Example: Sewer System Modeling

An Integrated Urban Drainage Model in OpenHydroQual

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Overview

This example builds an integrated urban-drainage model centred on a *gravity sewer network*. Stormwater is generated on two subcatchments, collected at catch basins, and conveyed through circular sewer pipes that run under gravity into a detention pond. The pond discharges through a piped outlet to a receiving water, overflows to the same receiving water through a weir when it fills, and loses water to the subsurface by infiltrating down a layered soil column to groundwater. The whole system is driven by a measured precipitation record and by evapotranspiration computed with the Penman model, and is run as a long-term dynamic simulation spanning roughly one year.

The model demonstrates how the sewer components (catch basins and sewer pipes) combine with surface-hydrology, storage, and subsurface components into a single mass-balance system that OpenHydroQual solves simultaneously. If this is your first model, work through the *Foundations* tutorial first; this example assumes you are comfortable placing blocks, connecting them with links, attaching sources, and running a simulation.

Plugins required. Enable these under **File → Preferences → Add Plugin**: the *Sewer system* plugin (catch basins and sewer pipes), the *Pond* plugin (the detention pond and weir), the *Unsaturated soil* plugin (the soil column), and the *Evapotranspiration models* plugin (the Penman source). The core *main components* set provides the catchments, fixed-head boundaries, and precipitation source.

Data files. Download the forcing data and save them locally:

- Precipitation: `https://openhydroqual.com/wp-content/Data/Sample_Rain_Data.txt`
- Temperature: `https://openhydroqual.com/wp-content/Data/Temp_2010.csv`
- Relative humidity: `https://openhydroqual.com/wp-content/Data/Humidity_2010.csv`
- Solar radiation: `https://openhydroqual.com/wp-content/Data/Solar_2010.csv`
- Wind speed: `https://openhydroqual.com/wp-content/Data/Wind_2010.csv`

1 Step 1: Two Catchments

Begin with the precipitation forcing and the two subcatchments that generate runoff.

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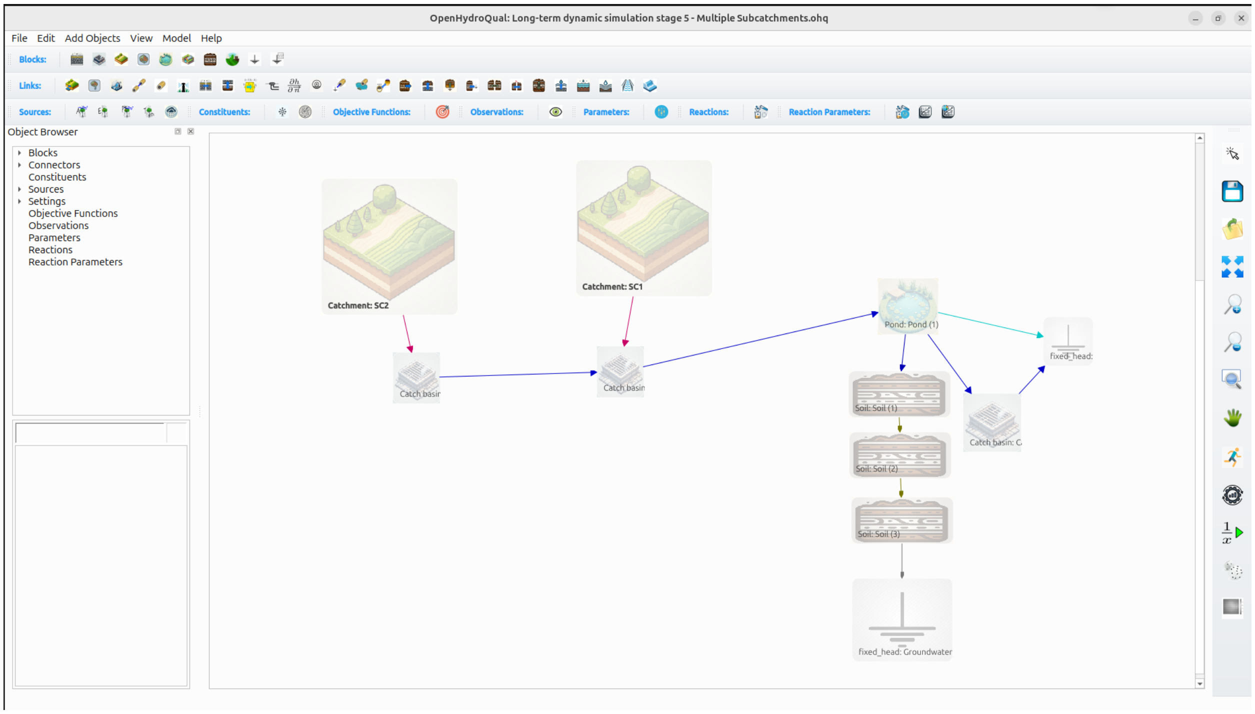


Figure 1: The completed model: two subcatchments drain to catch basins, gravity sewer pipes convey flow through a detention pond to the receiving water, the pond overflows through a weir, and it infiltrates down a three-layer soil column to a groundwater boundary.

