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Introduction

UWOT components are classified into four categories that have to do with: Household Appliances, Signal, Hydrosystem, and Energy. Each component is classified into one of these categories.

The **Household Appliance** category includes the components inside household. Namely, the appliances that consume water (e.g. washing machine, toilet, shower, etc), the appliances that offer decentralized water management (local greywater treatment and local SUDS), and the components that represent the part of the mains directly serving every household (e.g. distribution network of potable water, drainage network, etc). Note that during the design of a household network, components from other categories can be included (e.g. an impervious area).

The **District Network** category includes the components that represent the district-level infrastructure of the water cycle. For example, it includes the distribution network of the potable water, the distribution of green water (reclaimed water from centralized treatment facilities), the stormwater drainage and sewerage systems.

The **Signal** category includes the components that aggregate and route signals (e.g. the nodes and the valves of a water network). The Summation and Mix components are the most common components of this category. The former is used to represent tee pipe fittings inside households (to aggregate the output of the household appliances), and the latter is used to represent diversions of water flow (confluences or junctions). This category also includes components that introduce into UWOT signals from timeseries calculated externally (the IN component for quantity and the FL for quality) and components that log signals (the LG component). The components of this category do not influence any pot and do not have brands and specifications.

The **Hydrosystem** category includes the components that convey, treat and store water. Some components of this category can simulate processes of the natural or artificial hydrosystem (for example the pervious/impervious for surface runoff, the Surface Water component for a lake, the Aqueduct component for an aqueduct, etc.). Some components of this category apply to arbitrary scale (for example, pervious and impervious areas of a household or a whole district), whereas other components refer to large scale only (for example, potable mains, raw water aqueducts, etc.)

The **Energy** category includes the components that are involved in the energy-water nexus with emphasis on renewable resources. For example, the Hydro Turbine component, the Renewable component (to simulate water pumps driven by wind turbines) and the Solar Panel component to simulate photovoltaic and solar heater panels. This category includes also the Blue Green component that simulates the urban heat island effect, in which the latent heat is used as an ecosystem services metric.

Household

Typical household appliances (BA, DW, HB, KS, OU, SH, WC, WM)

The appliances inside households are the bath (BA), the dishwasher (DW), the handbasin(HB), the kitchen-sink (KS), the outside uses (OU), the shower (SH), the toilet (WC) and the washing machine (WM).

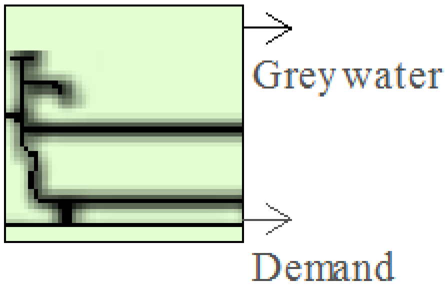

Figure 1: Example of a household appliance. The UWOT Bath component.

Signals. All these UWOT components have two outputs. The demand for the water (potable or, if applicable, green) required for the operation and the demand to drain the output of the appliance (wastewater or, if applicable, grey). The demand for water and the output are estimated with the formulas:

$\mathrm{Oqn\_1}_t = d \times f_t \times \mathrm{oc}_t \times \mathrm{dt}$
$\mathrm{Oql\_1}_t = q$
$\mathrm{Oqn\_2}_t = \mathrm{Oqn\_1}_t$
$\mathrm{Oql\_2}_t = -1$

where Oqn_1 and Qql_1 stand for the quantity in L/(time-step) and quality in mg/L of the signal emitted by port 1 (port 1 is the upper one in Figure above i.e. the one named "Grey water"), Oqn_2 and Qql_2 stand for the quantity and quality of the signal emitted by port 2, d is the water consumed by the appliance per use, q is the quality of the output signal in mg/L (taken from the technology library), f_t is the frequency of use at the time-step t of a specific appliance in uses/day/person, oc_t is the occupancy at the time-step t (taken equal to 1 for outside uses), and dt is the simulation time-step in days. The quality of the demand (Oql_2) is set to -1 to indicate the assumption that provided water complies with the quality regulations. This value is typically assigned to all pull signals (pull is a signal that has opposite direction with the actual flow).

Pots influenced by this component. The household appliances influence the energy, the capital and the operational pots of the group to which each appliance belongs to. The required energy per time-step is calculated using the formula:

$E_t = \varepsilon \times f_t \times \mathrm{oc}_t \times \mathrm{dt}$

where ε is the kWh consumed by appliance per use (from the technology library). The operational cost is calculated similarly i.e.

$C_{Ot} = c_o \times f_t \times \mathrm{oc}_t \times \mathrm{dt}$

where c_o is the operational cost per use (from the technology library). The capital cost is taken directly from the technology library.

NOTE. For the calculation of the previous quantities Oqn_1_t, Oqn_2_t and the resources E_t, C_{Ot}, a time-step greater than day was assumed. For sub-daily time-steps the frequency of use of every appliance is multiplied by a value, which is called “Demand fluctuation”. This value is kept constant equal to 1 for time-steps greater than one day whereas it may vary for smaller time-steps according to the formula $D_i/(\sum_{i=1...n} D_i) \times n$, where D_i is the expected household demand at time-step i and n is the number of time-steps (it is the user's responsibility to employ the previous formula, UWOT is expecting the output of the formula). For example, for hourly time-step, a typical set of 24 first values of the “Demand fluctuation” timeseries could be the following: 0.09, 0.06, 0.07, 0.11, 0.12, 0.36, 0.13, 1.11, 2.76, 2.81, 1.73, 1.32, 1.05, 1.22, 1.03, 0.96, 1.03, 1.40, 1.60, 1.32, 0.99, 1.16, 0.78, 0.51, 0.28.

Local Treatment (LT)

This component receives grey water from the household appliances and produces green (treated grey). A tank fitted into the appliance holds the incoming greywater.

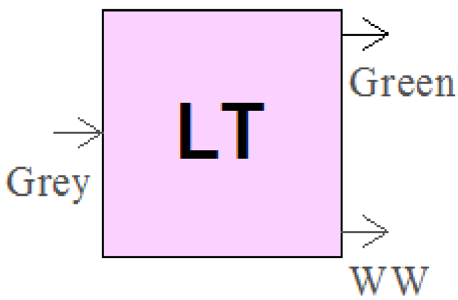

Figure 2: The UWOT Local Treatment component.

Signals. The amount of incoming water at time-step t is Iqn_t (L/time-step) with quality Iql_t (mg/L). If Iqn_t is greater than the treatment capacity k given (from the technology library) in L/day, the volume V_t (L) inside tank increases. If V_t exceeds the tank capacity $V_{\max}$ (component parameter), the tank spills to the wastewater output. The quantity and quality of the signals are:

Oqn_$1_t = k \times \mathrm{dt} - d_t$
Qql_$1_t = 0$
Oqn_$2_t = \mathrm{spl}_t$
Qql_$2_t = \mathrm{Iql}_t$

where d_t is the deficit (L/time-step), spl_t is the tank spill, and Iql stands for quality in mg/L of the incoming signal, Oqn_1, Oqn_2 and Qql_1, Qql_2 stand for the quantity in L/(time-step) and quality in mg/L of the ports 1 and 2 respectively (port 1 is the upper one i.e. the named "Green").

Water budget. The water budget of the greywater tank is:

$V_{t\text{-}1/2} = V_{t\text{-}1} + (\text{Iqn}_t - k \times \text{dt}) \times 1$ time-step
$d_t = -\min(0, V_{t\text{-}1/2})$
$\text{spl}_t = -\min(0, V_{\max} - V_{t\text{-}1/2}) / 1$ time-step
$V_t = \min(V_{\max}, V_{t\text{-}1/2})$

Pots influenced by this component. This component influences the energy, the capital and operational cost pots of the group to which this appliance belongs to. The required energy per time-step is calculated by the formula:

$E_t = \varepsilon \times \text{dt}$

where ε is the consumed energy in kWh per day (from the technology library) and dt is the simulation time-step in days. The capital cost is taken directly from the technology library. The operational costs is calculated by the formula:

$C_{Ot} = c_o \times \text{dt}/365$

where c_o is the operational cost per year (from the technology library).

Local SUDS (LS)

This component receives the runoff water from the pervious and impervious areas of a household and reduces the runoff volume by infiltrating a portion of it.

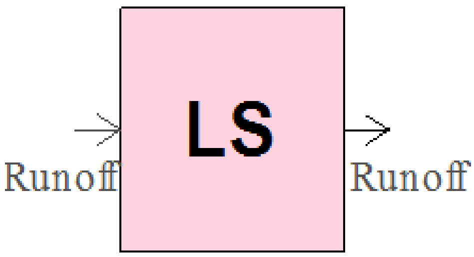

Figure 3: The UWOT Local SUDS component.

Signals. The quantity and quality of the emitted signal are:

$\text{Oqn}_t = \text{Iqn}_t \times (1 - \text{nf})$
$\text{Qql}_t = \text{Iql}_t$

where Iqn and Iql stand for quantity in L/(time-step) and quality in mg/L of the incoming signal, Oqn and Qql stand for the quantity in L/(time-step) and quality in mg/L of the output signal and nf is the infiltration coefficient (from the technology library).

