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The effect of input data resolution and complexity on the uncertainty of hydrological predictions in a humid vegetated watershed

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Supplemental materials

S1. Description of SWAT-HS

SWAT-HS is a modified version of the SWAT model version 2012 (SWAT2012) that improves the prediction of saturation-excess runoff. Similar to SWAT, SWAT-HS is a semi-distributed model that simulates hydrological and water quality processes based on Hydrological Response Units (HRUs). Two main modifications made in SWAT-HS include: (i) adding information of topography and soil water storage capacity to HRUs; and (ii) introducing a surface aquifer that allows lateral exchange of subsurface water from upslope to downslope areas.

SWAT-HS uses topographic index (TI) as the basis for hydrological modeling, like some other variable source area models: TOPMODEL (Quinn and Beven, 1993;Beven and Kirkby, 1979), SWAT-VSA (Easton et al., 2008), SWAT-WB (White et al., 2011). The topographic index (TI) is defined as Eq. (1).

$$TI = ln\left(\frac{\alpha}{tan(\beta)K_s D}\right) \tag{1}$$

where TI is the soil topographic index [with units of ln(d m $^{-1}$)], α is the upslope contributing area per unit contour length (m), $\tan(\beta)$ is the local surface topographic slope, K_s is the mean saturated hydraulic conductivity of the soil (m d^{-1}), and D is the soil depth (m).

To keep the model semi-distributed, we divide the watershed into a limited number of wetness classes (maximum 10 classes in the current SWAT-HS). Each wetness class is assigned a soil water storage capacity, the amount of water that can be stored above field capacity in the soil before the soil becomes saturated. Soil water storage capacities in wetness classes in SWAT-HS is assumed to follow Pareto distribution as:

$$edc_i = S_{\max}\left[1-(1-A_i)^{1/b}\right] \tag{2}$$

where edc_i is the soil water storage capacity in wetness class i, $Smax$ is the maximum soil water storage capacity of the watershed, A_i is the fraction of the watershed for which the storage capacity is less than edc_i, and b is the shape parameter.

The lower *edc* values are assigned to the wetness classes having high TI values, locating in downslope areas (“wetter” wetness classes) while higher *edc* values are assigned to wetness classes with low TI values in upslope areas (“drier” wetness classes). *Smax* and *b* are two parameters controlling the Pareto distribution and are calibrated.

S1.1. HRUs with added information of topography and soil water storage capacity

SWAT-HS divides the watershed into subbasins. Subsequently, the subbasin is further divided into HRUs which are a unique combination of soil, land use, and slope as in SWAT, with an additional component: wetness class. To create HRUs in SWAT-HS, first, the soil map was overlaid with the wetness class map to create a new soil map in which the same soil types in different wetness classes have different soil names but retain the same soil characteristics. The new soil name reflects both wetness class and soil type. Subsequently, this new soil map is overlaid with land use and slope maps to create HRUs using the regular procedure in SWAT for HRU definition. In this study, we assumed that slope is not a part of HRU discretization for simplification purpose although slope is used in topographic index calculation and thus incorporated into wetness classes.

