Table 1: Equations from model descriptions and their implementation in MARRMoT

| **Process** | **Details** | **Flux function** | **Constitutive function** | **Constraint(s)** | **MARRMoT code** | **Used in model …** |
| --- | --- | --- | --- | --- | --- | --- |
| Abstraction | Groundwater abstraction at a constant rate | abstraction\_1 |  | None, taken from a store with possible negative depth |  | 25 |
|  |  |  |  |  |  |  |
| Baseflow | Standard linear reservoir | baseflow\_1 |  |  |  | 2, 4, 6, 8, 9, 12, 13, 15, 16, 17, 18, 20, 21, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 43, 44, 45, 46 |
|  | Non-linear outflow from a reservoir | baseflow\_2 |  | To prevent complex numbers, S = [0,∞> |  | 9, 11 |
|  | Empirical exponential outflow from a reservoir | baseflow\_3 |  | Empirical equation, so interwoven with other equations that no constraints are needed. Also implicitly assumes time step |  | 7 |
|  | Exponential outflow from a deficit store | baseflow\_4 |  |  |  | 14 |
|  | Non-linear outflow scaled by current relative storage | baseflow\_5 |  | To prevent complex numbers, S = [0,∞> |  | 22 |
|  | Quadratic outflow from reservoir if a storage threshold is exceeded | baseflow\_6 |  |  |  | 25 |
|  | Non-linear outflow from a reservoir | baseflow\_7 |  | To prevent complex numbers, S = [0,∞> |  | 39, 42 |
|  | Exponential scaled outflow from a deficit store | baseflow\_8 |  |  |  | 23 |
|  | Linear outflow from a reservoir if a storage threshold is exceeded | baseflow\_9 |  |  |  | 20 |
|  |  |  |  |  |  |  |
| Capillary rise | Capillary rise scaled by relative deficit in receiving store | capillary\_1 |  |  |  | 37 |
|  | Capillary rise at a constant rate | capillary\_2 |  |  |  | 13, 15 |
|  | Capillary rise if the receiving store is below a storage threshold | capillary\_3 |  |  |  | 38 |
|  |  |  |  |  |  |  |
| Depression storage | Exponential inflow rate into surface depressions | depression\_1 |  |  |  | 36 |
|  |  |  |  |  |  |  |
| Evaporation | Evaporation at the potential rate | evap\_1 |  |  |  | 2, 6, 12, 13, 16, 17, 18, 23, 25, 26, 27, 33, 34, 36, 38, 39, 41, 42, 44, 45, 46 |
|  | Evaporation at scaled plant-controlled rate | evap\_2 |  |  |  | 18, 36 |
|  | Evaporation scaled by relative storage below a wilting point and at the potential rate above wilting point | evap\_3 |  |  |  | 3, 11, 14, 21, 26, 34, 37, 42 |
|  | Scaled evaporation if storage is above the wilting point, constrained by a limitation parameter | evap\_4 |  |  |  | 15 |
|  | Evaporation from bare soil, scaled by relative storage | evap\_5 |  |  |  | 4, 8, 9, 16 |
|  | Transpiration from vegetation at the potential rate if storage is above a wilting point and scaled by relative storage if not | evap\_6 |  |  |  | 4, 9, 16 |
|  | Evaporation scaled by relative storage | evap\_7 |  |  |  | 1, 3, 10, 11, 19, 22, 24, 29, 30, 31, 32, 33, 35, 45 |
|  | Transpiration from vegetation, at potential rate if soil moisture is above the wilting point, and linearly decreasing if not. Also scaled by relative storage across all stores | evap\_8 |  |  |  | 8 |
|  | Evaporation from bare soil scaled by relative storage and by relative water availability across all stores | evap\_9 |  |  |  | 8 |
|  | Evaporation from bare soil, scaled by relative storage | evap\_10 |  |  |  | 8 |
|  | Evaporation quadratically related to current soil moisture | evap\_11 |  |  |  | 7 |
|  | Evaporation from deficit store, with exponential decline as deficit goes below a threshold | evap\_12 |  |  |  | 5 |
|  | Exponentially scaled evaporation | evap\_13 |  |  |  | 40 |
|  | Exponentially scaled evaporation that only activates if another store goes below a certain threshold | evap\_14 |  |  | \* | 40 |
|  | Scaled evaporation if another store is below a threshold | evap\_15 |  |  |  | 41, 45 |
|  | Scaled evaporation if another store is below a threshold | evap\_16 |  |  |  | 17, 25 |
|  | Scaled evaporation from a store that allows negative values | evap\_17 |  | None, because the store is allowed to go negative |  | 39 |
|  | Exponentially declining evaporation from deficit store | evap\_18 |  |  |  | 46 |
|  | Non-linear scaled evaporation | evap\_19 |  |  |  | 23, 43 |