Pots influenced by this component. This component influences the infiltration, the capital and operational cost pots of the group this component belongs to. The infiltration at the time-step t is calculated by the formula:

$\mathrm{Nf}_t = \mathrm{Iqn}_t \times \mathrm{nf}$

The capital cost is taken directly from the technology library. The operational costs is calculated by the formula:

$C_{\mathrm{O}t} = c_{\mathrm{o}} \times \mathrm{dt}/365$

where c_{o} is the operational cost per year (from the technology library).

District network

Storm Drain (DS)

This UWOT component simulates the part of the urban stormwater collection network that directly serves a household (multi-storey apartments are considered as one household with many occupants).

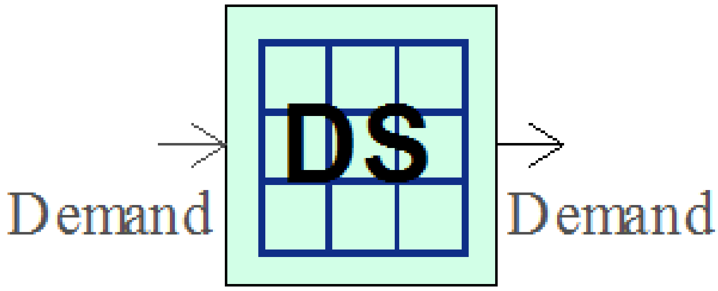

Figure 4: The UWOT Storm Drain component.

Signals. The quantity of the output signal is lower than that of the incoming because a portion of collected water ψ (from the technology library) leaks.

$$Oqn\_1_t = Iqn_t \times (1 - \psi)$$
$$Qql\_1_t = Iql_t$$

Pots influenced by this component. The Storm Drain component influences the losses, the capital and operational pots of the group to which it belongs to. The leakage is calculated by the formula:

$$L_t = Iqn_t \times \psi$$

The capital cost is taken from the technology library. The operational costs is calculated by the formula:

$$C_{Ot} = c_o \times dt/365$$

where c_o is the operational cost per year (taken from the technology library).

Grey water line (GL)

This UWOT component simulates the part of the centralized grey collection network (for developments that employ centralized greywater treatment) that directly serves a household (multi-storey apartments are considered as one household with many occupants).

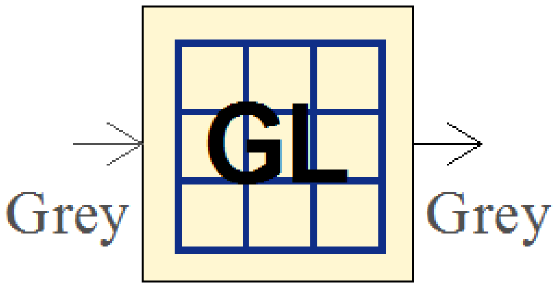

Figure 5: The UWOT Grey Line component.

Signals. See Storm Drain (DS).

Pots influenced by this component. The same pots with the Storm Drain plus the energy pot of the group to which it belongs to because it is assumed that energy is consumed for pumping. If Iqn_t is the quantity of the incoming signal and ε is the specific energy in kWh/L (from the technology library) the consumed energy is:

$E_t = \varepsilon \times Iqn_t$

Potable distribution (PL)

This UWOT component simulates the part of the potable distribution network that directly serves a household (multi-storey apartments are considered as one household with many occupants).

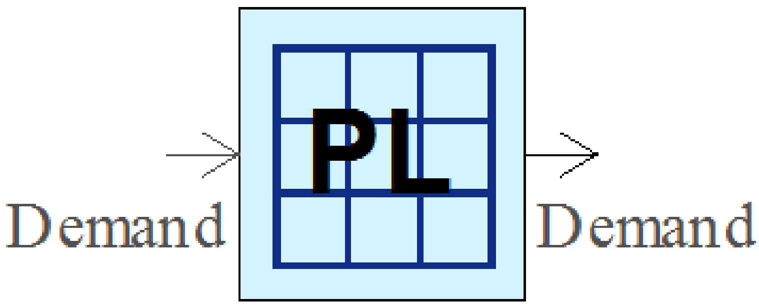

Figure 6: The UWOT Potable distribution component.

Signals. The amount of the output signal is higher than that of the incoming because a percentage of transmitted water ψ (from the technology library) is supposed to leak.

$Oqn\_1_t = Iqn_t \times (1 + \psi)$
$Qql\_1_t = -1$

Pots influenced by this component. See Grey water line (GL).

Sewage Collection (SG)

This UWOT component simulates the part of the urban sewage collection network that directly serves a household (multi-storey apartments are considered as one household with many occupants).

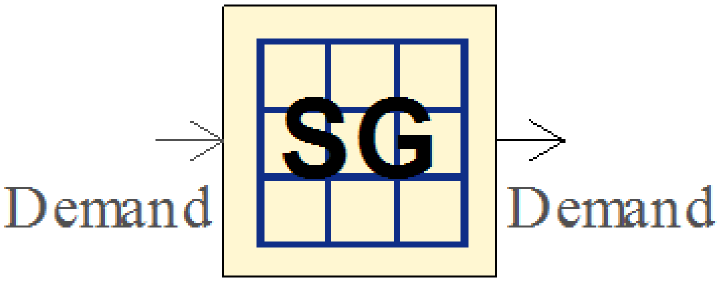

Figure 7: The UWOT Sewage Collection component.

Signals. See Storm Drain (DS).

Pots influenced by this component. See Storm Drain (DS).

Signal

Divergence (DV)

This UWOT component diverges the incoming signal to the second output port if the quantity exceeds a prescribed threshold θ (provided by timeseries). This component can be used both with push and pull signals.

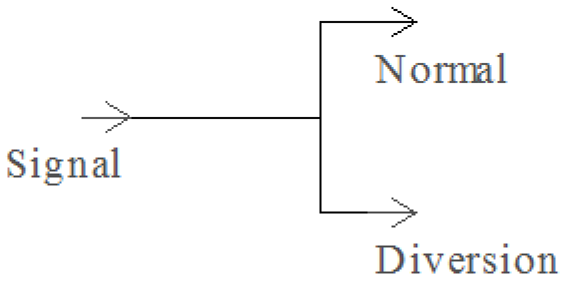

Figure 8: The UWOT Divergence component.

Signals. This UWOT component offers three operational modes. In the first mode only the amount of water exceeding the prescribed capacity θ_t is diverted. This can be used to ensure no capacity exceedance of downstream aqueducts by diverting supplementary 'flow' to alternative routes. It also can be used in case of simulating a failure (set θ_t equal to 0). In this mode, the outputs of this component are calculated by the following formulas:

$Oqn\_1_t = \min(Iqn_t, \theta_t)$
$Qql\_1_t = Iql_t$
$Oqn\_2_t = 0$ if $Iqn_t < \theta_t$ otherwise $Iqn_t - \theta_t$
$Qql\_2_t = Iql_t$

where Iqn and Iql stand for quantity in L/(time-step) and quality in mg/L of the incoming signal, Oqn_1, Oqn_2 and Qql_1, Qql_2 stand for the quantity in L/(time-step) and quality in mg/L of the signals of the ports 1 and 2 respectively (port 1 is the upper one i.e. the named “Normal”).

In the second mode, the whole amount of the incoming water is diverted if it exceeds the prescribed quantity threshold (this is useful in case of components that have an upper flow limit they can operate). In this mode the outputs of this component are calculated by the following formulas:

$Oqn\_1_t = Iqn_t$ if $Iqn_t < \theta_t$ otherwise 0
$Qql\_1_t = Iql_t$
$Oqn\_2_t = 0$ if $Iqn_t < \theta_t$ otherwise Iqn_t
$Qql\_2_t = Iql_t$

The third mode is invoked if $\theta_t < 0$. In this case θ_t is expected to provide the percentage of incoming signal diverted to the second port and the outputs of this component are calculated by the following formulas:

$Oqn\_1_t = (100 – \max(\mathrm{abs}(\theta_t),100))/100 \times Iqn_t$
$Qql\_1_t = Iql_t$
$Oqn\_2_t = \max(100, \mathrm{abs}(\theta_t)) / 100 \times Iqn_t$
$Qql\_2_t = Iql_t$

Flow Control (FC)

This UWOT component clones the incoming signal into two identical output signals. A typical use of this component is to control the yield of an upper reservoir to a lower reservoir (In port is connected to the upper reservoir and Out port is connected to the lower). The incoming signal represents an operational signal and can be provided by external timeseries (IN component). This component emits one push (port Out) and one pull signal (port In).

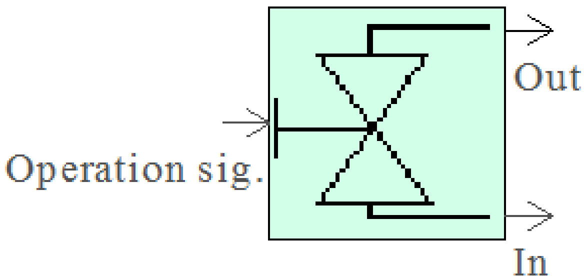

Figure 9: The UWOT Flow Control component.

Signals. The quality of the output 1 (port 1 is the upper one i.e. the named “Out”) is set equal to the quality q_t of the water stored inside the reservoir that has the same group id with this component. If more that one reservoirs have the same group id, then one is randomly selected. If no reservoir is found within the group, the q_t is set equal to 0.

$Oqn\_1_t = Iqn_t$
$Qql\_1_t = q_t$
$Oqn\_2_t = Iqn_t$
$Qql\_2_t = -1$

Filter (FL)

This UWOT component leaves the quantity of the incoming signal unaffected, but sets the quality equal to a constant or to a value q_t of timeseries. This component can be used only with push signals.

