Watershed Dynamics
Streamflow STELLA Model: Technical Details

Using the Model

From the opening control panel, students can specify the percentages of different land uses that make up the watershed, using four 'slider' controls. Students can set values for *Percent Farm*, *Percent Forest*, *Percent Urban* and *Percent Suburb*. The sum of the four land use percentages must equal 100. If it does not, students will be prompted to correct the model before running it. Students can also change the amount of rainfall that will fall during the simulation by double-clicking on the *Rainfall* graph and entering their own graph. Finally, double clicking on the *Streamflow Prediction* graph will let students enter their prediction for the results of the simulation.

Logic behind the Model

The discussion that follows describes the entire model's logic. You can also see the logic by moving to the Streamflow Model's "Construction Layer". We have provided this discussion because some teachers are interested in why and how the model works; *however, you can use the model without ever examining the logic*.

Assumptions

In the STELLA Streamflow Model, we assume that all rainwater falling on the watershed eventually flows into the stream. We also assume that stream discharge before rainfall occurs is negligible.

Subsystems

The four subsystems that make up the model are Rainfall, Runoff, Subsurface Flow and Streamflow.

Rainfall

The Rainfall subsystem consists only of the amount of rainfall that falls during the simulation. This is entered using either a graphical input ("stretching" a graph) or by typing numbers into a 14-day data table. Students access these controls by double-clicking on the red "Rainfall" graph in the control panel. The Rainfall subsystem is connected to both the Runoff and the Subsurface Flow subsystems.

Runoff

Surface runoff is rainwater that flows directly into the stream because the surface infiltration capacity is zero. Infiltration capacity equals zero when the surface is impervious (e.g., roads, sidewalks, or buildings.) or the surface storage and soil are saturated. The amount of surface runoff depends on the watershed's soil and cover type (see Table 1). Soils are classified into four Hydrologic Soil Groups (HSG's) based on their minimum infiltration rate:

Group A
Low runoff potential and high infiltration rates, even when thoroughly wetted (i.e., sand, loamy sand, or sandy loam)

Group B
Moderate infiltration rates when thoroughly wetted (i.e., silt loam or loam)

Group C
Low infiltration rates when thoroughly wetted (i.e., sandy clay loam)

Group D
High runoff potential, very low infiltration rates when thoroughly wetted (i.e., clay loam, silty clay loam, sandy clay, silty clay, or clay).

The United States Department of Agriculture (USDA) has established an empirical equation that estimates runoff based on the soil and cover type. Knowing soil and cover type, you can find the corresponding curve number (CN) from Table 1. The curve numbers for each land use have been entered in the corresponding soil figures as follows: *Farm Soil* (68), *Forest Soil* (36), *Urban Soil* (94), and *Suburb Soil* (89). You can change any of these values. Keep in mind that CN values may vary greatly with specific land use conditions. For example, although the model considers all forests as equivalent, a pre-settlement, old-growth forest would have a lower CN than a younger, second- or third-growth forest.

Using the equation below, the runoff subsystem computes the amount of runoff flowing into the stream for each land use. The sum of the runoff for the four land uses is transferred to *Runoff*. This value is connected to both the Subsurface Flow and Stream Flow subsystems.

$$Q = \frac{[P - 0.2\,(1000/CN - 10)]^2}{P + 0.8\,(1000/CN - 10)}$$

Q = runoff (inches)
P = rainfall (inches)
CN = runoff curve number

Subsurface Flow
Subsurface water is the portion of rainwater that is delayed by the vegetation and soil and flows more slowly into the stream than surface runoff. Any rain that does not become runoff makes up the subsurface flow. *Into Ground* contains the value of rainwater that did not directly flow into the stream, *Rainfall* minus *Runoff*. This rainwater is then sent through *Percolate* to the stock, *Percolating Water*. A "conveyor stock" delays the movement of all of this water a fixed amount of time. After an additional, randomly varying *Time Lag*, the water becomes *Groundwater*. This phase does nothing more than delay the water from reaching the watershed. Once the rainwater has passed through the ground, it becomes *Subsurface Flow*. This value is then connected to the Stream Flow subsystem.

Stream Flow

This subsystem determines the amount of water flowing into the stream from the rainfall event. *Stream inches* is equal to the *Runoff* plus the *Subsurface Flow*. *Stream inches does not represent the height of water in the stream*. It represents the stream volume per watershed area. Actual stream height would vary with stream length and width, and with stream base flow (the stream flow which existed prior to the rainfall event). We elected to use the unconventional "stream inches" unit so that the scales for rainfall and stream flow would be the same. The area under the Rainfall and Actual Stream Flow curves will consequently also be the same. We have found that it is easier for students to predict (and understand) the system behavior using this convention. However, it is certainly appropriate to discuss with students the relationship between stream channel structure and water height.

Table 1. Runoff Curve Numbers*

Cover Type	Condition	Curve Numbers for Hydrologic Soil Group			
		A	**B**	**C**	**D**
Open Space (lawns, parks, golf courses, cemeteries)	Poor (grass cover < 50%)	68	79	86	89
	Fair (grass cover 50% to 75%)	49	69	79	84
	Good (grass cover > 75%)	39	61	74	80
Impervious Areas (paved areas, roofs, etc.)		98	98	98	98
Urban (Commercial)		89	92	94	95
Urban (Industrial)		81	88	91	93
Residential	1/4 acre lot	61	75	83	87
	1/2 acre lot	54	70	80	85
	1 acre lot	51	68	79	84
	2 acre lot	46	65	77	82
Fallow Land (farm land not actively cultivated)	Bare Soil	77	86	91	94
	Crop Residue Cover	74	83	88	90
Row Crops	Straight Row	67	78	85	89
	Contoured	70	79	84	88
Pasture (continuous grazing)		49	69	79	84
Meadow (protected from grazing, mowed for hay)		30	58	71	78
Brush		35	56	70	77
Woods/Grass Combination (orchard or tree farm)		43	65	76	82
Woods	Poor (heavy grazing or regular burning)	45	66	77	83
	Fair (grazed but not burned; some forest litter covers soil)	36	60	73	79
	Good (protected from grazing; litter and brush adequately cover soil)	30	55	70	77

Soil Groups:

1. Low runoff potential. Consist mainly of well-drained sands or gravels. High rate of water transmission.
2. Moderate infiltration rates. Moderately well-drained to well-drained soils. Moderately fine to moderately coarse textures. Moderate rate of water transmission.
3. Slow infiltration rates. Soils with moderately fine to fine texture. Slow rate of water transmission.
4. High runoff potential. Very slow infiltration rates. Consist mainly of clay soils, soils with a permanent high water table, soils with a clay layer at or near the surface and shallow soils over nearly impervious material. Very slow rate of water transmission.

*Adapted from *Urban Hydrology for Small Watersheds. USDA Soil Conservation Service Technical Release 55, June 1986*.