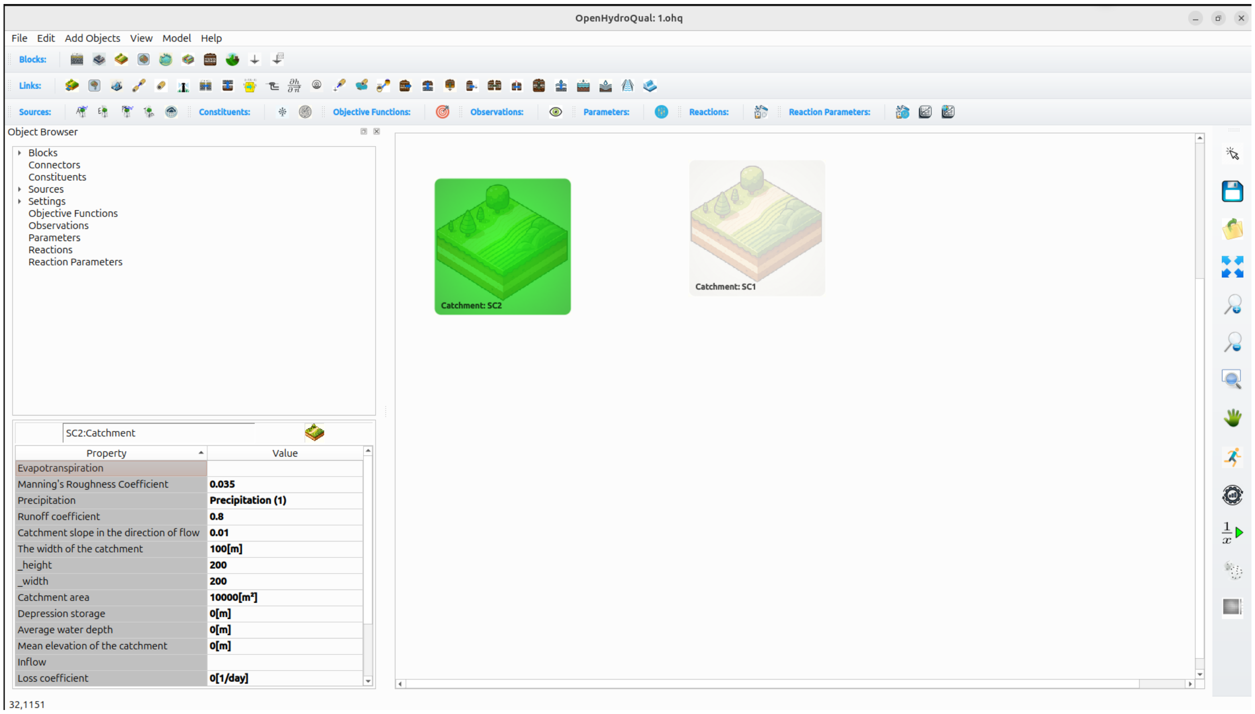
1. **Create a precipitation source.** On the **Sources** toolbar click the precipitation button . Select the new *Precipitation (1)* entry under the **Sources** branch, click the value box next to its *Precipitation Cumulative* property, and load `Sample_Rain_Data.txt` (the three-column start-time/end-time/depth precipitation format).
2. **Place two catchment blocks** from the **Blocks** toolbar and rename them `SC1` and `SC2`. An object's name is simply another entry in its property panel — the *Name* property — which you edit exactly like any numeric value. Renaming is optional but keeps the model readable, and it is how every object in this example is given the name we refer to it by.
3. **Attach precipitation** to each: set the *Precipitation* slot of both catchments to *Precipitation (1)*.
4. **Assign the catchment properties** in Table 1. The two share their hydrologic parameters and differ only in area.