Signals. If Iqn and Iql stand for the quantity (L/time-step) and quality (mg/L) of the incoming signal, then the emitted signal is given by the formulas:

$Oqn_t = Iql_t$
$Qql_t = q_t$

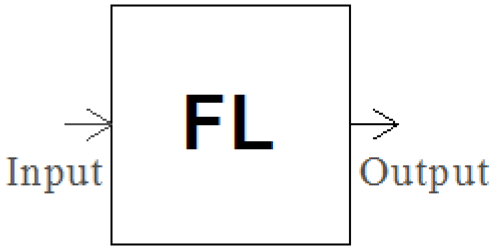

Figure 10: The UWOT Filter component.

In-line Logger (IL)

This UWOT component logs the quantity and quality of the incoming signal but does not terminate the signal. This component can be used both with push and pull signals.

Figure 11: The UWOT In-Line Logger component.

Signals.

$Oqn_t = Iqn_t$
$Qql_t = Iql_t$

Incoming signal (IN)

This UWOT component introduces into the network a signal with quantity either derived from timeseries in_t (L/time-step) calculated externally or a constant value. The quality is set to -1. If necessary, the FL component can be used (in series) to define the quality. This component can be used both with push and pull signals.

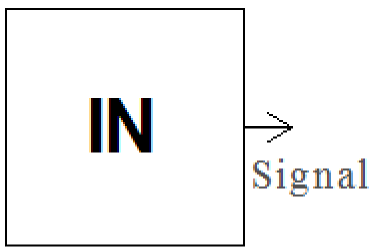

Figure 12: The UWOT In component.

Signals. The value provide by the timeseries is multiplied by mf (component parameter).

$Oqn_t = mf \times in_t$

$Oql_t = -1$

Logger (LG)

This UWOT component logs the quantity and quality of the incoming signal. This component has only one input port (terminates the signal flow). This component can be used both with push and pull signals.

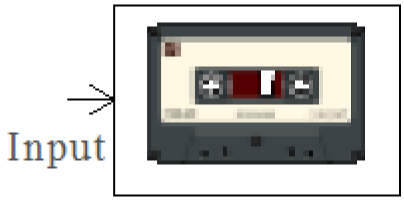

Figure 13: The UWOT Logger component.

Multi time scales threshold (MT)

This UWOT component diverges the incoming signal to the second output port whenever and for as long as the summation of the outgoing signal exceeds the daily, monthly or annual threshold. The thresholds are defined in the specifications of the selected brand for this component.

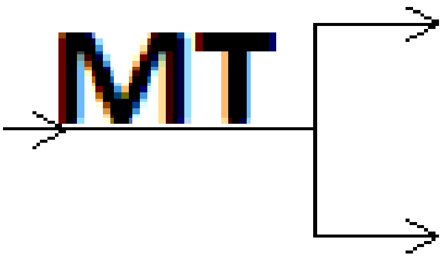

Figure 14: The UWOT multi time scales threshold.

Mix (MX)

This UWOT component mixes its incoming signals. This component can be used only with push signals.

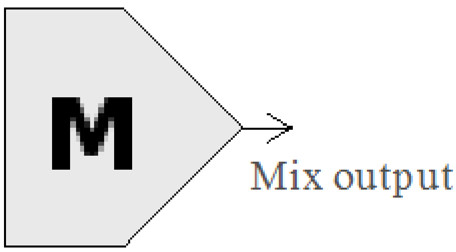

Figure 15: The UWOT Mix component.

Signals. If $Iqn_1, Iqn_2, \ldots, Iqn_n$ the quantities (L/time-step) and $Iql_1, Iql_2, \ldots, Iql_n$ the qualities (mg/L) of the input signals at the time-step t (this component can receive arbitrary number of signals), the output quantity and quality are:

$Oqn_t = Iqn_1 + Iqn_2 + \ldots + Iqn_n$
$Oql_t = (Iql_1 \times Iqn_1 + Iql_2 \times Iqn_2 + \ldots + Iql_n \times Iqn_n) / Oqn_t$

Quality Splitter (QS)

This UWOT component observes the quality q_t of the water stored inside the reservoir that has the same group id with this component. At least one reservoir should have the same group id and if more that one reservoir has the same group id, then one is selected randomly. If q_t exceeds a prescribed threshold θ (component parameter), then the incoming signal is diverged to the second port (port 1 is the upper one i.e. the named "Split 1"). This component can be used only with pull signals.

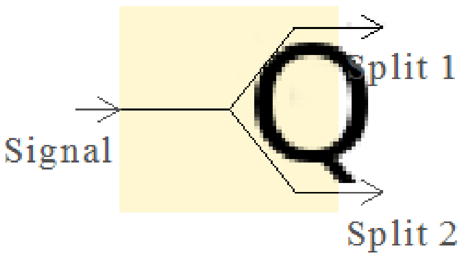

Figure 16: The UWOT Quality Splitter component.

Signals. If Iqn_t (L/time-step) is the quantity of the incoming signal:

$Oqn\_1_t = Iqn_t$ if $q_t < \theta$ otherwise 0
$Qql\_1_t = -1$
$Oqn\_2_t = 0$ if $q_t < \theta$ otherwise Iqn_t
$Qql\_2_t = -1$

Signal Lag (SL)

This UWOT component introduces a time lag s (component parameter) to the incoming signal. It can be used to simulate the time a flow takes to reach from one point to another. This component should be included in closed loops otherwise an error will occur. This component can be used both with push and pull signals.

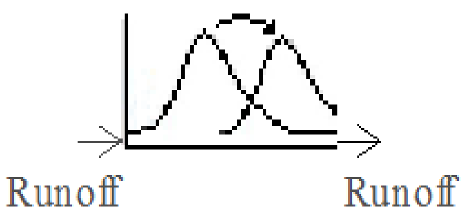

Figure 17: The UWOT Signal Lag component.

Signals. If $Iqn_{t\text{-}s}$ is the quantity (L/time-step) and $Iql_{t\text{-}s}$ is the quality (mg/L) of the incoming signal at time t-s, the output signal at time t is:

$Oqn_t = Iqn_{t-s}$
$Qql_t = Iql_{t-s}$

Summation (SM)

This UWOT component applies a simple summation on its incoming signals. This component can be used only with pull signals (for summing up push signals see Mix (MX)). If Iqn_1, Iqn_2, …, Iqn_n the quantities of the input signals at time-step t (this component can receive arbitrary number of signals), the output quantity (Oqn) and quality (Oql) are:

$Oqn_t = Iqn_1 + Iqn_2 + \dots + Iqn_n$
$Oql_t = -1$

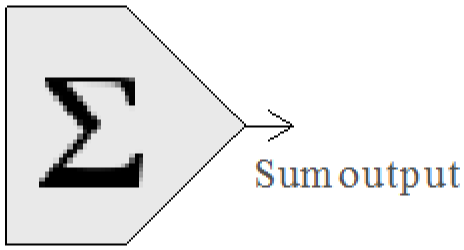

Figure 18: The UWOT Summation component.

Splitter (SP)

This UWOT component splits the incoming demand signal into the two output ports. It can be used both with push (e.g. stormwater and wastewater) and pull signals (e.g. raw water demand).

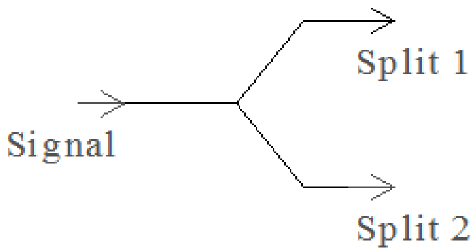

Figure 19: The UWOT Splitter component.

Signals. If Iqn_t is the quantity (L/time-step) and Iql_t is the quality (mg/L) of the incoming signal, the incoming signal is split into two output signals according to the formulas:

$Oqn\_1_t = Iqn_t \times p_t$
$Oql\_1_t = Iql_t$
$Oqn\_2_t = Iqn_t \times (1 - p_t)$
$Oql\_2_t = Iql_t$

The calculation of the coefficient p_t is based on the concept that the demand signal should be diverted according to the water availability of the resources downstream each of the two output ports. Parameter p_t is calculated by the formula:

$p_t = \alpha + b_i \times V_{i\,t}/K_i$

where α and b_i are component parameters, $V_{i\,t}$ is the water storage of the reservoir (or a combination of reservoirs) i at time-step t, and K_i is the capacity of i. For more information check Rozos and Makropoulos (2013).

A reasonable management policy will yield positive b_i values if reservoir i is downstream of port 1 and negative is downstream port 1 (which translates into the plausible policy to use more water from this reservoir if it has plenty of water).

The whole incoming signal is diverted to one port if it is detected that the reservoirs downstream of the other port are empty (according to previous, reservoirs with positive b_i values should be downstream of port 1 and reservoirs with negative b_i values should be downstream of port 2). In case boreholes are employed as backup, their capacity is assumed infinite during this decision process (although failure will occur and will be recorded as capacity exceedance).

Time series exceedence splitter component (ES)

This UWOT component diverges the incoming signal to the second output port whenever the value of the watched timeseries (provided externally) exceeds the given threshold (parameter of the component).

