THE HYDROLOGY OF A SLOPING FRAGIAQUALF

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ABSTRACT

A field experiment was conducted on a sloping Tokomaru silt loam (Typic Fragiaqualf). This soil has a permeable topsoil, but is underlain with an impermeable fragipan at 500 - 700 mm. Paired runoff plots (100 m^2 in area) were constructed, and over a four-year period, rainfall, water table levels and runoff were monitored. Infiltration and saturated hydraulic conductivity were also measured. During the study period, forty surface runoff events occurred with most of these being relatively minor events where less than 1 mm of runoff was generated. Subsurface flow rather than overland flow removed most of the excess rain over winter and early spring.

The dominant surface-runoff-generating process was found to be saturation overland flow. Hortonian runoff only occurred when the infiltration capacity was reduced by pugging of the soil surface. When such a treatment was applied to one of the plots, the saturated hydraulic conductivity of the topsoil was reduced from 500 - 1200 mm/day to only 0.8 mm/day. For the damaged plot, 25% (1.8 mm) of the 7.2 mm of rain which fell over a seven hour period became overland flow. This compared to 18% (1.3 mm) of the rain becoming surface runoff on the undamaged plot.

Aspects of modelling and simulation are discussed and several rainfall-runoff models are reviewed. A simple, physically-based, finite-difference model for predicting water table behaviour and runoff generation is described. The model uses the Dupuit-Forchheimer assumptions for flow below the water table, and it assumes a constant hydraulic potential between the water table and the surface.

Water table behaviour during and following a rainstorm was predicted reasonably accurately. Using hourly rainfall data, the occurrence and magnitude of runoff surface events over a winter/spring period were simulated. The model was also used to illustrate the importance of slope angle in subsurface flow and runoff generation. Over a winter/spring period, a 100 m^2 plot with a 10% slope was predicted to have nine days on which overland flow occurred, and subsurface flow rates which sometimes exceeded 30 mm/day. For the same period, a plot with a 2% slope was shown to have much less subsurface flow (with rates not exceeding 10 mm/day), and nineteen days of surface runoff.

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CHAPTER 1

INTRODUCTION

A great deal of New Zealand's hill country consists of shallow, permeable topsoils overlying less permeable subsoils, which in turn are underlain by almost impermeable layers. The ultimate barriers to water percolation in the soil are most commonly the parent rocks from which the soils are derived. These are mainly mudstones and siltstones, but they can also be compacted gravels or conglomerates, and in soils derived from loess, a densely compacted fragipan.

The hydrological processes occurring on such hillsides are the subject of this study. During dry periods the hill-soils hold very little water and the perennial streams are barely flowing. In summer therefore, pasture growth is often restricted by a lack of water.

The autumn and early winter rains are mostly soaked up by the soil and, in general, have little immediate effect on streamflow. Once the soil wets up again, usually by mid-winter, the mechanism whereby the soil is able to regulate the amount of water entering the watercourses becomes less effective. The reservoir becomes replete, and further rain proceeds directly to the streams causing posssible flooding and erosion during large storms.

In many hill country areas it has been observed that surface runoff occurs only during the most intense rainstorms. This suggests that the dominant hydrological process for water movement downslope is that of subsurface flow. The objectives of this study were to determine the principal hydrological processes occurring on a hillside, and to develop a simple model to simulate these processes.

Firstly the principles underlying our present understanding of hillslope hydrology need to be outlined. Chapter 2 is devoted to doing this. Chapter 3 describes measurements of the water table behaviour and runoff processes found in a humid climate, on a pasture-covered slope with a permeable soil underlain by an impermeable layer at 500 - 700 mm depth. Measurement of soil hydraulic properties is also detailed. Chapter 4 reviews the simulation of hillslope hydrology. Chapter 5 describes a particular model developed to simulate the hillslope hydrological data presented in Chapter 3. Chapter 6 presents and discusses the results obtained using this model. Chapter 7 summarizes the conclusions reached.