Note: precipitation units. The precipitation series carries a unit, selectable in the same value box. The sample file `Sample_Rain_Data.txt` happens to be in meters, which is also the default, so here you can load it without changing anything. This is a lucky coincidence rather than the norm: rainfall data are far more often in millimeters or inches, and OpenHydroQual has no way to know the unit of a plain data file. Whenever your file is *not* in meters, you must set the precipitation unit to match it on the value box after loading — otherwise the depths are read in the wrong unit and the rainfall is off by a large factor (a file in millimeters read as meters overstates rainfall a thousandfold).

Table 1: Subcatchment properties. The two catchments share roughness, slope, width, and runoff coefficient; only the area differs.

Property	`SC1`	`SC2`
Catchment area [m^2]	20,000	10,000
Manning's roughness coefficient	0.035	0.035
Slope in direction of flow	0.01	0.01
Width [m]	100	100
Runoff coefficient	0.8	0.8

A runoff coefficient of 0.8 means 80% of rainfall becomes runoff and the remaining 20% is treated as an initial loss — representative of a partially impervious urban surface.



SC2:Catchment

Property	Value
Evapotranspiration	
Manning's Roughness Coefficient	0.035
Precipitation	Precipitation (1)
Runoff coefficient	0.8
Catchment slope in the direction of flow	0.01
The width of the catchment	100[m]
_height	200
_width	200
Catchment area	10000[m^2]
Depression storage	0[m]
Average water depth	0[m]
Mean elevation of the catchment	0[m]
Inflow	
Loss coefficient	0[1/day]

Figure 2: The two catchments on the canvas. `SC2` is selected, showing its assigned area (10,000 m^2), Manning coefficient, slope, width, runoff coefficient, and the attached *Precipitation (1)* source.

2 Step 2: Two Catch Basins

Catch basins are the inlet/junction nodes of the sewer. Add two *catch basin* blocks from the **Blocks** toolbar (Sewer system plugin) — one beneath each catchment — and set their bottom (invert) elevations:

The `SC2` basin sits higher (2.5 m) than the `SC1` basin (1.25 m), so the sewer will run downhill from the `SC2` basin toward the `SC1` basin and on to the pond.

Table 2: Inlet catch basins. Each has a nominal base area of 1 m^2.

Catch basin	**Bottom elevation [m]**
Catch basin receiving `SC1`	1.25
Catch basin receiving `SC2`	2.5

3 Step 3: The Detention Pond

The *pond* is the storage node at the centre of the system. It also loses water to evaporation, so create the evapotranspiration source first.

1. **Create a Penman evapotranspiration source** on the **Sources** toolbar. Assign its four climate time series — relative humidity (`Humidity_2010.csv`), temperature (`Temp_2010.csv`), solar radiation (`Solar_2010.csv`), wind speed (`Wind_2010.csv`) — and the parameters in Table 3.
2. **Place a pond block** (Pond plugin) named `Pond (1)` and set: stage–area coefficient $\alpha = 500$, stage–area exponent $\beta = 2$, bottom elevation = 0 m, initial storage = 0, and attach the Penman source to its *Evapotranspiration* slot. The pond's surface area grows with depth as $A = \alpha\, h^{\beta}$.