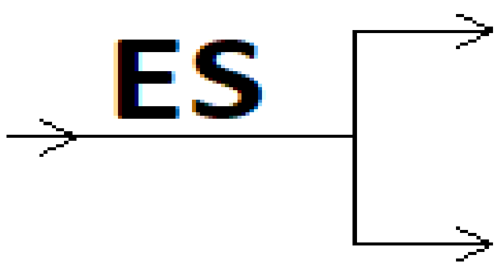

Figure 20: The UWOT time series exceedence splitter component.

Multiplication (X)

This UWOT component multiplies the incoming signal with a constant value or a value taken from timeseries n_t. This component can be used both with push and pull signals.

Signals. If Iqn_t is the quantity (L/time-step) and Iql_t is the quality (mg/L) of the incoming signal, the output signal is:

$\mathrm{Oqn}_t = \mathrm{Iqn}_t \times n_t$
$\mathrm{Qql}_t = \mathrm{Iql}_t$

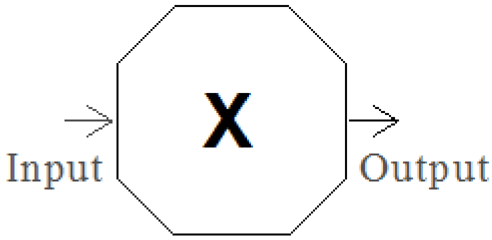

Figure 21: The UWOT Multiplication component.

The introduction of this component influences also the pots of any upstream component. For example, assume a Multiplication with constant multiplier equal to 10, if there is a washing machine upstream, the energy, the capital and operational costs of this washing machine will be multiplied by 10.

The Multiplication component can be used to multiply the output of a representative household to simulate a greater urban area. In this case, all emitted signals from this household network (the potable water demand, the runoff, the wastewater) should be multiplied using a dedicated Multiplier component, but all these Multiplier components must have the same multiplier value or the same timeseries.

Hydrosystem

Aqueduct (AQ)

This UWOT component simulates the transmission of water via conduits with leakage ψ (dimensionless ranging from 0 to 1) and capacity k in L/day (both taken from the technology library). This component has actually two output ports, but only one is available to the user for connections. This component can be used only with pull signals.

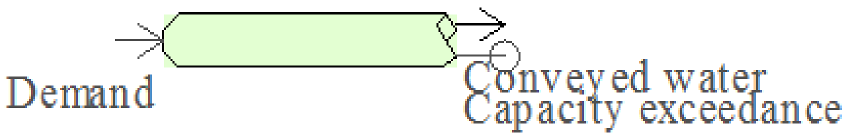

Figure 22: The UWOT Aqueduct component.

Signals. With the introduction of this component, and transparent to the user, a Logger is automatically introduced and connected to the second output port of Aqueduct. This auto-placed Logger logs the output of the second Aqueduct port. If Iqn_t is the quantity (L/time-step) of the incoming signal, the outputs are:

$\mathrm{Oqn\_1}_t = \mathrm{Iqn}_t \times (1 + \psi)$
$\mathrm{Qql\_1}_t = -1$
$\mathrm{Oqn\_2}_t = \max(0, \mathrm{Iqn}_t - k \times \mathrm{dt})$
$\mathrm{Qql\_2}_t = -1$

where ψ is the portion of incoming water the leaks (from the technology library).

Pots influenced by this component. Aqueduct influences the leakage, energy, and the capital pots of the group to which it belongs to. The required energy per time-step is calculated using the formula:

$E_t = \varepsilon \times \min(\mathrm{Iqn}_t, k \times \mathrm{dt})$

where ε is the specific energy in kWh/L (from the technology library).

The leakage is calculated by the formula:

$L_t = \mathrm{Iqn}_t \times \psi$

whereas the capital cost of an aqueduct with length l in m (component parameter) and cost per meter c_{L} in pounds/m (from the technology library) is calculated by the formula:

$C_{\mathrm{C}t} = c_{\mathrm{L}} \times l$

Centralized Greywater (CG)

This UWOT component simulates the centralized greywater treatment units. It has one input, the greywater flow from upstream, and two outputs, the produced green water and the amount of water exceeding treatment capacity. It assumed that a tank with capacity $V_{\max}$ is included in the appliance to store the incoming greywater.

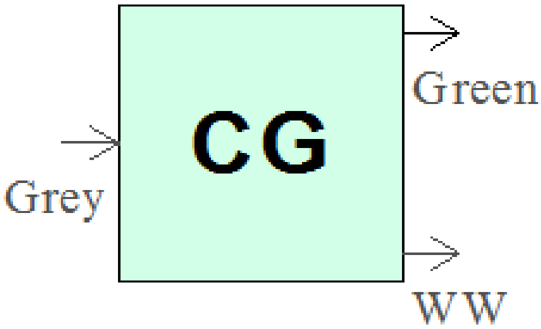

Figure 23: The UWOT Centralized Greywater component.

Signals. The amount of incoming water at time step t is Iqn_t (L/time step) with quality Iql_t (mg/L). If Iqn_t is greater than the treatment capacity k given (from the technology library) in L/day, the stored volume V_t (L) inside the tank increases. If V_t exceeds the tank capacity $V_{\max}$ (component parameter), the tank spills to the wastewater output. It is assumed a removal rate equal to 99%. The quantity and quality of the signals are:

$\mathrm{Oqn\_1}_t = k \times \mathrm{dt} - d_t$
$\mathrm{Qql\_1}_t = 0.01 \times \mathrm{Iql}_t$
$\mathrm{Oqn\_2}_t = \mathrm{spl}_t$
$\mathrm{Qql\_2}_t = \mathrm{Iql}_t \times (\mathrm{Iqn}_t - 0.01 \times \mathrm{Oqn\_1}_t) / \mathrm{Oqn\_2}_t$

where d_t is the deficit (L/time step), spl_t is the tank spill, and Iql stands for quality in mg/L of the incoming signal, Oqn_1, Oqn_2 and Qql_1, Qql_2 stand for the quantity in L/(time step) and quality in mg/L of the ports 1 and 2 respectively (port 1 is the upper one i.e. the named “Green”).

Water budget. The water budget of the greywater tank is:

$V_{t\text{-}1/2} = V_{t\text{-}1} + (\mathrm{Iqn}_t - k \times \mathrm{dt}) \times 1$ time step
$d_t = -\min(0, V_{t\text{-}1/2})$
$\mathrm{spl}_t = -\min(0, V_{\max} - V_{t\text{-}1/2})$ / 1 time step
$V_t = \min(V_{\max}, V_{t\text{-}1/2} + d_t)$

Pots influenced by this component. This component influences the energy, the capital and operational cost pots of the group to it belongs to. The required energy per time-step is calculated by the formula:

$E_t = \varepsilon \times \min(\mathrm{Iqn}_t, \mathrm{k} \times \mathrm{dt})$

where ε is the specific energy in kWh per treated amount of water in L (from the technology library), k is the unit capacity in L/day (from the technology library), and dt is the simulation time-step in days. The capital cost is taken directly from the technology library. The operational costs is calculated by the formula:

$C_{Ot} = c_o \times \mathrm{dt}/365$

where c_o is the operational cost per year (from the technology library).

Centralized Rainwater (CR)

This UWOT component simulates the centralized rainwater treatment units. It has one input, the upstream runoff, and two outputs, the produced green water and the amount of water exceeding treatment capacity.

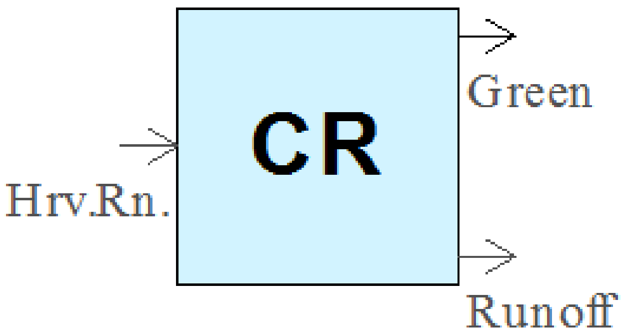

Figure 24: The UWOT Centralized Rainwater component.

Signals. See Centralized Greywater (CG).

Water budget. See Centralized Greywater (CG).

Pots influenced by this component. See Centralized Greywater (CG).

Centralized SUDS (CS)

This UWOT component simulates the centralized SUDS. It has one input, the upstream runoff, and one output, the mitigated runoff. This component infiltrates a fraction nf of the stored volume per day (from the technology library, units days^{-1}). The capacity of the detention tank is V_{max} given in L (component parameter)

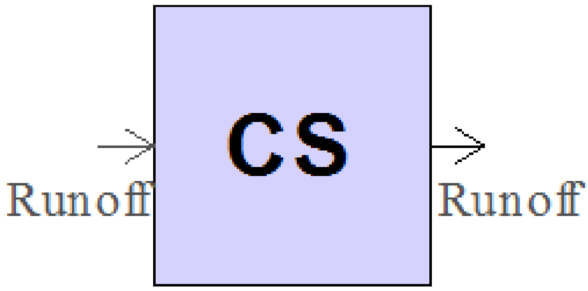

Figure 25: The UWOT Centralized SUDS component.

