Storage routing

About storage routing

Storage routing is based on mass conservation and the assumption of monotonic relationships between storage and discharge in a link.

Note: The stability criteria must also be satisfied for a model to run correctly. If this is not the case, the following error appears during runtime: ***Routing parameters have caused instability in storage routing***. Refer to Stability criteria for more information.

This is a simplification of the full momentum equation and assumes that diffusion and dynamic effects are negligible. The method uses index flow in flux, storage and mass balance equations. A weighting factor is used to adjust the bias between inflow and outflow rate, hence allowing for attenuation of flow. The storage routing equation is shown below and some of its terms are represented diagrammatically in Figure 1.

Equation 1	$S = K \bullet \overline{q}^{m}$

where:

S is the storage in the reach,

k is the storage routing constant

m is the storage routing exponent, and

q~ is the index flow, which is given by

Equation 2	$\overline{q} = (x \bullet I + (1 - x) \bullet O)$

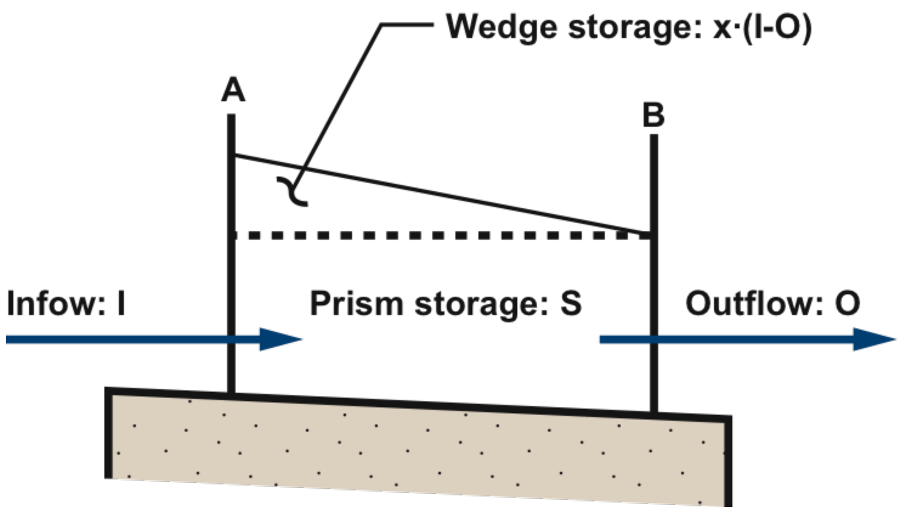
where:

I is the inflow to the reach during the time-step,

O is outflow from the reach during the time-step and

x is the inflow bias or attenuation.

Figure 1. Prism and wedge storage



Dead storage

Dead storage refers to the capacity of a storage that is below the minimum operating level. At this water level, there is no outflow. The level of the reach with respect to dead storage at the beginning of the time-step affects its level in subsequent time-steps as follows:

- The reach is at or below dead storage and the fluxes during the time-step are insufficient to raise the level above the dead storage;
- The reach is above dead storage but fluxes during the time-step would lower the level in the reach below dead storage; or
- The reach is above dead storage and remains above dead storage during the time-step.

To determine if the reach is at or below the dead storage level, Source:

- Computes an initial storage estimate by using inflows to fill the reach up to but not exceeding the dead storage level;
- Computes a revised storage estimate based on any remaining inflows and fluxes, but ignoring outflows; or
- If the revised storage estimate is above dead storage, then outflows are computed. Otherwise, the initial storage estimate is used and outflows are set to zero.

Initial Estimation of Storage Constant (k)

An initial value of k can be determined by

- For linear routing (ie m=1) k is equal to the wave travel time divided by the number of divisions. The wave travel time is how long the wave takes to move through the reach
- For non-linear routing, (m1) k can be calculated using the known wave travel time for the reach and the chosen value of m for a representative flow rate

Equation 3	$k = \frac{T_w}{n \times m \times Q_w^{m-1}}$

where:

T_w is the known travel time for the reach in seconds

n is the number of divisions

Q_w is the flow rate at which you want the travel time to be T_w in m^3/s.

Configuring storage routing

Figure 2 shows the feature editor for storage link routing and Table 1 outlines the parameters required.