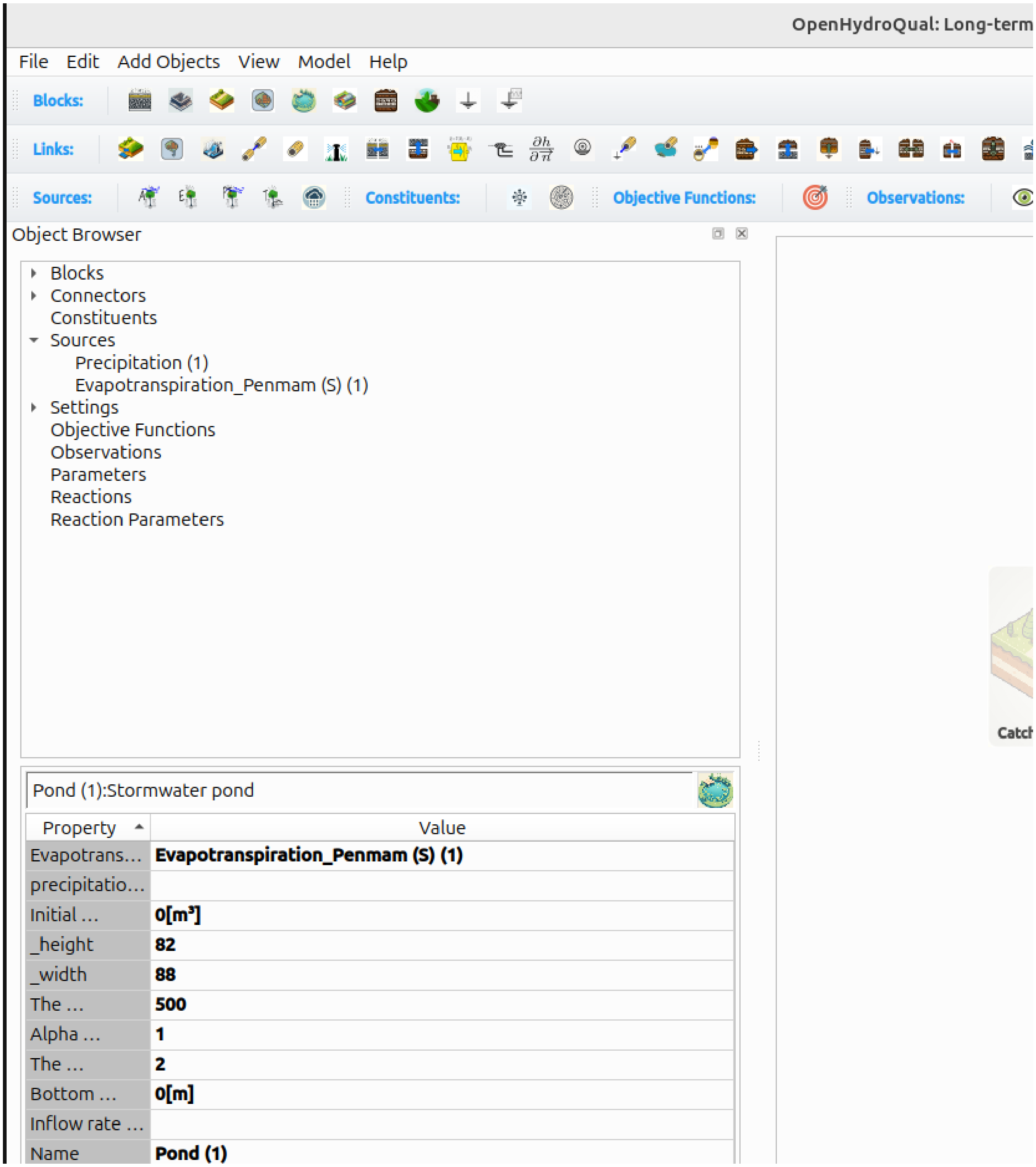
Table 3: Penman evapotranspiration source parameters.

Property	**Value**
Psychrometric constant γ	66.8
Wind measurement height z_2	2
Surface roughness height z_0	0.0003
Solar radiation scale factor	1
Wind scale factor	1

4 Step 4: Catchment Outlets and Sewer Pipes

Now connect the runoff path. *Sewer pipes* are circular conduits carrying flow between nodes under gravity (Manning's equation for partially full flow); each is defined by its length, diameter, Manning roughness, and the invert elevations at its two ends.

1. **Connect the catchment outlets.** Using the *Link from a catchment* connector, drain each catchment into its basin: `SC1` into the `SC1` basin and `SC2` into the `SC2` basin. These overland-flow links take no parameters of their own.
2. **Lay the inlet sewer pipes** (Sewer system plugin). Both share a Manning coefficient of 0.013 and a diameter of 0.1016 m (4 inches), differing in length and invert elevations (Table 4). The diameter is a good reminder that every dimensional property can be entered in any of the units offered in its value box: OpenHydroQual converts to its internal units automatically, so rather than typing `0.1016` in metres you can enter `4` and pick *inches* from the unit selector. The same applies to every length, area, and elevation in this example.



- Blocks
- Connectors
- Constituents
- Sources
    - Precipitation (1)
    - Evapotranspiration_Penmam (S) (1)
- Settings
- Objective Functions
- Observations
- Parameters
- Reactions
- Reaction Parameters