|  | Evaporation limited by a maximum evaporation rate and scaled below a wilting point | evap\_20 |  |  |  | 20 |
|  | Threshold-based evaporation with constant minimum rate | evap\_21 |  |  |  | 28 |
|  | Threshold-based evaporation rate | evap\_22 |  |  |  | 44 |
|  |  |  |  |  |  |  |
| Exchange | Water exchange between aquifer and channel | exchange\_1 |  | The “channel” store in this model has 0 time delay, so the incoming flux to the channel is the maximum channel-to-groundwater flux size. Groundwater has infinite depth |  | 36 |
|  | Water exchange based on relative storages | exchange\_2 |  |  |  | 38 |
|  | Water exchange with infinite size store based on threshold | exchange\_3 |  |  |  | 36 |
|  |  |  |  |  |  |  |
| Infiltration | Infiltration as exponentially declining based on relative storage (taken from a flux) | infiltration\_1 |  |  |  | 18, 36, 44 |
|  | Delayed infiltration as exponentially declining based on relative storage (taken from a store) | infiltration\_2 |  |  |  | 36 |
|  | Infiltration to soil moisture of liquid water stored in snow pack | infiltration\_3 |  |  |  | 37 |
|  | Constant infiltration rate | infiltration\_4 |  |  |  | 15, 23, 40, 44 |
|  | Maximum infiltration rate non-linearly based on relative deficit and storage | infiltration\_5 |  | To prevent complex numbers, S = [0,∞>  To prevent numerical issues with a theoretical infinite infiltration rate, fluxout < 10^9 |  | 23 |
|  | Infiltration rate non-linearly scaled by relative storage | infiltration\_6 |  |  |  | 43 |
|  |  |  |  |  |  |  |
| Interception | Interception excess when maximum capacity is reached | interception\_1 |  |  |  | 16, 18, 22, 26, 34, 36, 39, 42, 44, 45 |
|  | Interception excess after a constant amount is intercepted | interception\_2 |  |  |  | 2, 13, 15 |
|  | Interception excess after a fraction is intercepted | interception\_3 | \* |  | \* | 8 |
|  | Interception excess after a time-varying fraction is intercepted | interception\_4 |  |  |  | 32, 35 |
|  | Interception excess after a combined absolute amount and fraction are intercepted | interception\_5 |  |  |  | 23 |
|  |  |  |  |  |  |  |
| Interflow | Interflow as a scaled fraction of an incoming flux | interflow\_1 |  |  |  | 18, 36 |
|  | Non-linear interflow | interflow\_2 |  | To prevent complex numbers, S = [0,∞> |  | 37 |
|  | Non-linear interflow (variant) | interflow\_3 |  | To prevent complex numbers, S = [0,∞> |  | 10, 19, 42, 43 |
|  | Combined linear and scaled quadratic interflow | interflow\_4 |  | To prevent complex numbers, S = [0,∞> |  | 45 |
|  | Linear interflow | interflow\_5 |  |  |  | 28, 33, 41 |
|  | Scaled linear interflow if a storage in the receiving store exceeds a threshold | interflow\_6 |  |  |  | 41 |
|  | Non-linear interflow if storage exceeds a threshold | interflow\_7 |  | To prevent complex numbers, S-θ1Smax = [0,∞> |  | 9 |
|  | Linear interflow if storage exceeds a threshold | interflow\_8 |  |  |  | 3, 12, 27, 38 |
|  | Non-linear interflow if storage exceeds a threshold (variant) | interflow\_9 |  | To prevent complex numbers, S-θ2 = [0,∞> |  | 4, 11, 16, 39 |
|  | Scaled linear interflow if storage exceeds a threshold | interflow\_10 |  |  |  | 14 |
|  | Constant interflow if storage exceeds a threshold | interflow\_11 |  |  |  | 20 |
|  |  |  |  |  |  |  |
| Misc | Auxiliary function to find contributing area | area\_1 |  |  |  | 23 |
|  | General effective flow (returns flux [mm/d]) | effective\_1 |  |  |  | 22, 23, 25, 39, 40, 42, 43, 44, 45, 46 |
|  | Storage excess when store size changes (returns flux [mm/d]) | excess\_1 |  |  |  | 10, 19, 22, 37, 44 |
|  | Phenology-based correction factor for potential evapotranspiration (returns flux [mm/d]) | phenology\_1 |  |  |  | 35 |
|  | Phenology-based maximum interception capacity (returns store size [mm]) | phenology\_2 |  | Assumes to guarantee |  | 22 |
|  | Split flow (returns flux [mm/d]) | split\_1 |  |  |  | 5, 11, 13, 17, 21, 25, 26, 28, 29, 33, 34, 40, 41, 42, 43, 45, 46 |
|  |  |  |  |  |  |  |
| Percolation | Percolation at a constant rate | percolation\_1 |  |  |  | 37 |
|  | Percolation scaled by current relative storage | percolation\_2 |  |  |  | 21, 26, 34 |
