

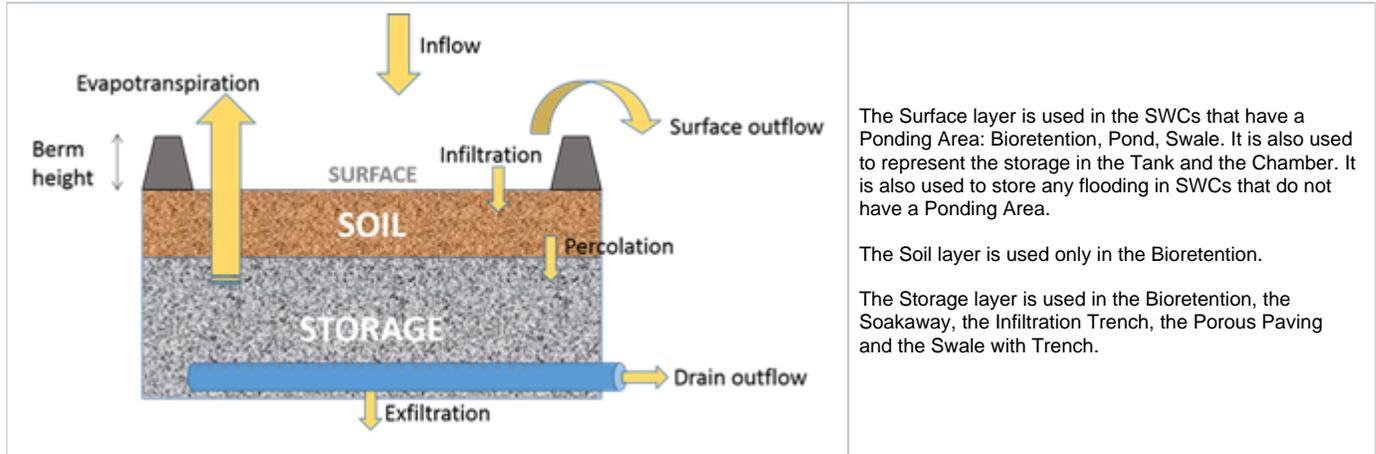
Analysis of Stormwater Controls

Stormwater Controls are structures designed to hold, delay, infiltrate water on its travel to the outfall of the system. Due to their specific nature, they are represented differently in the engine compared to Junctions/Manholes and Connections.

The Analysis of Stormwater Controls in InfoDrainage is based upon the **SWMM5 LID methods** (Low Impact Development), but these methods have been extended to provide **additional features** (see note at the bottom of this page).

The SWMM5 LID methods are described in a lot of details in Chapter 6 of the EPA [Reference Manual Volume III — Water Quality](#).

A Stormwater Control can be made of multiple inter-connected layers with different properties. Here is a sketch of the representation of layers within the SWMM5 LID methods:



Connections can be attached to any layer in a SWC, this applies to both incoming connections, either via an Inlet or a direct connection (No Restriction inlet), and outgoing connections, either via an outlet or a direct connection (Free Discharge outlet).

Pollutant removal can be specified in each layer.

The Stormwater Control layers

A Stormwater Control can be made of up to 3 layers. These layers can exchange water depending on individual inflows, outflows and available capacity.

Surface layer

The Surface layer can receive incoming water, store, infiltrate water and let water out (*evapotranspiration is currently not available*).

The infiltration is calculated using a constant seepage rate. If the layer below is full, the water cannot infiltrate down and will keep accumulating in the Surface layer.

A different infiltration rate can be specified for the base and for the sides of the Surface layer (although the side infiltration removes water from the system).

The shape of the Surface layer can be customised in two ways:

- In the Pond and Tank SWCs, the shape of the Surface layer can be specified in the form of a Depth-Area curve.
- In the Bioretention and the Swale, the side slopes can be specified.

Soil layer

The Soil layer can receive incoming water, store, infiltrate water and let water out (*evapotranspiration is currently not available*). The Soil layer is available only in the Bioretention SWC.

The water within the Soil layer is considered to be distributed uniformly within the layer (vertically and horizontally). The water content of the Soil layer is constrained by the following 3 parameters:

- Porosity: this is in effect the maximum water content in the layer.
- Field Capacity: this is the water content after the soil has drained fully, i.e. water cannot infiltrate down any more because matric forces with the soil medium overcome the gravity. However, the remaining water is still available to plants and can evaporate.
- Wilting Point: this is the water content below which the water is not available to plants. It is assumed here that the Wilting Point is the lowest possible value of the water content.

The percolation rate through the Soil layer is calculated using the [Darcy equation](#).

To help the user with setting the soil parameters values, a number of pre-defined Soil types area available. User defined values can be set if needed.

| Soil type | Field Capacity (%) | Wilting Point (%) |
|------------|--------------------|-------------------|
| Sand | 6.2 | 2.4 |
| Loam | 23.2 | 11.6 |
| Clay | 37.8 | 26.5 |
| Loamy Sand | 10.5 | 4.7 |
| Sandy Loam | 19.0 | 8.5 |
| Clay Loam | 31.0 | 18.7 |
| Sandy Clay | 32.1 | 22.1 |
| Silty Clay | 37.1 | 25.1 |

These values are taken from section 5.5 of the EPA [Reference Manual Volume I — Hydrology](#).

Storage layer

The Storage layer can receive incoming water, store, exfiltrate water and let water out (*evapotranspiration is currently not available*).