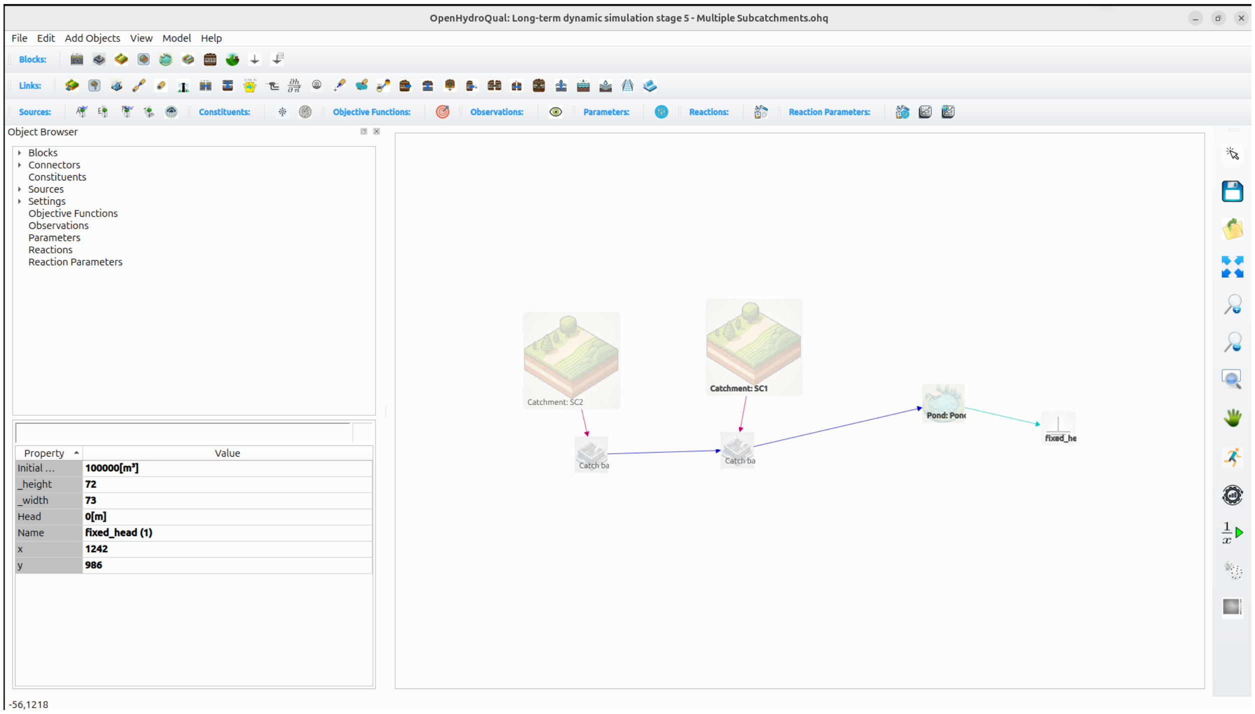
Pond (1):Stormwater pond

Property	Value
Evapotrans…	**Evapotranspiration_Penmam (S) (1)**
precipitatio…	
Initial …	**0[m³]**
_height	**82**
_width	**88**
The …	**500**
Alpha …	**1**
The …	**2**
Bottom …	**0[m]**
Inflow rate …	
Name	**Pond (1)**

Figure 3: The two sources (*Precipitation (1)* and the Penman evapotranspiration source) under the **Sources** branch, with the `Pond (1)` property panel open showing its stage–area coefficients, bottom elevation, and the attached Penman source.

Table 4: Inlet sewer pipes. Both: Manning coefficient 0.013, diameter 0.1016 m.

From	**To**	**Length [m]**	**Start invert [m]**	**End invert [m]**
`SC2 basin`	`SC1 basin`	500	2.6	1.35
`SC1 basin`	`Pond (1)`	100	1.35	0.1



Property	Value
Initial ...	100000[m³]
_height	72
_width	73
Head	0[m]
Name	fixed_head (1)
x	1242
y	986

Figure 4: The collection network: each catchment drains to its catch basin, and gravity sewer pipes connect the basins in series and on to the pond.

5 Step 5: Receiving Water and the Pond Outlet

The pond discharges to a receiving water through a short piped outlet. We place that boundary, add the downstream catch basin, and connect the outlet pipes (these pipes can only be drawn now, since they terminate at the receiving water just created).

1. **Add the receiving water.** Place a *fixed-head boundary* ⏚ named `Outfall` (the model's `fixed_head (1)`) with *Head* = 0 — an infinite reservoir at the model datum.
2. **Add the downstream catch basin** (bottom elevation −0.2 m), sitting between the pond and the outfall.
3. **Lay the outlet pipes** (Table 5): from the pond to the downstream basin, and from that basin to the receiving water.

Table 5: Outlet sewer pipes. Both: Manning coefficient 0.013, diameter 0.1016 m.