Signals. If Iqn and Iql the quantity in L/(time-step) and quality in mg/L of the incoming signal, the output signal is given by the formulas:

$\text{Oqn}_t = \text{spl}_t$
$\text{Qql}_t = \text{Iql}_t$

Water budget. The volume of water inside detention tank V_t and the overflow spl_t at time-step t is given by the formulas:

$V_{t\text{-}1/2} = \max(0,\ V_{t\text{-}1} - V_{t\text{-}1} \times \text{dt} \times \text{nf} + \text{Iqn}_t\ )$
$\text{spl}_t = \max(0,\ \ V_{t\text{-}1/2} - V_{\max})$
$V_t = \min(V_{t\text{-}1/2},\ V_{\max})$

Pots influenced by this component. This component influences the infiltration, the capital and operational cost pots of the group it belongs to. The infiltration at the time-step t is calculated by the formula:

$\text{Nf}_t = \ V_{t\text{-}1} \times \text{dt} \times \text{nf}$

The capital cost is estimated from specific cost c_V (from the technology library) of pounds per L of detention tank capacity.

$C_{Ct} = c_V \times \ V_{\max}$

The operational costs is calculated by the formula:

$C_{Ot} = \ c_o \times \text{dt}/365$

where c_o is the operational cost per year (from the technology library).

Centralized WasteWater (CW)

This UWOT component simulates the centralized wastewater treatment units. It has one input, the wastewater from an urban area, and one output, the treated wastewater.

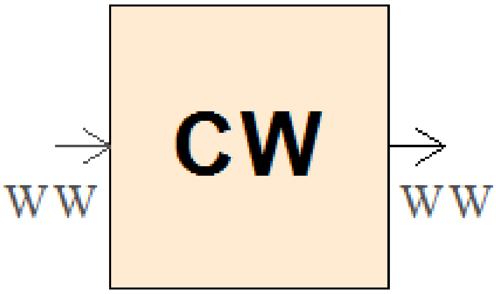

Figure 26: The UWOT Centralized Wastewater treatment component.

Signals. During normal operation 90% of the quality load is removed. The quality of the incoming signal should not fall below the 10 mg/L (). If this happens, the unit is bypassed and the output signal quality equals that of the input. If the incoming signal quantity exceeds the treatment capacity k in L/day (from the technology library), the exceedance bypasses the unit.

$$\begin{aligned}
\mathrm{Oqn}_t &= \mathrm{Iqn}_t \\
\mathrm{Qql}_t &= \mathrm{Iql}_t\text{, if } \mathrm{Iql}_t < 10\text{ mg/L} \\
&= 0.1 \times \mathrm{Iql}_t\text{, if } \mathrm{Iql}_t > 10\text{ mg/L and } \mathrm{Iqn}_t < k \\
&= \big((\mathrm{Iqn}_t - k) \times \mathrm{Iql}_t + 0.1 \times k \times \mathrm{Iql}_t \big) \,/\, \mathrm{Iqn}_t\text{, if } \mathrm{Iql}_t > 10\text{ mg/L and } \mathrm{Iqn}_t > k
\end{aligned}$$

Pots influenced by this component. See Centralized Greywater (CG).

Signal Detention (DT)

This UWOT component simulates the runoff detention process by operating as storage route reservoir. This component has one input that tops up a conceptual reservoir and one output that empties this reservoir. The conceptual reservoir has infinite capacity. This component can be used both with pull and push signals.

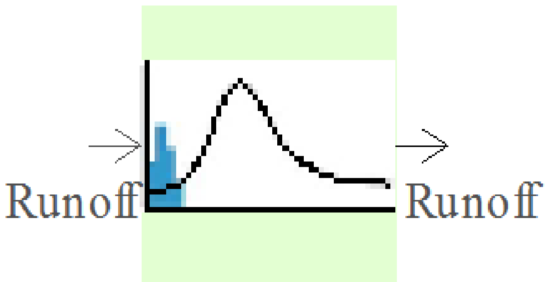

Figure 27: The UWOT Signal Detention component.

Signals. The output of this component depends on the water depth h (mm) inside the conceptual reservoir, the detention coefficient df (1/mm$^{0.5}$/min) and the upstream drained area A.

$$\begin{aligned}
\mathrm{Oqn}_t &= \min(h_{t-1},\ \mathrm{df} \times h_{t-1}^{1.5} \times \mathrm{dt}) \times A \\
\mathrm{Qql}_t &= \mathrm{Iql}_t,
\end{aligned}$$

where dt is the time-step in minutes.

Water budget. The water depth inside the conceptual reservoir is:

$h_t = \max(0, h_{t\text{-}1} + (\mathrm{Iqn}_t - \mathrm{Oqn}_t) / A)$

Ground Water (GW)

This UWOT component simulates the abstractions from aquifer by an array of boreholes. This component can receive only pull signals.

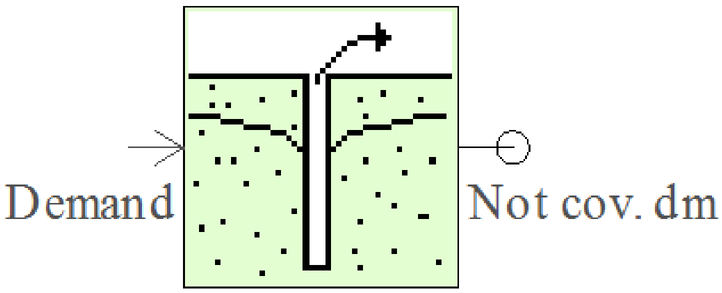

Figure 28: The UWOT Groundwater component.

Signals. This component has one output port, which is not available for connections. With the introduction of this component, and transparent to the user, a Logger is automatically introduced and connected to this port. The logged signal is the amount of demand Iqn_t in L/d exceeding the total capacity of the array of nbores (component parameter) boreholes each one of them having capacity k in L/d, i.e. the amount $\max(0,\ \mathrm{Iqn}_t - k \times \mathrm{nbores} \times \mathrm{dt})$.

Pots influenced by this component. This component influences the energy, the infiltration, the capital and operational cost pots of the group it belongs to. The infiltration (the negative sign indicates abstraction from the aquifer whereas the positive recharge) at the time-step t is calculated by the formula:

$\mathrm{Nf}_t = -\min(\mathrm{Iqn}_t, k \times \mathrm{nbores} \times \mathrm{dt})$

The capital cost is taken from the technology library and multiplied by nbores. The operational cost is calculated by the formula:

$C_{\mathrm{O}t} = c_{\mathrm{o}} \times \mathrm{nbores} \times \mathrm{dt}/365$

where c_{o} is the operational cost per year (from the technology library) of a single borehole.

Impervious (IM)

This UWOT component simulates the runoff from impervious areas. This component generates push signals.

Figure 29: The UWOT Impervious component.

Signals. A fraction ev of the rainfall R_t (given in mm/time-step, and obtained from external timeseries) that falls on the area A (m^2) of this component at each timestep is assumed to evaporate. The output of this component is:

$\mathrm{Oqn}_t = R_t \times A \times (1 - \mathrm{ev})$
$\mathrm{Qql}_t = q$

where is q the output quality (mg/L) taken from the technology library.

Pots influenced by this component. This component influences the evaporation pot of the group it belongs to. The evaporation at the time-step t is calculated by the formula:

$\mathrm{Ev}_t = A \times \mathrm{ev} \times R_t$

Sewer Mining (MN)

This component simulates sewer mining units. It receives wastewater from sewerage, treats a fraction of the incoming flow and returns the rest, along with the treatment sludge. This component generates push signals.

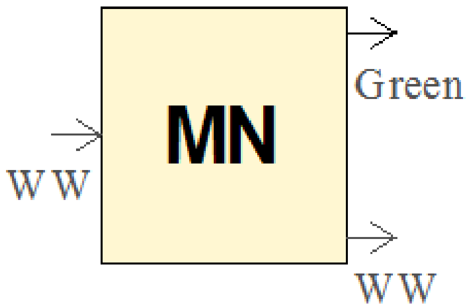

Figure 30: The UWOT Sewer Mining component.

Signals. The amount of incoming water at time-step t is Iqn_t (L/time-step) with quality Iql_t (mg/L). It is assumed a removal rate equal to 99%. The amount of the volume that the unit can treat k (L/d) is exiting the first output port (named "Green"). The amount of the volume that is not treated along with the treatment sludge are exiting from the second output port (named "WW").The quantity and quality of the emitted signals at the two output ports are:

$\mathrm{Oqn\_1}_t = \min(k \times \mathrm{dt}, \mathrm{Iqn}_t)$
$\mathrm{Qql\_1}_t = 0.01 \times \mathrm{Iql}_t$
$\mathrm{Oqn\_2}_t = \mathrm{Iqn}_t - \mathrm{Qql\_1}_t$
$\mathrm{Qql\_2}_t = \mathrm{Iql}_t \times (\mathrm{Iqn}_t - 0.01 \times \mathrm{Oqn\_1}_t) / \mathrm{Oqn\_2}_t$

where Iqn and Iql stand for quantity in L/(time-step) and quality in mg/L of the incoming signal, Oqn_1, Oqn_2 and Qql_1, Qql_2 stand for the quantity in L/(time-step) and quality in mg/L of the ports 1 and 2 respectively, where port 1 is the one named "Green".

Pots influenced by this component. This component influences the energy, the capital and operational cost pots of the group to which this component belongs to. The required energy per time-step is calculated by the formula:

$E_t = \varepsilon \times k$

where ε is consumed energy in kWh per L of produced green water (from the technology library). The capital cost is taken directly from the technology library. The operational costs is calculated by the formula:

$C_{Ot} = c_o \times dt/365$

where c_o is the operational cost per year (from the technology library).

Pump (PM)

This component simulates a pump with given gross energy head h (given in m, value obtained from component parameter). This component can be used both with pull and push signals.

