 1961, Hewlett and Nutter 1970), and it is often the major component of stormflow from undisturbed forests (Hewlett and Hibbert 1967, Kirkby and Chorley 1967, Whipkey 1967). Subsurface flow often moves rapidly to streams through macrochannels--interconnected root channels, animal burrows, soil cracks, and natural pipes that are open to the surface (Whipkey 1967, Weyman 1970, Aubertin 1971, Jones 1971, England 1975).

In an undisturbed forest, flow processes operate in equilibrium with the environment, and sediment yield usually is less than 300 pounds per acre per year (Ursic and Dendy 1965, Douglass 1974); disturbances to the environment may destroy the equilibrium and increase sediment yields.

LOGGING

Excluding logging roads and landings, logging, even clearcutting, seldom disturbs more than 30 percent of the soil surface in an area (Garrison and Rummell 1951, Herrick and Deitschman 1956, Dyrness 1965, Dickerson 1968, Zasada 1973). Some concentration of runoff in skid trails and localized rill erosion are inevitable (Dickerson 1975), but if precautions are taken to locate skid trails on the contour and ridgetops, avoiding stream channels, then sediment yield can be minimized, and the normal flow processes may continue for a time. Rothacher (1965), for example, reported that overland flow was rare on the upper and middle slopes of watersheds even on clearcut areas temporarily devoid of vegetation in western Oregon. However, several things that increase erosion may occur.

Diminished cover reduces evapotranspiration and increases soil moisture (Metz and Douglass 1959, Lull and Fletcher 1962, Troendle 1970). Subsequent downslope drainage expands the stormflow source areas (Hewlett 1961, Hewlett and Hibbert 1967). The source areas, particularly those adjacent to streams, reach saturation soon after rainfall begins, causing overland flow and initiating sheet and rill erosion (Kirkby and Chorley 1967).

If subsurface flow dominated water movement before logging, increased flow through the macrochannels may accelerate erosion within the soil openings. Consequently, sediment delivery to streams may increase even in the absence of surface erosion. In Tennessee, the production of sediment by piping has been observed following logging, and in northern Mississippi it has been found to occur after intensive site preparation.[1/] Jones (1971) observed that piping and "pseudo-piping" (a term he applies to flow through soil cracks and root channels) are effective agents in the erosion process in humid and in arid environments. Gullies and stream channel extensions are sometimes formed as soil pipes erode internally and then collapse (Buckham and Cockfield 1950, Jones 1971).

The forest floor of hardwood and pine stands quickly decomposes in warm humid climates once the overstory is removed (Ursic 1970, Dickerson 1972). If a clearcut area is not rapidly invaded by grasses or herbaceous plants, the soil becomes exposed to the direct impact of rainfall. As a result, the soil surface, including macrochannel openings, is likely to become sealed, reducing infiltration and increasing overland flow and sediment yields (Duley 1939, Meyer and Monke 1965).

INTENSIVE SITE PREPARATION

Some methods of intensive site preparation cause only minor soil disturbance. Brush chopping, for example, leaves much of the forest floor intact, especially when dense brush and logging debris absorb most of the force of the bulldozer and chopper. Detention storage of water and sediment may actually increase if the chopper's blades penetrate the forest floor perpendicular to the flow of water (Ursic 1974). Organic matter is left in place, there is only minor disturbance to the A-horizon, and the normal flow processes are likely to remain unaltered until the organic matter decomposes from continued exposure of the forest floor.

1/ Personal communication from S. J. Ursic and P. D. Duffy.

Site preparation methods that may have important hydrologic impacts are shearing and piling, bedding, discing, and root raking. After these methods are applied, forest sites resemble areas prepared for agricultural use. Removal of vegetative cover and much of the forest floor, soil compaction, and sealing of the macrochannels alter the normal flow processes. Preliminary observations in northern Mississippi where three intensive site preparation treatments--shearing and windrowing, bedding on the contour, and brush chopping--are being compared on three small watersheds, indicate that peak flows from the sheared and windrowed watershed are significantly higher than those from the other watersheds. The high peak flows reflect lower detention storage and greater soil compaction on the sheared and windrowed site than on either the brush chopped or bedded sites.

If a temporary cover crop is sown immediately after site preparation, adequate cover may be obtained to hold much of the soil in place until the new crop of trees is established or at least until herbaceous plants invade the area. The percent of vegetal cover required to protect a site varies with slope steepness and length, rainfall energy, and soil erodibility (Smith and Wischmeier 1962, Farmer and Van Haveren 1971). Mississippi subterranean clover was sown on the three intensively prepared watersheds discussed above. The clover cover ranged from 17 to 27 percent in late winter 1976, and although it is not yet adequate to protect the sites fully, the extensive mat of roots produced by the plants affords some protection.

SEWAGE DISPOSAL

Increased urbanization has compounded problems of municipal waste water disposal and stream pollution. It is feasible to use the forest biosystem as a "living filter" for reclaiming waste water (Sopper 1971, Sopper and Kardos 1972). Secondary benefits are increased groundwater recharge and tree growth.

Purification of the waste water depends primarily on microbial decomposition, chemical precipitation, ion exchange, and plant uptake taking place in the upper soil horizons (Sopper 1971, Carlson and Young 1975). The recommended procedure for optimizing these reactions is sprinkling the effluent at controlled rates to maintain aerobic conditions within the soil.

Before sewage disposal on forest lands is undertaken, however, the soils must be characterized as to their recharge potential. If areas subject to rapid subsurface flows are selected as disposal sites and high application rates are used, the effluent may pass unaltered through macrochannels to streams and pose serious pollution problems. Sites having either soils of low permeability or shallow, permeable layers overlying impermeable soils would have to be sprinkled at very low rates to prevent direct piping to streams.

EVALUATING SITES FOR INTENSIVE MANAGEMENT

Optimum forest management soon may require categorization of forest lands according to their suitability for specific treatments. Methods of categorizing sites must recognize the variable, rather than fixed, nature of stormflow source areas and also the potential impact of land treatment on the source areas and stormflow processes. Various techniques can be used to classify large areas of land, and potential problems on individual sites can be identified by any of several signs.

Topographic maps characterize length, angle, and configuration of watershed slopes and, with soil maps, can indicate areas with internal drainage problems. Recent developments in infrared aerial photography and radar imagery offer promise for differentiating groundwater recharge areas from non-recharge areas, which may be an excellent way of classifying forest land (Engman 1974).

Visual observations may reveal much about the hydrology of smaller areas. Intermittent springs or seeps on hillslopes or near channels of headwater zones often indicate subsurface flows above impermeable subsoils. Isolated mounds of sediment in or near otherwise well-covered channels may indicate accelerated erosion from piping. Although overland flow generally is negligible on undisturbed forest slopes, the mounding of litter and small twigs in surface depressions may signal localized zones of overland flow caused by shallow or poorly drained soils. Soil augering and road-cuts are often used to reveal the nature and depth of surface soils and underlying strata.

SUMMARY

Logging, intensive site preparation, and sewage disposal can alter stormflow volumes and rates and the basic flow processes. To avoid stream pollution and rapid erosion, the potential impact of a proposed management practice on an area to be treated should be evaluated.

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