From	To	Length [m]	Start invert [m]	End invert [m]
`Pond (1)`	downstream basin	20	0.1	0.05
downstream basin	`Outfall`	30	0.05	0

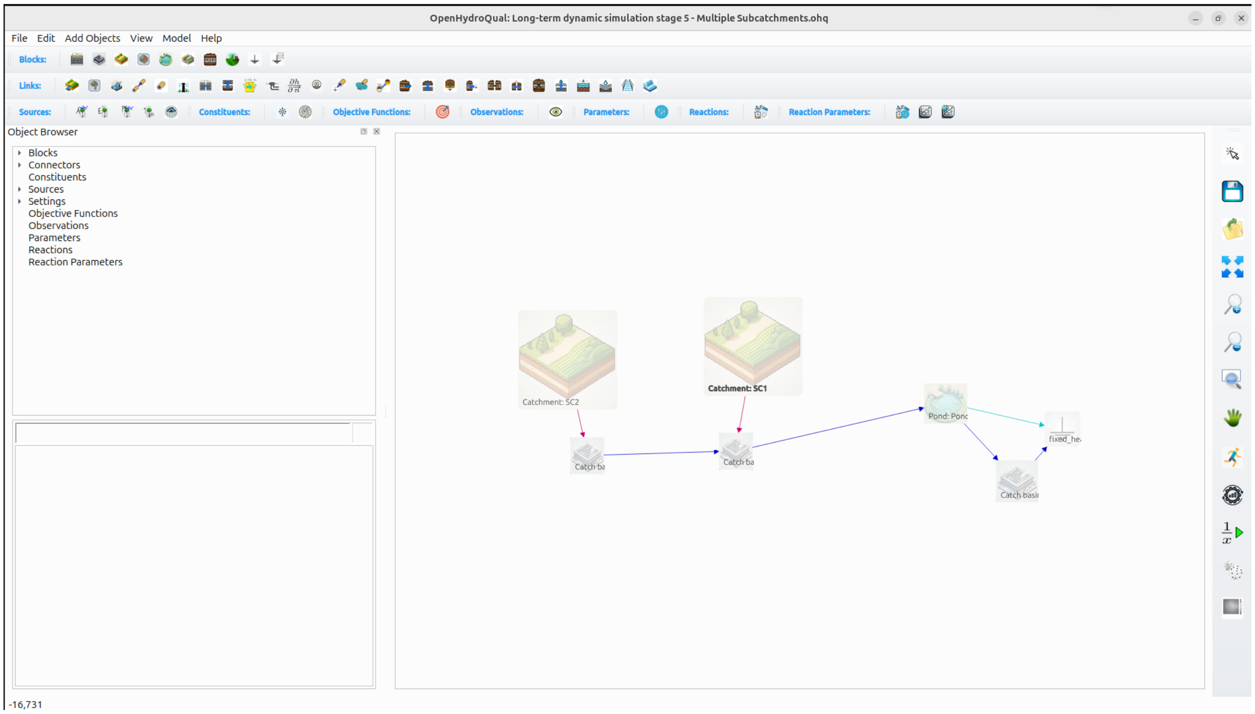


Figure 5: The fixed-head receiving water selected, showing its *Head* held at 0 m. The pond's piped outlet runs through the downstream catch basin to this boundary.

6 Step 6: Overflow from the Pond to the Receiving Water

When the pond fills past a threshold it spills directly to the receiving water through a weir, independent of the piped outlet. Connect `Pond (1)` → `Outfall` with a *weir* connector `weir.png` and set:

- Weir coefficient $\alpha = 294000$
- Weir exponent $\beta = 1.5$
- Crest elevation = 1.2 m

The weir passes no flow until the pond stage exceeds the crest, then discharges as $Q = \alpha\,(h - h_{\text{crest}})^{\beta}$. This is the high-flow relief path that protects the downstream pipe.

7 Step 7: Soil Layers and Groundwater

The pond is unlined, so water infiltrates into the soil beneath it and percolates to groundwater, represented by three stacked *unsaturated soil* blocks discharging to a deep groundwater boundary.

1. **Add three soil blocks** (Unsaturated soil plugin) named `Soil (1)`, `Soil (2)`, `Soil (3)`, stacked top to bottom; they share the properties in Table 6 and differ only in bottom elevation.

2. **Add the groundwater boundary.** Place a *fixed-head boundary* named `Groundwater` with *Head* = −1.5 m.

3. **Connect the infiltration path:** `Pond (1)` → `Soil (1)` with a *surface water to soil* link; `Soil (1)` → `Soil (2)` and `Soil (2)` → `Soil (3)` with *soil to soil* links; and `Soil (3)` → `Groundwater` with a *soil to fixed-head* link.

Table 6: Unsaturated soil properties (shared by all three layers, except bottom elevation).