Water accumulates at the base of the Storage layer, up to the specified height (i.e. different behaviour from the Soil layer). Only the Porosity can be used to describe the material in the Storage layer.

The Storage layer can exfiltrate water out of the SWC, either through the base of the layer, through the sides, or both. The exfiltration is calculated using a constant seepage rate (different rates for base and sides).

An under-drain can be specified in the Bioretention, Porous Paving, Infiltration Trench and Swale with Trench. The under-drain is characterised by the diameter and height above the base, a friction coefficient, as well as the number of barrels. The under-drain flow is calculated using either the Manning equation or the Colebrook-White equation, with the head difference between the water level in the layer and the under-drain downstream end driving the flow. The under-drain can be used as an alternative to the regular outlets (see below) for taking water out of the Storage layer.

Flooding

When the Surface layer is filled above its nominal capacity (due to the inflow exceeding the outflow for a sustained period, or the layer below preventing any infiltration), it is considered to be in a flooding state.

Flooded water is stored in an area equal to the top area of the Surface layer. Except where the soffit of the SWC is below the exceedence level, as is possible in Tank, Cellular Storage and Chamber, where the maximum plan area will be used.

The flooding volume can be visualised in the SWC results. Similarly, to a Manhole, flooding water can return into the Surface layer at a later stage if there is capacity again.

Inlets and Outlets

Any [Inlets](#) and [Outlets](#) that can be used for Junctions can also be used for Stormwater Controls, and operates in the same way.

An outlet is attached to a given layer depending on the Invert Level of the outlet and the respective base levels of the SWC layers. Inlets will be attached to the top layer, unless the inlet destination is changed as per a Bioretention or Swale with Trench. Unlike in standard SWMM5, an inlet or outlet can be attached to any layer.

Note that in the case of an inflow into a sub-surface layer, and for some reason the water cannot move downward (if the layer below is full, or the exfiltration rate is zero), then the layer will progressively fill up and eventually the water can move into the layer above.

An outlet uses the water level in the considered layer to calculate the head driving the flow. Aside from this detail, the outlets operate as described in the [Outlets](#) section.

Time of Travel and Lateral Inflow

The time it takes for water to travel vertically from one layer to the next, or to exfiltrate, is captured by the time-stepped calculations of fluxes between layers and the regular update of the water content in each layer. As noted above the percolation rate through the Soil layer is calculated using the Darcy equation. On the other hand, any water that comes into the Storage layer instantly drops at the bottom of the layer.

This representation of vertical travel is deemed appropriate, however the horizontal travel of water is ignored in the SWMM5 LID methods. Any amount of water that comes into a layer is assumed to be instantly uniformly distributed with the layer. This is appropriate for the Surface layer of a Pond, or in a Storage layer with a large porosity. However this does not capture the time it takes for water to move through the length of a long Swale with a dense vegetation, or through a Storage layer with a small Porosity.

To address this, a Stormwater Control with a Horizontal retention time is divided into a series of child LID units with connections between them to capture the time of travel. In the Surface layer, the water is routed horizontally like in a regular link, where the Mannings or Colebrook-White roughness is the key parameter influencing the time of travel. On the other hand, in the Soil and Storage layers, the horizontal routing is calculated using the Darcy equation, where the Conductivity is the key parameter influencing the time of travel.

A SWC is divided in 2 to 5 child LID objects, depending on the length of the SWC.

The software reports the averaged result across the child LIDs, which can make the interpretation of the results more complex where conductivity is low or roughness is high on long systems.

The inlets are connected to the first child LID (unless Lateral Inflow is On), and the outlets are connected to the last child LID. Assuming a simple scenario of water coming in at the inlet, the water needs to have travelled to the last child LID before it can leave the SWC. Due to the averaging across the child LIDs, the water depth (for the considered layer) can be zero in the last child LID (i.e. no outflow) while the average depth in the SWC is significant.

For Stormwater Controls where a Lateral Inflow is used, the inflow is spread equally across the child LIDs so that it is distributed along the length of the SWC.

Pollutants

Pollutant concentrations are calculated in each layer at each computational time-step, although currently the SWC results display only the concentration averaged across all layers. The concentrations in a given layer are calculated in a similar way to a Storage node, accounting for the concentration in the current stored volume, the incoming load (external inflow or inflow from another layer), load removed through outlets, under-drain and exfiltration, and the effect of evaporation.

Pollutant removal can be specified in each layer, not just in the Storage layer as in standard SWMM5. The removal method and the removal rate can be specified independently for each pollutant in each layer.

Percentage Removal method removes a set percentage from the incoming load at each computational time-step.

First Order Decay removes a calculated amount from the pollutant mass contained in the layer at each computational time-step. The mass of pollutant removed is calculated using an exponential equation, see [here](#).

Info

List of features that have been extended beyond the SWMM5 LIDs features:

- Inflow into any layer.
- Outlet connected to any layer.
- Surface layer can be assigned a depth-area and a depth-perimeter curve to represent a complex shape.
- Lateral Infiltration.
- Swale with Trench
- Time of Travel and Lateral Inflow.
- Initial depth in the Surface layer.
- Pollutant concentrations calculated in each layer.
- Pollutant removal can be specified in each layer.

To enable the SWCs to be analysed as part of the hydraulic network, the custom Hydraulic LID methods are executed as part of the hydraulic analysis (with the Junctions and Connections), at a much finer time-scale than the Catchment LID methods (executed as part of the hydrological analysis).