Impacts of Streamflow Production Mechanisms on the Evolution of River Basin Topography: The WE-38 Basin in Pennsylvania

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Abstract. Fluvial erosion processes are driven by water discharge on the land surface, which depends on precipitation rates, soil moisture dynamics, and groundwater flow. The discharge, whether in the form of overland flow or channelized flow, is produced by surface runoff and groundwater discharge. Surface runoff occurs if the rainfall intensity exceeds the infiltration capacity, and groundwater discharge is generated if the groundwater table intersects the land surface. In this analysis, we hypothesize that the mechanisms responsible for the production of water discharge affect the patterns of fluvial erosion and produce quantitatively different basin topographies over time. Furthermore, we hypothesize that the differences in the basin topographies produce a feedback mechanism that systematically impacts the production of water discharge in response to precipitation events. In order to test these hypotheses, a detailed hydrologic model is imbedded into an existing landscape evolution model. Precipitation is generated by a stochastic process that includes realistic inter-storm variation, and the precipitation is partitioned between surface runoff and groundwater recharge using specified infiltration and recharge rates. Groundwater flow is described by a two-dimensional Dupuit equation for a homogeneous, isotropic, unconfined aquifer with an irregular underlying impervious layer. The model is applied to the WE-38 basin, an experimental watershed in Pennsylvania. This site was selected as a study area because substantial hydrologic and geomorphic data is available including rainfall, streamflow, and water table information. First, the hydrologic model is calibrated to reproduce the observed streamflow for 1990 using the observed rainfall as the input. Then, the combined hydrologic/geomorphic model is used to investigate two end-member cases. In one case, the infiltration capacity is set to zero, so surface runoff produces all water discharge. In the other case, the infiltration capacity is large enough that groundwater discharge is the primary source of discharge. The resulting topographies are analyzed and their hydrologic behavior is characterized. The results indicate that the topography generated by groundwater discharge has deeper cuts at channel locations and a greater extension of the river networks than the topography generated by surface runoff. In addition, the topography generated by groundwater discharge has a shape that tends to inhibit the development of saturated areas.