Property	**Value**
Area [m^2]	1000
Layer depth [m]	0.5
Saturated conductivity K_{sat} [m/day]	0.00864
van Genuchten α	0.2
van Genuchten n	1.25
Saturated moisture θ_s	0.46
Residual moisture θ_r	0.1
Initial moisture θ	0.2
Specific storage	0.01
Bottom elevation [m]	−0.5, −1.0, −1.5 (layers 1–3)

8 Step 8: Run and Inspect the Results

1. **Set the simulation period.** Under **Settings** → **General Settings**, set the *Simulation start time* to 1/1/2010 and the *Simulation end time* to about 12/30/2010 — a full year of

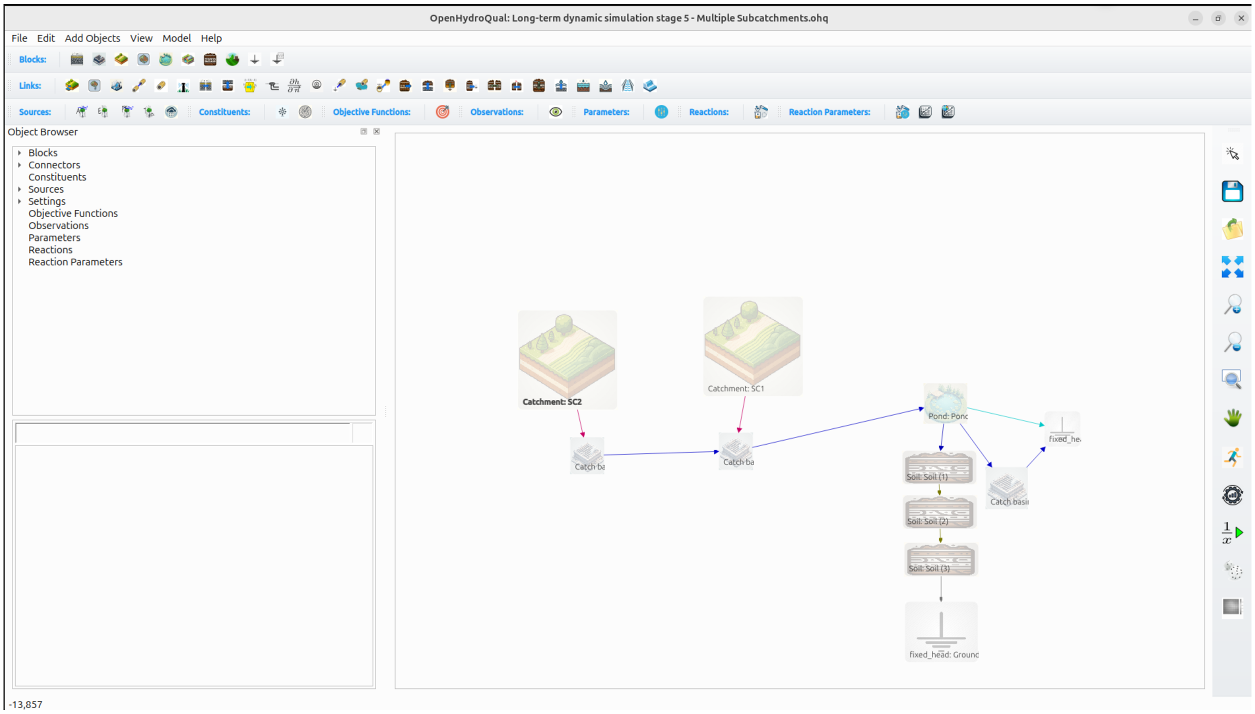


Figure 6: The infiltration path: the pond drains to the three-layer soil column, which discharges to the groundwater fixed-head boundary.