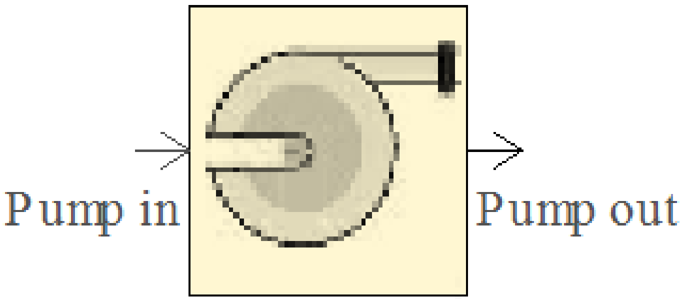

Figure 31: The UWOT Pump component.

Signals. The quantity and quality of the emitted signal are:

$Oqn_t = Iqn_t$
$Qql_t = Iql_t$

where Iqn and Iql stand for quantity in L/(time-step) and quality in mg/L of the incoming signal, Oqn and Qql stand for the quantity in L/(time-step) and quality in mg/L of the output port.

Pots influenced by this component. This component influences the energy pot of the group it belongs to. The required energy per time-step is calculated by the formula:

$E_t = Oqn_t \times h \times \varepsilon$

where ε is the specific energy in kWh/L/m.

The capital cost is taken directly from the technology library. The operational costs is calculated by the formula:

$C_{Ot} = c_o \times dt/365$

where c_o is the operational cost per year (from the technology library).

Potable Transmission (PT)

This UWOT component simulates the transmission of potable water via conduits. This component can be used only with pull signals.

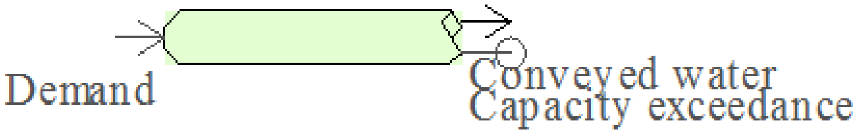

Figure 32: The UWOT Potable Transmission component.

Signals. See Aqueduct (AQ).

Pots influenced by this component. See Aqueduct (AQ).

Pervious (PV)

This UWOT component simulates the runoff from pervious areas. It employs a soil moisture model to simulate the evaporation, infiltration and runoff processes. This component generates push signals.

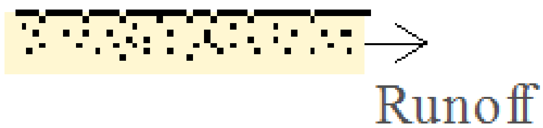

Figure 33: The UWOT Pervious component.

Signals. The rainfall R_t (mm/time-step), which is obtained from external timeseries, that falls on the area A (m^2) of this component at each time-step is assumed to increase the soil moisture s_t (mm). At each time-step a fraction ev (days^{-1}) of the soil moisture is assumed to evaporate whereas a fraction nf (days^{-1}) is assumed to infiltrate. When the soil gets saturated, i.e. exceeds its capacity k (mm), it creates runoff:

$$\mathrm{Oqn}_t = \max(0, s_{t\text{-}1/2} - k) \times A$$
$$\mathrm{Oql}_t = q$$

where the output quality q (mg/L) is taken from the technology library.

Pots influenced by this component. This component influences the evaporation and the infiltration pots of the group it belongs to:

$$E_t = A \times \mathrm{ev} \times s_{t\text{-}1} \times \mathrm{dt}$$
$$\mathrm{Nf}_t = A \times \mathrm{nf} \times s_{t\text{-}1} \times \mathrm{dt}$$

Water budget. The soil moisture at each time-step is:

$$s_{t\text{-}1/2} = \max(\ 0,\ s_{t\text{-}1} + (R_t - s_{t\text{-}1} \times (\mathrm{ev} + \mathrm{nf}) \times \mathrm{dt}\ ) \times 1 \text{ time-step}\ )$$
$$s_t = \max(s_{t\text{-}1/2}, k)$$

Service Reservoir (RS)

This UWOT component simulates service reservoirs, which serve as a buffer between the demand of a district and water supply. This component can be used only with pull signals.

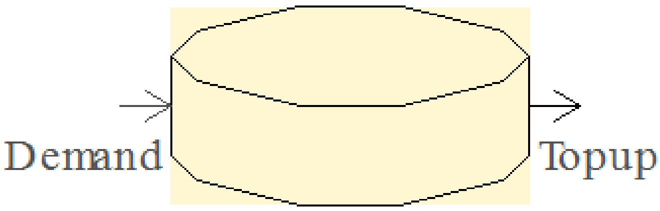

Figure 34: The UWOT Reservoir component.

Signals. This component receives the demand signal from a district Iqn_t (L/time-step) and emits a demand signal to top-up the reservoir. If V_t is the stored water volume (L) at time-step t, $V_{\max}$ is the reservoir capacity, and dt the time-step length in days:

$$\mathrm{Oqn}_t = \min(\ \mathrm{rf} \times V_{\max} \times \mathrm{dt},\ \ V_{\max} - V_{t\text{-}1} + \mathrm{Iqn}_t \times 1 \text{ time-step}\ )$$
$$\mathrm{Qql}_t = -1$$

where rf is the refile rate (days^{-1}), which depends on the characteristics of the network that supplies water to the reservoir and on the capacity of the reservoir (for example 0.5 days^{-1} means it takes one day to fill 50% of the reservoir).

Pots influenced by this component. This component influences the capital cost pot. If c_{V} is the cost per L of capacity then the capital cost is:

$$C_{\mathrm{C}t} = V_{\max} \times c_{\mathrm{V}}$$

Water budget. The stored volume V_t (L) inside reservoir is:

$$V_t = \max(\ 0,\ \ V_{t\text{-}1} + (\mathrm{Oqn}_t - \mathrm{Iqn}_t \times 1 \text{ time-step})\ )$$

The quality q_t of the stored volume inside reservoir is:

$$q_t = (q_{t\text{-}1} \times V_{t\text{-}1} + \mathrm{rql}_t \times \mathrm{Oqn}_t \times 1 \text{ time-step}) / (V_{t\text{-}1} + \mathrm{Oqn}_t \times 1 \text{ time-step})$$

The quality of inflowing water, rql_t, does not depend on the quality of the signals emitted/received by this component, which have values equal to -1. Instead, it is calculated by the formula:

$$\mathrm{rql}_t = \sum_j q_{jt} \prod_i p_{ijt}\ ,\ \text{ for } j=1 \ldots n,\ i=1 \ldots m_j$$

where q_{jt} is the quality of the j water treatment plant or service reservoir during time-step t, p_{ijt} is the portion during time-step t of the incoming signal to splitter i going to the splitter port on the route to the j water treatment plant during time-step t, n is the number of water treatment plants connected with this service reservoir, and m_j is the number of splitters on the path between the service reservoir and the j water treatment plant. It is evident that $\sum_j \prod_i p_{ijt} = 1$.

Surface water (SW)

This UWOT component simulates the surface water resources. It receives one push (“Runoff”) and one pull (“Demand”) signal, and emits one pull (“Not covered demand”) and one push (“Spill”) signal.

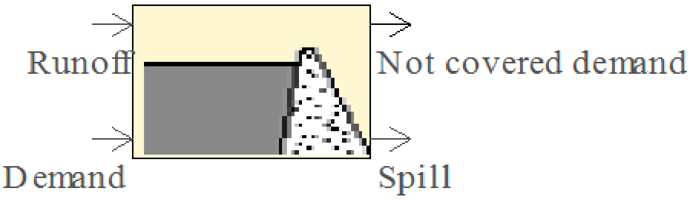

Figure 35: The UWOT Surface Water component.

Signals. This component receives the demand to dispose runoff Iqn_1 (L/time-step) with quality Iql_1 (mg/L) from an upstream component and the demand signal for water Iqn_2 (L/time-step), and emits two signals, the failure to meet demand Oqn_1 (L/time-step) and the amount of water that overflows Oqn_2 (L/time-step) with quality Oql_2 (mg/L). If $V_{\max}$ (L) is the capacity of the surface resource:

$$\mathrm{Oqn\_1}_t = -\min(0,\ V_{t\text{-}1/2})$$
$$\mathrm{Qql\_1}_t = -1$$
$$\mathrm{Oqn\_2}_t = -\min(0,\ V_{\max} - V_{t\text{-}1/2})$$
$$\mathrm{Qql\_2}_t = q_t$$

where q_t (mg/L) is the quality of water inside dam at time-step t.

Pots influenced by this component. This component influences the capital cost, the operational cost and the infiltration pots. The capital cost is taken directly from the technology library. The operational cost is calculated by the formula:

$$C_{\mathrm{O}t} = c_{\mathrm{o}} \times \mathrm{dt}/365$$

where c_{o} is the operational cost per year (from the technology library). The infiltration is estimated from the formula:

$$\mathrm{Nf}_t = \max(0,\ h_t \times b_1 + b_0) \times \mathrm{dt}$$

where b_1 (L/m/day) and b_0 (L/day) parameters taken from the technology library. The absolute water level h_t is calculated by the formula:

$$h_t = \max(0,\ a_2\, V_t^2 /(10^{18}\ \mathrm{L^2/hm^6}) + a_1\, V_t /(10^9\ \mathrm{L/hm^3}) + a_0\ )$$

where a_0 (m), a_1 (m/hm^3), and a_2 (m/hm^6) parameters taken from the technology library.