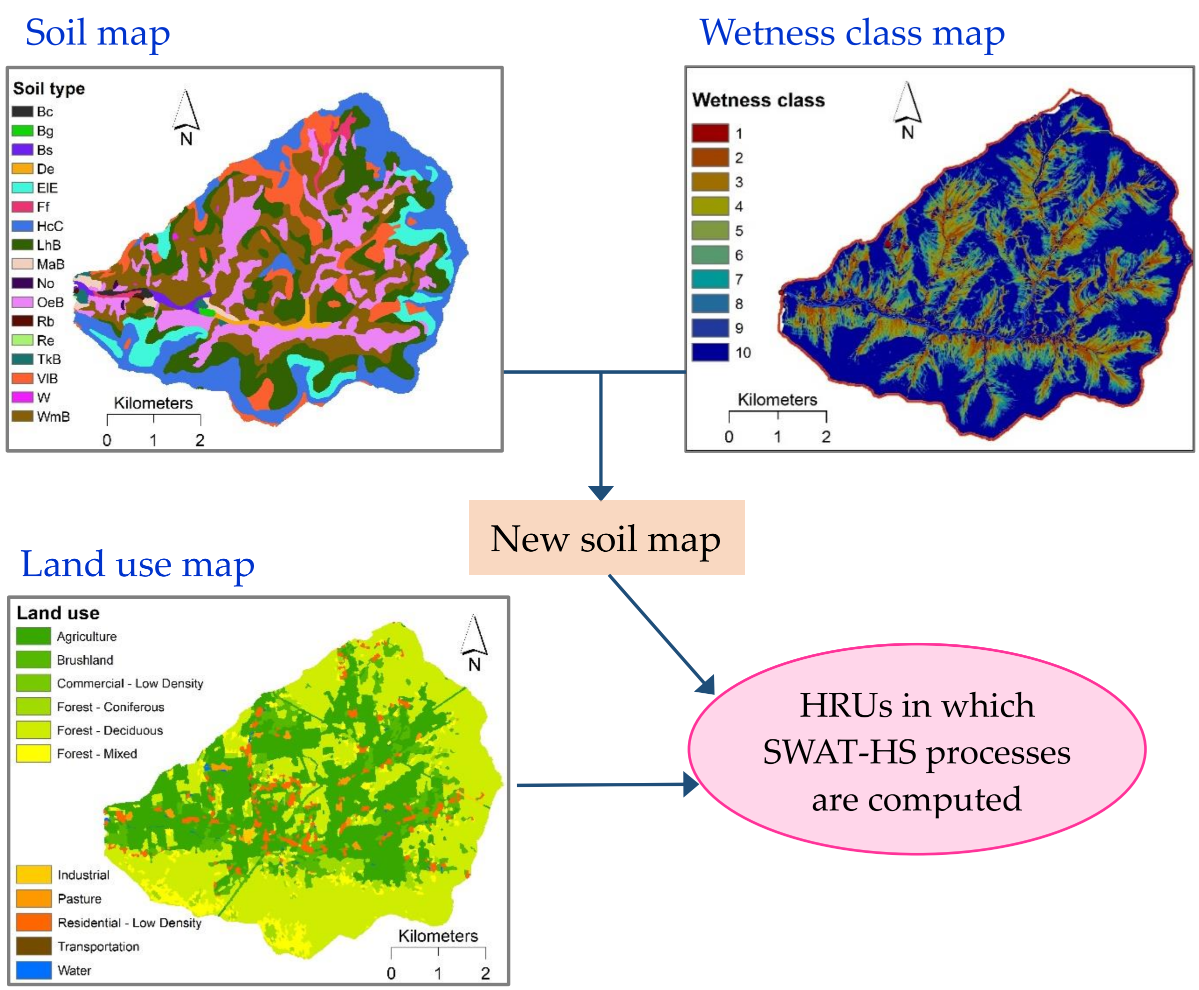

Figure S1: Creating HRUs from soil, land use and wetness maps in SWAT-HS (an example of the Town Brook watershed)

Once HRUs are created, each of them has details of its land use type, its soil type with soil name reflecting the wetness class number in which it is located. Each HRU has the initial soil water storage capacity depending on which wetness class it is located. This storage capacity will change over time depending on climate inputs and other processes occurring in the soil profile (percolation, uptake, evaporation, generation of different types of flow) which are affected by soil and land use information.

S1.2. Surface aquifer creating connectivity between wetness classes and routing lateral flow

In SWAT-HS, interaction is created between wetness classes through a "surface aquifer" so that downslope wetness classes can receive input from upslope wetness classes. The surface aquifer connects all wetness classes across the hillslope and transmits subsurface flow that is generated from this aquifer (known as lateral flow in SWAT) laterally through the hillslope from "drier" (upslope) to "wetter" (downslope) wetness classes.

Figure S2 illustrates the behavior of the water table in the surface aquifer in a hillslope with 10 wetness classes. The distribution of soil water storage capacities of wetness classes results in the shape of water table across the hillslope shown as the blue line in Figure S2. Supposing this is the initial water table, when there is hydrological input, the water table will rise to the red line (water table after rain). The amount of water that is above the soil surface becomes saturation-excess runoff, and the remaining becomes infiltration to the soil. Based on the amount of water stored in the surface aquifer, lateral flow is estimated by a non-linear equation and redistributed to the HRUs in the wetness classes that are saturated.

