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Core rainfall-runoff regimes and models

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Four dominant regimes for catchment rainfall-runoff models are linked to three key ratios that determine the dominant style of simple focal model for areas not dominated by snow and ice. These ratios are between
1. Hillslope response time and channel response time (response time ratio: RTR)
2. Potential evapotranspiration and precipitation (aridity)
3. Catchment area and storm area (storm area ratio: SAR)
with the third of these ratios typically a combination of the first two. According to whether the first two ratios are greater or less than unity, the four focal models are the Unit hydrograph, TOPmodel, a Solitary Storm model and an Erosion Plot model. Each of these models makes different assumptions that are exactly applicable in a restricted range of circumstances, and approximately valid under a much wider and more realistic range, thereby providing core principles within more complex models.

The Unit Hydrograph is strictly valid if channel routing velocity is constant in time and space, and if hydrograph output is directly proportional to the excess rainfall available for storm runoff. The Geomorphological Unit Hydrograph provides a theoretical link between the shape of the unit hydrograph and the channel network structure. This link is, however only consistent for large RTR – in practise for catchments larger than about 100 km2.

TOPmodel estimates flow into a channel network from hillslopes. It is most strictly valid for the convex divide areas that generally occupy more than half of a catchment area. The key assumptions are that runoff is spatially uniform and that hydraulic gradient can be approximated by surface gradient (i.e. not in very low gradient areas). Implicitly this requires spatially uniform rainfall that reaches the saturated soil level simultaneously, and therefore application within small catchment areas.

In an intense storm that is much smaller than its catchment, the main focus of modelling is in the diffusive and advective spreading of the runoff generated beyond the storm area. This area may be associated with intense deposition of sediment, changing channel characteristics dynamically.

Storms in small arid areas are comparable to erosion plots, in which the response is most simply expressed in terms of a threshold, which may be overflowing the capacity of a simple bucket or show a more graduated response in which the threshold defines the storm size that generates 50% runoff.

More complex realistic models not only recognise the approximations inherent in these core regimes, but also generally incorporate components from more than one type of regime.