Water budget. The available water volume V_t (L) and quality q_t (mg/L) are:

$V_{t\text{-}1/2} = V_{t\text{-}1} + \text{Iqn\_1}_t - \text{Iqn\_2}_t - \text{Nf}_{t\text{-}1}$
$q_t = (q_{t\text{-}1} \times V_{t\text{-}1} + \text{Iql\_1}_t \times \text{Iqn\_1}_t \times 1 \text{ time-step}) / (V_{t\text{-}1} + \text{Iqn\_1}_t \times 1 \text{ time-step})$
$V_t = \max(0, \min(V_{\max}, V_{t\text{-}1/2}))$

Tank (TN)

This UWOT component simulates water tanks. It receives one push ("Green") and one pull ("Demand") signal, and emits one pull ("Demand") and one push ("Spill") signal.

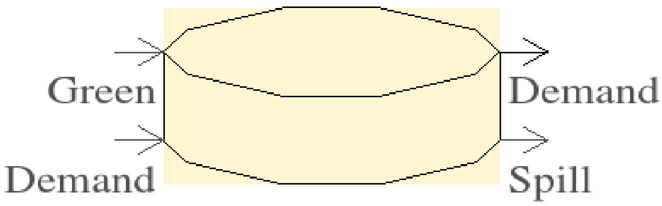

Figure 36: The UWOT Tank component.

Signals. This component receives a push signal Iqn_1 (L/time-step), for example the demand to dispose green water produced by an upstream component, and a pull signal Iqn_2 (L/time-step), for example the demand for green water to be used in appliances that can use green water. This component emits a pull signal Oqn_1 (L/time-step), the demand for potable water from mains, and a push signal Oqn_2 (L/time-step), the demand to dispose water in case of tank overflow. If $V_{\max}$ is the capacity of the tank:

$\text{Oqn\_1}_t = -\min(0, V_{t\text{-}1} + \text{Iqn\_1}_t - \text{Iqn\_2}_t)$
$\text{Qql\_1}_t = -1$
$\text{Oqn\_2}_t = -\min(0, V_{\max} - V_{t\text{-}1/2})$
$\text{Qql\_2}_t = 0$

Pots influenced by this component. This component influences the capital cost pot:

$C_{Ct} = V_{\max} \times c_V$

where c_V is the cost per L of tank capacity, and the operational cost:

$C_{Ot} = c_o \times \text{dt}/365$

where c_o is the operational cost per year (from the technology library).

Water budget. The available water volume V_t (L) and (quality is not simulate because compliance to water quality regulations is assumed) is:

$V_{t\text{-}1/2} = \max(0, V_{t\text{-}1} + \text{Iqn\_1}_t - \text{Iqn\_2}_t)$
$V_t = \min(V_{\max}, V_{t\text{-}1/2})$

Treatment Plant (TP)

This UWOT component simulates the water treatment plants. It receives one pull signal and emits one pull signal.

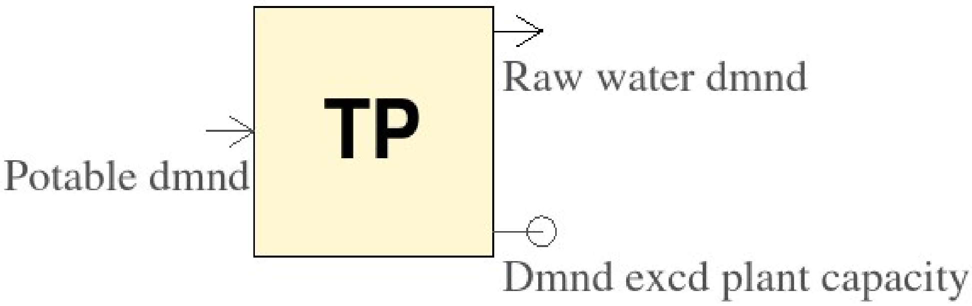

Figure 37: The UWOT Treatment Plant component.

Signals. This component receives the demand Iqn (L/time-step) for potable water and emits demand for raw water Oqn_1 (L/time-step), which higher than the Iqn to compensate for the losses ψ during the treatment process. If Iqn exceeds the capacity K of the treatment plant, the exceedance Oqn_2 (L/time-step) is recorded in the automatically placed logger.

$\text{Oqn\_1}_t = \text{Iqn}_t \times (1 + \psi)$
$\text{Qql\_1}_t = -1$
$\text{Oqn\_2}_t = -\min(0,\ \text{ntp} \times K \times \text{dt} - \text{Iqn}_t)$
$\text{Qql\_2}_t = -1$

where ntp (component parameter provided by the user) is the number of parallel treatment units.

Pots influenced by this component. This component influences the capital and operational cost, the energy, and the water losses pots. The capital cost is taken from the technology library and is multiplied by ntp. The operational cost is estimated by the formula:

$$C_{\text{O}t} = \text{ntp} \times c_{\text{o}} \times \text{dt}/365$$

where c_{o} is the operational cost per year (from the technology library). The energy is estimated by the formula:

$$E_t = \min(\text{ntp} \times K \times \text{dt},\quad \text{Inq}) \times \varepsilon$$

where ε is the kWh consumed per treated L (from the technology library). The water losses are estimated by the formula:

$$L_t = \text{Iqn}_t \times \psi$$

Water budget. The quality q_t of the water provided by the treatment plant is:

$$q_t = (q_{t-1} + \text{rql}_t \times (1 - \text{RR})) / 2$$

where RR is the removal rate whereas rql_t, the quality of inflowing water, is calculated by the formula:

$$\text{rql}_t = \sum_j q_{jt} \prod_i p_{itj}, \text{ for } j=1 \ldots n, i=1 \ldots m_j$$

where q_{jt} is the quality of the j water surface or ground water resource during time-step t, p_{ijt} is the portion during time-step t of the incoming signal to splitter i going to the splitter port on the route to the j water resource, n is the number of water resources connected with this treatment plant, and m_j is the number of splitters on the path between the treatment plant and the j water resource. It is evident that $\sum_j \prod_i p_{ijt} = 1$.

Water Body (WB)

This UWOT component logs the signals (mainly push signals) that end up to the water bodies.

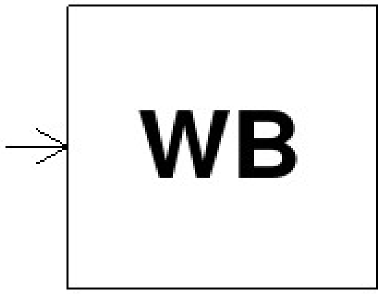

Figure 38: The UWOT Water Body component.

Waste Pipes (WP)

This UWOT component simulates the components that convey the waste water and storm water. This component can be used only with push signals.

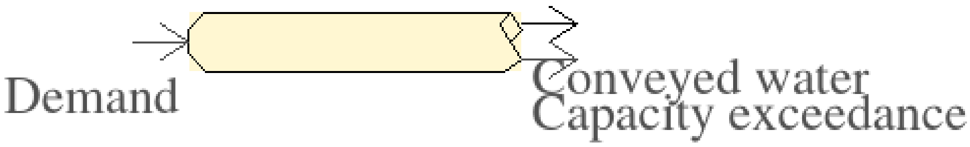

Figure 39: The UWOT Waste Pipes component.

Signals. This component has two output ports. The first gives the pipe or conduit output and the second gives the Combined Sewer Overflows. If the relative leakage of this component is ψ (dimensionless raging from 0 to 1) and the capacity k in L/day (both taken from the technology library), then the outputs are:

$Oqn\_1_t = Iqn_t \times (1 - \psi)$
$Qql\_1_t = Iql_t$
$Oqn\_2_t = \max(0,\ \ Iqn_t - k \times dt)$
$Qql\_2_t = Iql_t$

Pots influenced by this component. See Aqueduct (AQ).

Thornthwaite model (TH)

This UWOT component is a soil moisture accounting model useful for building simple hydrological models. This component takes input timeseries of rainfall and gives one output, which corresponds to the overflow due to saturation. This component influences also the infiltration pot. More information can be found in Rozos (under review).

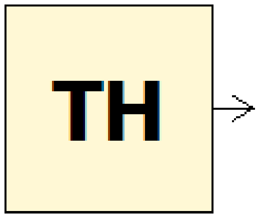

Figure 40: The UWOT Thornthwaite component.

Energy-Water nexus

Blue Green (BG)

This UWOT component simulates the green urban areas.

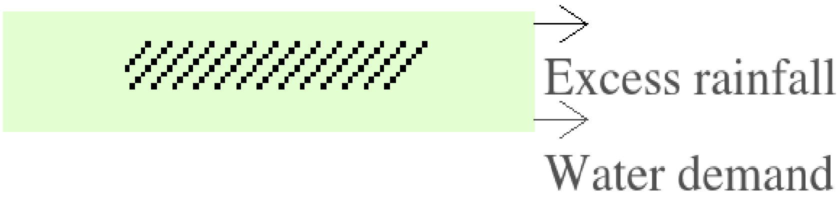

Figure 41: The UWOT Blue Green component.