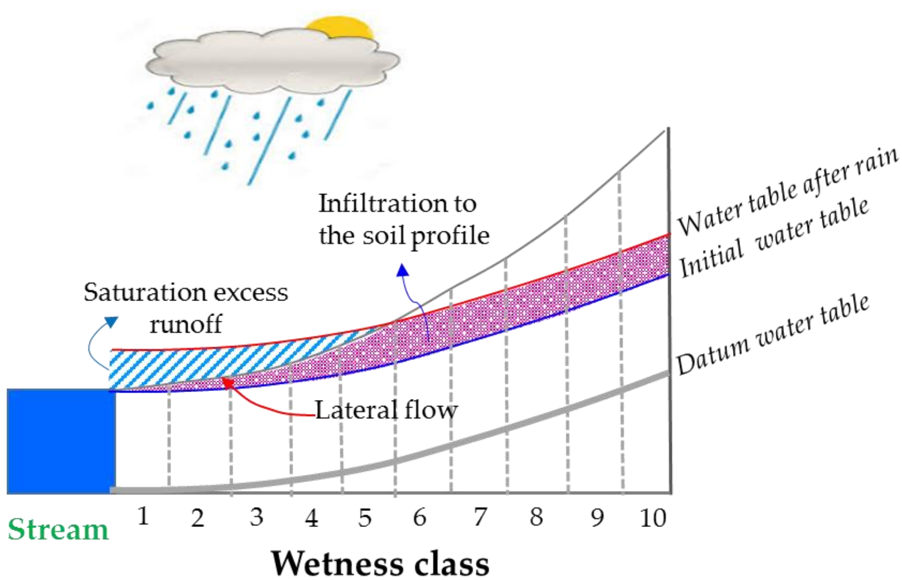

Figure S2: Illustration of behavior of water table in surface aquifer in SWAT-HS

The lateral flow in SWAT-HS is generated as the following equation using the linear (*latA*) and exponential (*latB)* coefficients:

$$\overline{latQ} = latA * \overline{S_1} \wedge latB$$

where ($\overline{latQ}$) is lateral flow for the sub-basin, $\overline{S_1}$ is the amount of water stored in the surface aquifer, *latA* and *latB* are constant coefficients.

With the two above modifications, saturation-excess runoff in SWAT-HS is generated in the "wetter" (downslope) wetness classes by two processes: (i) rain falls in wet areas with limited storage capacities where the excess water becomes runoff, and (ii) water from the upland areas is transported laterally to the lowland areas and the water exceeding soil storage capacity becomes runoff.

S2. Uncertainty of streamflow predictions in different SWAT-HS setups

S2.1. Uncertainty of streamflow predictions in SWAT-HS setups using different DEM resolutions

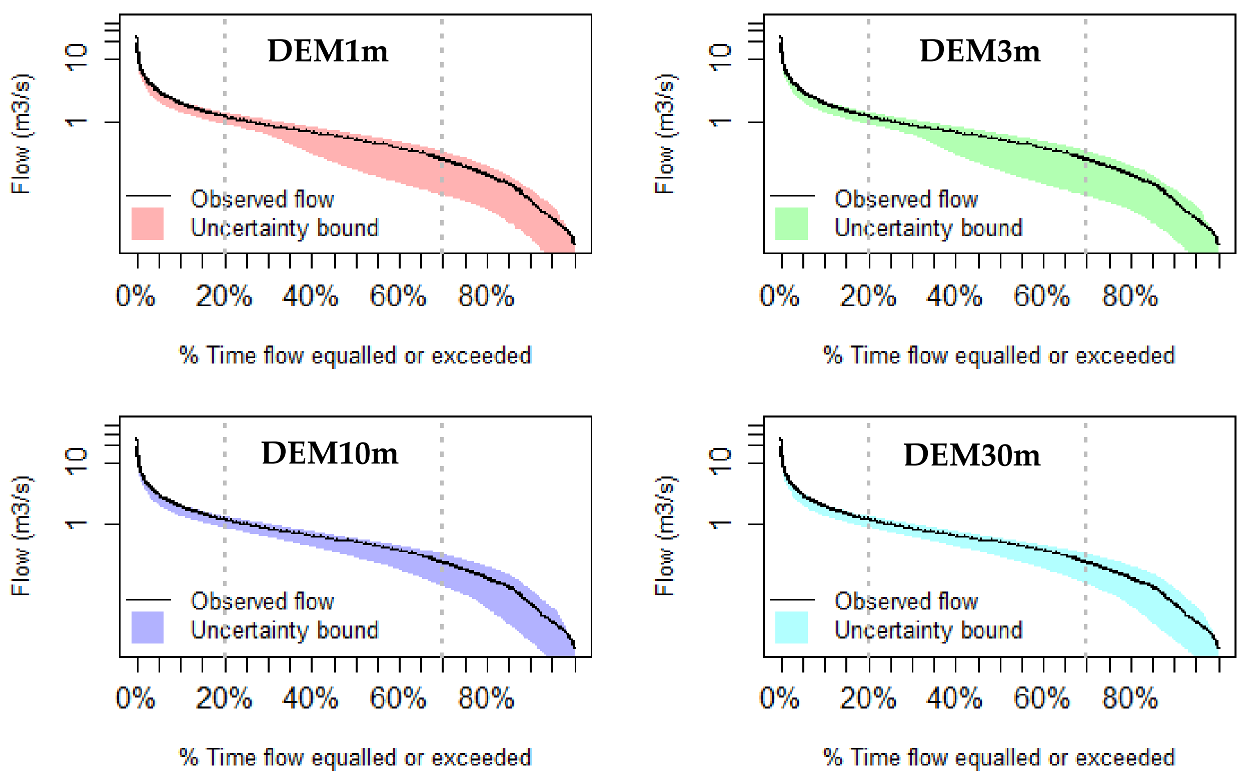

Figure S3: Uncertainty of streamflow predictions by SWAT-HS using different DEM resolutions

