Deep processes

There are two model options for processes deep below ground; regional groundwater flow and aquifers. The regional groundwater flow model simulates groundwater flow between subbasins, but no explicit storage of deep groundwater. The aquifer model simulates aquifer storage and delay before regional groundwater reaches the destination.

Regional groundwater flow

Soil regional groundwater flow creation

Regional groundwater flow from a subbasin is calculated before the subbasin and class loops. This water is added to the downstream subbasin (in the class-loop part of the code) and/or to the outlet lake of the present subbasin (in the routing calculation part of the code). A subbasin dependent variable (*grwtolake*) governs the allocation between them. The outflow from a subbasin is calculated as a percentage of the water-retention capacity with a recession coefficient (*rcgrw*) e.g. for the lowest soil layer (*k*) the groundwater outflow for a class becomes:

$$q_{grw}(t) = rcgrw \times \left(soil(k) - wp(k) - fc(k) \right) \quad soil(k) > fc(k) + wp(k)$$

Groundwater flows are summarized for all classes in proportion to their areas and converted to volume flow out of the subbasin.

Soil addition of regional groundwater flow

The groundwater flow to be added to the bottom layer (and mixed) is added in the class loop portion of the code. If the layer then becomes full of water, it will be pressed into the layer above and mixed, etc. Please note that if downstream subbasin is much smaller than the upstream subbasin, groundwater inflows can become large. If part of the groundwater flow is to go to the outlet lake in the subbasin this is added to the volume of the lake in the routing part of the code.

Regional groundwater to outlet lake

With an input variable in GeoData.txt, an outlet lake may be flagged to receive inflow from the regional groundwater. The coefficient (grwtolake) specifies the portion of the produced regional groundwater flow which is led to the subbasins outlet lake.

Links to relevant procedures in the code

Modules (file)	Procedures	Sections
regional_groundwater_module (regional_groundwater.f90)	calculate_regional_groundwater_flow	soil regional groundwater flow creation
	calculate_soillayer_groundwaterflow_removal	soil regional groundwater flow creation
	add_regional_groundwater_flow_to_soil	soil addition of regional groundwater flow
	add_regional_groundwater_flow_to_olake	regional groundwater to outlet lake

Aquifiers

Deep percolation

Deep percolation is determined by a recession coefficient (*rc_grw*). The recession coefficient is set based on the recession parameter (*rcgrwst*) which is soil type dependent, but if it is not set the general parameter (*rcgrw*) is used instead. The recession coefficient can also be regionally adjusted by the correction parameter (*aqpercorr*).

$$rc_{grw} = rcgrw\left(or\ rcgrwst\right) \times \left(1 + aqpercorr\right)$$

Deep percolation from lowest soil layer in model is determined by the recession coefficient and the available water for runoff in the soil layer (*qperc (mm/timestep)*).

$$q_{perc}\left(t\right) = rc_{grw} \times \left(sm - fc - wp\right) \quad sm > fc + wp$$

Deep percolation from main river in model is determined by the recession coefficient and the water in the river (*qperc (m3/timestep)*).

$$q_{perc}\left(t\right) = rc_{grw} \times \left(waterdepth\right)$$

The water is removed from river water and the queue in proportion to their relative volumes.

Deep percolation delay and aquifer recharge

Deep percolation from soil and rivers in all recharge subbasins of an aquifer is added together. This total deep percolation (*qperc*) is delayed before it recharges the aquifer (*qrech*).

The delay parameter (*delay*, in days) is specific for each aquifer. It can be adjusted by the regional parameter *aqdelcor*.

Return flow from aquifer

Outflow from the aquifer depend on the water in the aquifer (*vol*) and a rate. The rate is determined by a parameter (*retrate*) and a regional adjustement parameter (*aqretcor*).

$$q_{out} = retrate \times \left(1 + aqretcor\right) \times vol$$

The outflow may be divided between several receiving subbasins (*retfrac*). The water is added to the inflow of the main river of these subbasins.

The return flow is added to the main river of the receiving subbasin.

Nutrient processes related to aquifers

The organic nitrogen, particulate phosphorus, and organic carbon in water percolating from soil and river stay in the soil/river, while temperature, inorganic nitrogen and SRP follow the water to the aquifer. Inorganic nitrogen is subjected to denitrification in the aquifer (see Chapter 3 Denitrification).

Links to relevant procedures in the code

Modules (file)	Procedures	Sections
regional_groundwater_module (regional_groundwater.f90)	calculate_aquifer	
	calculate_regional_groundwater_flow	deep percolation
	calculate_soillayer_groundwaterflow_removal	
	calculate_river_groundwaterflow_removal	
	calculate_aquifer_percolation	
	calculate_percolation_delay	deep percolation delay and aquifer recharge
	calculate_delayed_water	
	calculate_aquifer_outflow	return flow from aquifer
	add_aquifer_flow_to_river	
	calculate_current_flow_from_aquifer	return flow from aquifer
		nutrient processes related to aquifers
	set_percolation_concentration	nutrient processes related to aquifers