|  | Non-linear percolation (empirical) | percolation\_3 |  |  |  | 7 |
|  | Demand-based percolation scaled by available moisture | percolation\_4 |  | To avoid erratic numerical behaviour, |  | 33 |
|  | Non-linear percolation | percolation\_5 |  | To prevent complex numbers, S = [0,∞> |  | 22 |
|  | Threshold-based percolation from a store that can reach negative values | percolation\_6 |  |  |  | 39 |
|  |  |  |  |  |  |  |
| Recharge | Recharge as scaled fraction of incoming flux | recharge\_1 |  |  |  | 18, 36 |
|  | Recharge as non-linear scaling of incoming flux | recharge\_2 |  | To prevent complex numbers, S = [0,∞> |  | 7, 37, 45 |
|  | Linear recharge | recharge\_3 |  |  |  | 19, 23, 24, 27, 30, 31, 32, 35, 38, 42 |
|  | Constant recharge from a store | recharge\_4 |  |  |  | 23, 44 |
|  | Recharge to fulfil evaporation demand if the receiving store is below a threshold | recharge\_5 |  |  |  | 20 |
|  | Non-linear recharge | recharge\_6 |  | To prevent complex numbers, S = [0,∞> |  | 44 |
|  | Constant recharge from a flux | recharge\_7 |  |  |  | 45 |
|  |  |  |  |  |  |  |
| Routing | Threshold-based non-linear routing | routing\_1 |  |  |  | 39 |
|  |  |  |  |  |  |  |
| Saturation excess | Saturation excess from a store that has reached maximum capacity | saturation\_1 |  |  |  | 1, 3, 4, 6, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 22, 24, 25, 30, 31, 32, 33, 35, 36, 39, 40, 41, 44, 45, 46 |
|  | Saturation excess from a store with different degrees of saturation | saturation\_2 |  | To prevent complex numbers, S/Smax = [0,∞> |  | 2, 13, 22, 28, 29 |
|  | Saturation excess from a store with different degrees of saturation (exponential variant) | saturation\_3 |  |  |  | 21, 26, 34 |
|  | Saturation excess from a store with different degrees of saturation (quadratic variant) | saturation\_4 |  |  |  | 7 |
|  | Deficit store: exponential saturation excess based on current storage and a threshold parameter | saturation\_5 |  | To prevent complex numbers, S = [0,∞> |  | 5 |
|  | Saturation excess from a store with different degrees of saturation (linear variant) | saturation\_6 |  |  |  | 40 |
|  | Saturation excess from a store with different degrees of saturation (gamma function variant) | saturation\_7 |  | To prevent numerical problems, S = [0,∞> |  | 14 |
|  | Saturation excess flow from a store with different degrees of saturation (min-max linear variant) | saturation\_8 |  |  |  | 45 |
|  | Deficit store: saturation excess from a store that has reached maximum capacity | saturation\_9 |  |  |  | 17, 25, 43, 46 |
|  | Saturation excess flow from a store with different degrees of saturation (min-max exponential variant) | saturation\_10 |  |  |  | 39 |
|  | Saturation excess flow from a store with different degrees of saturation (min exponential variant) | saturation\_11 |  |  |  | 23 |
|  | Saturation excess flow from a store with different degrees of saturation (min-max linear variant) | saturation\_12 |  |  |  | 23 |
|  | Saturation excess flow from a store with different degrees of saturation (normal distribution variant) | saturation\_13 |  |  |  | 42 |
|  | Saturation excess flow from a store with different degrees of saturation (two-part exponential variant) | saturation\_14 |  |  |  | 28 |
|  |  |  |  |  |  |  |
| Snow | Snowfall based on temperature threshold | snowfall\_1 |  |  |  | 6, 12, 30, 31, 32, 34, 35, 41, 43, 44, 45 |
|  | Snowfall based on a temperature threshold interval | snowfall\_2 |  |  |  | 37 |
|  | Rainfall based on temperature threshold | rainfall\_1 |  |  |  | 6, 12, 30, 31, 32, 34, 35, 41, 43, 44, 45 |
|  | Snowfall based on a temperature threshold interval | rainfall\_2 |  |  |  | 37 |
|  | Refreezing of stored melted snow | refreeze\_1 |  |  |  | 37, 44 |
|  | Snowmelt from degree-day-factor | melt\_1 |  |  |  | 6, 12, 30, 31, 32, 34, 35, 37, 43, 44, 45 |
|  | Snowmelt at a constant rate | melt\_2 |  |  |  | 44 |
|  | Glacier melt provided no snow is stored on the ice layer | melt\_3 |  |  | \* | 43 |
|  |  |  |  |  |  |  |
| Soil moisture | Water rebalance to equal relative storage (2 stores) | soilmoisture\_1 |  |  |  | 33 |
|  | Water rebalance to equal relative storage (3 stores) | soilmoisture\_2 |  |  |  | 33 |