S2.2. Uncertainty of streamflow predictions in SWAT-HS setups with different soil and land use input complexity

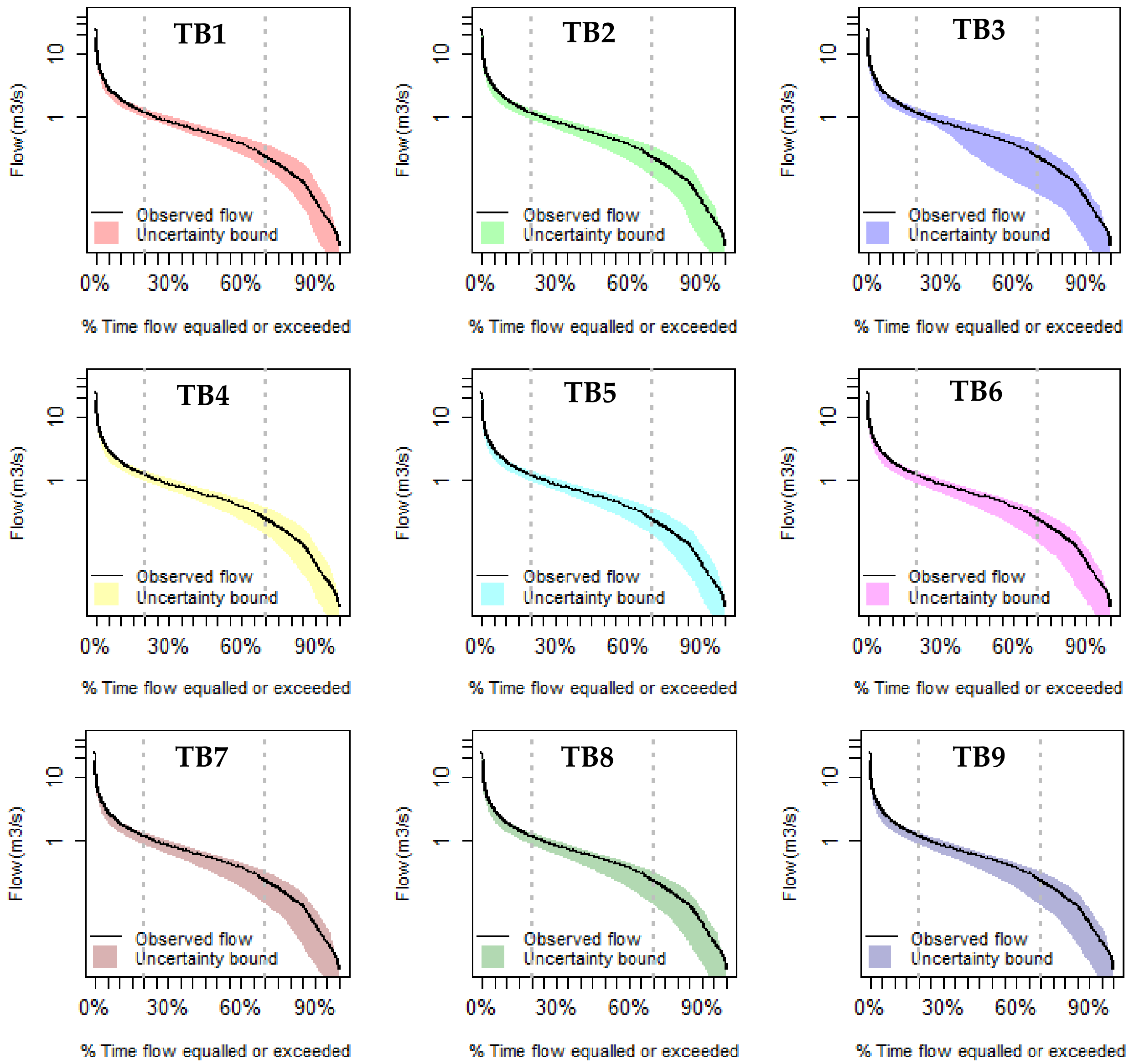

Figure S4: Uncertainty of streamflow predictions by SWAT-HS using different soil and land use input complexity