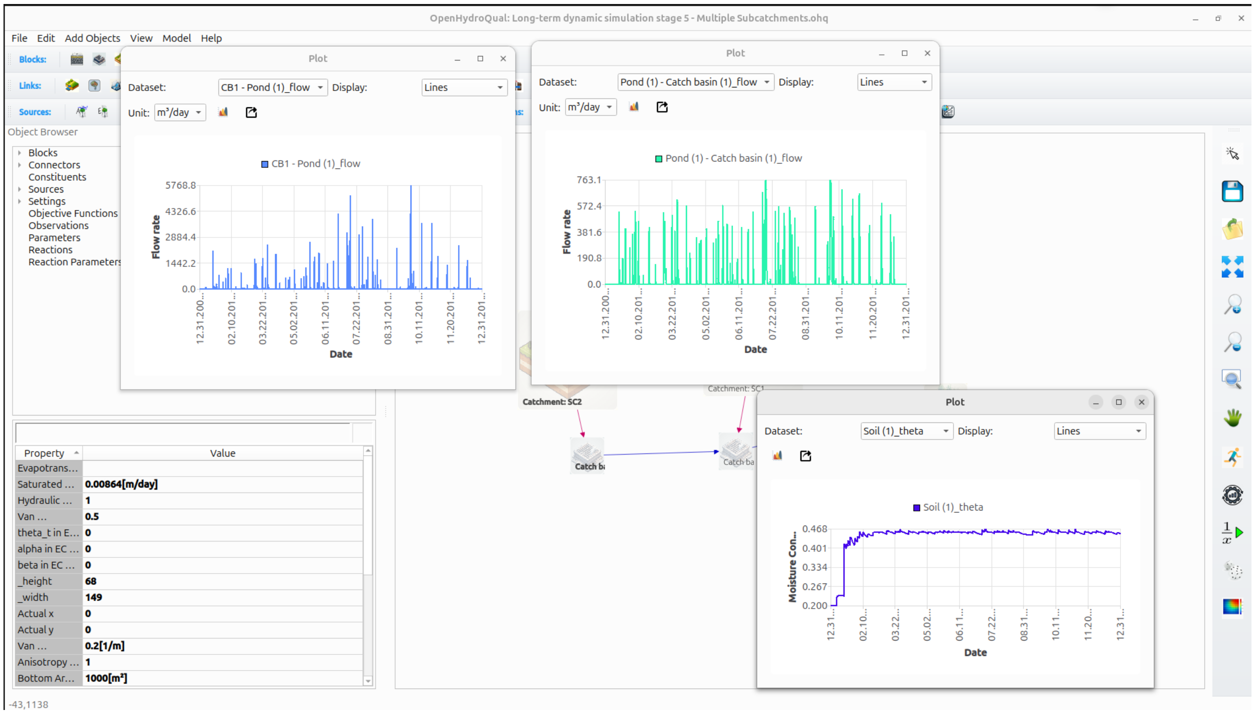
long-term dynamic simulation. (Internally these are serial day numbers, roughly 40178.8 and 40542.8.)

2. **Save and run** the model with the *Run Model* button 🏃. The defaults for the adaptive Newton–Raphson solver (Solver Settings) are appropriate; it takes small steps during storms and larger ones between them.

3. **Inspect the results** by right-clicking objects and using the **Results** menu:
    - **Sewer pipe flows** — runoff pulses propagating down the line and attenuating.
    - **Pond storage and stage**, noting when the stage tops the weir crest at 1.2 m.
    - **Weir overflow**, which is zero until the crest is exceeded, then spikes during the largest events.
    - **Infiltration** — the soil-to-groundwater flow and the moisture content θ of each layer.
    - **Mass balance** — over the year, rainfall in equals the sum of piped outfall discharge, weir overflow, infiltration to groundwater, and evapotranspiration.

9 Things to Explore

- **Pipe capacity.** As built, the sewer pipes are undersized: the flow they can carry by gravity is far less than the runoff delivered to them, so water backs up and the catch-basin depths climb to hundreds of meters — a clear sign of surcharge. Increase the sewer pipe diameters and watch the catch-basin depths and the pond stage fall as the pipes gain the capacity to convey the incoming flow.



Dataset: CB1 - Pond (1)_flow Display: Lines
Unit: m³/day

Dataset: Pond (1) - Catch basin (1)_flow Display: Lines
Unit: m³/day

Dataset: Soil (1)_theta Display: Lines

Property	Value
Evapotrans…	
Saturated …	0.00864[m/day]
Hydraulic …	1
Van …	0.5
theta_t in E…	0
alpha in EC …	0
beta in EC …	0
_height	68
_width	149
Actual x	0
Actual y	0
Van …	0.2[1/m]
Anisotropy …	1
Bottom Ar…	1000[m²]

Figure 7: Representative results: flow in the inlet pipe to the pond, flow in the pond's outlet pipe, and the moisture content θ of the top soil layer over the simulated year.

- **Detention sizing.** Change the pond stage–area coefficient α or the weir crest elevation to trade off detention storage against overflow frequency.
- **Infiltration.** Vary the soil K_{sat} to change how much water is lost to groundwater versus conveyed to the outfall.
- **Imperviousness.** Raise the subcatchment runoff coefficients toward 1 to mimic increased urbanization and observe sharper, larger sewer peaks.