Signals. This component incorporates a soil moisture module that employs Thornthwaite formula for estimating the potential evaporation. If K is the soil moisture capacity (mm), q (mg/L) is the quality of the excessive water washed out from this component (values of both K and q are taken from the technology library) and A (m^2) the green area (component parameter), then the excess rainfall (push signal emitted from port 1) and the water demand (pull signal emitted from port 2) are calculated as:

$$\mathrm{Oqn\_1}_t = A \times \max(0, s_{t+1/2} - K)$$
$$\mathrm{Qql\_1}_t = q$$
$$\mathrm{Oqn\_2}_t = -A \times \min(0, s_{t+1/2})$$
$$\mathrm{Qql\_2}_t = -1$$

Pots influenced by this component. This component influences the pots of infiltration Nf_t (L/time-step), evaporation Ev_t (L/time-step), energy E_t (kWh/time-step), capital C_{Ct} (pounds) and operational costs C_{Ot} (pounds/time-step). The formulas used to calculate this influence are:

$$\mathrm{Ev}_t = A \times \mathrm{ev}_t$$
$$E_t = -\mathrm{Ev}_t \times 0.683 \text{ kWh/L}$$
$$\mathrm{Nf}_t = A \times (\mathrm{nf} \times s_t \times \mathrm{dt} - \mathrm{ev}_t \times \mathrm{lzp})$$
$$C_{Ct} = A \times c_C$$
$$C_{Ot} = A \times c_o \times \mathrm{dt}/365$$

where ev_t is the evapotranspiration calculated by Hargreaves method, dt is the time-step length in days, T_t is the mean daily temperature (ºC), s_t is the soil moisture, nf is the fraction of soil moisture that infiltrates per day (day^{-1}), lzp is the fraction of evaporation coming from saturated zone, c_C is the capital cost per m^2, and c_o is the annual operational cost.

Water budget. The available soil s_t (mm) moisture is calculated as:

$$s_{t+1/2} = s_{t-1} + (R_t - \mathrm{ev}_t \times (1 - \mathrm{lzp}) - \mathrm{nf} \times s_{t-1} \times \mathrm{dt}) \times (1 \text{ time-step})$$
$$s_t = s_{t+1/2} - \max(0, s_{t+1/2} - K) - \min(0, s_{t+1/2})$$

where R_t (mm/time-step) is the rainfall at time-step t.

Hydro Turbine (HD)

This UWOT component simulates the generation of electricity from hydro turbines.

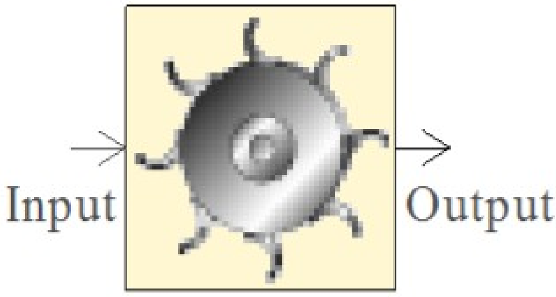

Figure 42: The UWOT Hydro Turbine component.

Signals. This component directly passes the incoming signal to its output:

$\mathrm{Oqn}_t = \mathrm{Iqn}_t$
$\mathrm{Oql}_t = \mathrm{Iql}_t$

Pots influenced by this component. This component influences the pots of energy E_t (kWh/time-step), capital C_{Ct} (pounds) and operational costs C_{Ot} (pounds/time-step). The capital cost is taken from technology library. The formulas used to calculate the energy are:

$E_t =$ 0, if $\mathrm{Iqn}_t < Q_{\min}$ or $H_t<H_{\min}$ or $H_t>H_{\max}$
otherwise
$E_t = -(a + b\times Q_t + c\times H_t + d\times Q_t^2 + f\times H_t^2 + g\times Q_t^3 + h\times H_t^3 + i\times Q_t\times H_t + j\times Q_t^2\times H + k\times Q_t\times H_t^2)\times \mathrm{dt}\times 24$ h/d
$C_{Ot} = c_o \times \mathrm{dt}/365$

where H_t is the hydraulic head of the associated reservoir (SW component on the same group with hydro turbine), and $Q_t = \min(\mathrm{Iqn}_t, a_{\mathrm{maxq}} + b_{\mathrm{maxq}} H_t) \times 1.157 \times 10^{-8} \times (\mathrm{m}^3/\mathrm{s})/(\mathrm{L/d})$. If no reservoir in the same group, then H_t is taken equal to 0; if more than one reservoirs on the same group, then the hydraulic head of one of them will be sarbitrarily elected. The factors a_{maxq}, b_{maxq}, $q_{\min}$, $H_{\min}$, $H_{\max}$ give the operational envelope of the turbine. The factors *a*, *b, c*, *d*, *f*, *g*, *h*, *i*, *j*, *k* are coefficients that give the hill chart of the turbine (taken from technology library). Regarding the operation of the hydro turbine, and c_o is the annual operational cost.

Renewable (RN)

This UWOT component simulates the water pumps driven by a renewable source (e.g. wind turbines).

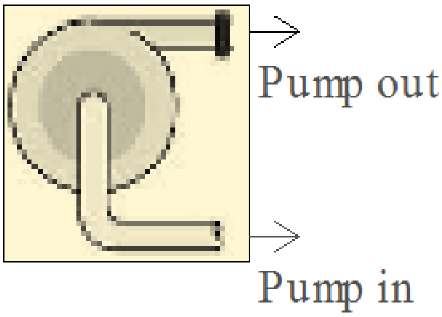

Figure 43: The UWOT Renewable component.

Signals. This component generates two output signals:

Oqn_1_t =min(V_t, 360000 (L m/time step)/(kWh/time step) × P_t / ($H2_t$ – $H1_t$))
$Qql\_1_t = q_t$
$Oqn\_2_t = Oqn\_1_t$
$Qql\_2_t = -1$

where P_t is the timeseries of the pump output power (kWh/time step), $H2_t$ and $H1_t$ (m) are the hydraulic heads of the higher and lower reservoirs respectively, q_t is the quality (mg/L) of the water stored inside lower reservoir, and V_t (L) is the volume of the water stored inside lower reservoir.

Pots influenced by this component. This component influences the pots of capital C_{Ct} (pounds) and operational costs C_{Ot} (pounds/time step). The capital cost is taken from technology library. The operational cost is estimated by the formula:

$C_{Ot} = c_o \times dt/365$

where c_o is the annual operational cost and dt is the time-step length in days.

Solar Panel (PA)

This UWOT component simulates the energy generated by solar panel (either photovoltaic or solar heater). It can be used only with daily time-step.

Figure 44: The UWOT Solar Panel component.

Pots influenced by this component. This component influences the pots of energy E_t (kWh/day), capital C_{Ct} (pounds) and operational costs C_{Ot} (pounds/day). To estimate energy, the astronomical formulas of Table 3.2 of Koutsoyiannis and Xanthopoulos (1999) are used to obtain the potential insolation So_j (kJ/m^2/day) of each day j of year that corresponds to the date of the time-step t (i.e. j takes values between 1 and 366)*. This value is multiplied by 0.000278 to convert to kWh/m^2/day. Then, the Bristow-Campbell formula is used to estimate the direct beam solar radiation (solar radiation reaching surface) of the time-step t:

$b_t = 0.036 \times \exp(-0.154 \times \mathrm{Tavg}_t)$;
$S_t = \mathrm{So}_j \times (1 - \exp(-b_t\,(\mathrm{Tmax}_t - \mathrm{Tmin}_t)^{2.4}))$

where Tavg_t is the mean daily temperature difference over a period of 30 days before t, Tmax_t – Tmin_t is the maximum and minimum temperature of the day t respectively (ºC), and A is the area (m^2).

The energy obtained by the solar pane is estimated by the formula:

$E_t = 0.000278 \times S_t \times A \times \mathrm{ef}$

where A is the solar panel area and ef is the efficiency coefficient (obtained from technology library).

The capital cost and operational cost estimations are based on the specific costs values c_C and c_o (obtained from the technology library):

$C_{Ct} = A \times c_C$
$C_{Ot} = A \times c_o \times \mathrm{dt}/365$

* The latitude of the project should be defined. See Hacks document on how to accomplish this.

Net Radiation (NR)

This UWOT component simulates the incoming solar radiation. It can be used only with daily time-step. This component can be used to simulate photovoltaic panels or solar heater.

Figure 45: The UWOT Net Radiation component.

Pots influenced by this component. This component influences the energy pot E_t (kWh/day). The direct beam solar radiation is calculated as described in Solar Panel (PA). The net radiation is calculated with the following formula:

$E_t = 0.000278 \times ((1 - \alpha)\,S_t - \mathrm{Ln}_t) \times A$

where A is the surface area, α is the albedo (taken equal to 0.2) and Ln_t is the net long-wave radiation (see Table 3.7 of Koutsoyiannis and Xanthopoulos, 1999). The estimation of the latter requires the relative sunshine, which is estimated from the formula (see Table 3.6 of Koutsoyiannis and Xanthopoulos, 1999):

$\mathrm{nN} = (S_t / \mathrm{So}_j - 0.25) / 0.50$

Wind Turbine (WN)

This UWOT component simulates the energy generated by a wind turbine. It influences only the energy pot.

Figure 46: The UWOT Wind Turbine component.

Pots influenced by this component. This component influences the energy pot E_t (kWh/time step). The formula used to calculate the generated energy is:

$E_t = \max((103.6 \times (v_t/r \times 0.28\ (\mathrm{m/s} \times \mathrm{h/km}))^{2.764} - 3.96)/100 \times c, 0) \times \mathrm{dt} \times 24\ (\mathrm{h/d})$

where v_t is the wind speed of the time step t in km/h, r is the rated wind speed in km/h, c is the maximum power output in kW ().

References

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