Figure 2. Storage routing link

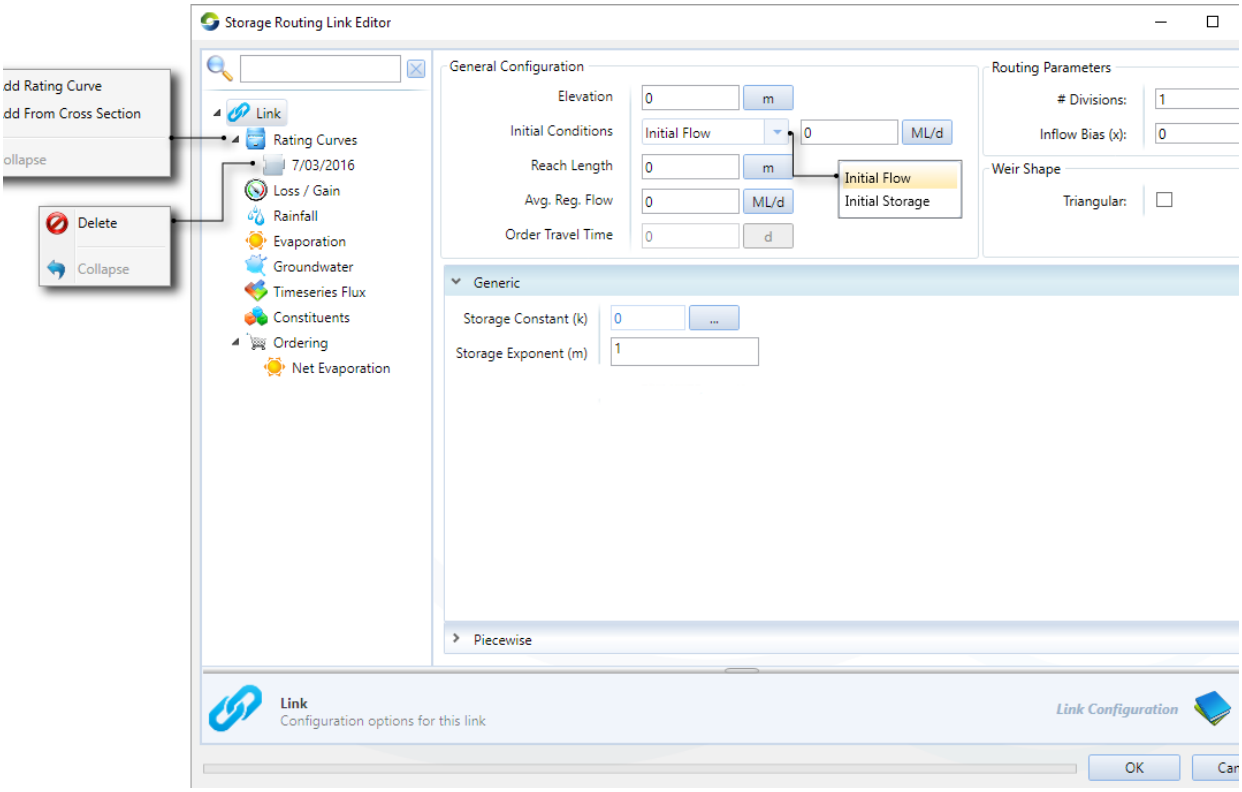


Table 1. Parameters for link storage routing

Parameter	Description	Units	Range	Default
General configuration				
Avg. Reg. Flow	Average regulated flow is used to calculate travel time for orders in the ordering phase. It is not used in the flow distribution phase. **Note**: When ordering is enabled **and** if the storage constant *k* > *0*, then average regulated flow must be greater than 0 to avoid calculation of an infinite order travel time. The exception is when storage exponent *m* = 1, in this case average regulated flow can equal 0.	megalitres per day	real 0	0 ML/d
Elevation	Note that while it is usual to use zero storage as the reference point for the elevation of a link or node, there is no convention for a link as to whether that should be at the start or end of the reach, or some point in between. Source has no mechanism for indicating the fall across a reach.			
Initial conditions	If necessary, one of these parameters may be used to seed a reach with either an initial flow or storage (see below) so that reach behaviour is fully defined from the first model time-step.			
Initial flow		megalitres per day	real 0	0 ML/d
Initial storage	The amount of water deemed to be in the link on the first time-step. For example, if there is a lag of two days, and there is 10ML in the link at the start of the run, then 5ML is deemed to be flowing out each day (total initial storage divided by lag).	megalitres	real 0	0 ML

Reach length	Source simulates evaporation and rainfall using the user defined reach length and a reach width (based on simulated flow and a user defined rating curve) to calculate surface area.	metres	real 0	0 m
Routing parameters				
# Divisions	Number of reach divisions. Conceptually, this parameter describes the number of times that a reach is replicated. The effective length of a reach is determined from its behaviour, which is controlled by the combination of the storage exponent m, the inflow bias x and the storage constant K. Specifying multiple reach divisions implies applying the same set of behavioural parameters multiple times. In other words, if the effective length of a single-division reach is 500 metres (as derived from its behavioural parameters), changing the ***# Divisions*** parameter to 2 implies a combined effective length of 1000 metres. If you want to sub-divide a 500 metre reach into two 250 metre sections, you must also change the behavioural parameters to achieve this.	whole units	integer 1	1
Inflow bias (attenuation factor, *x*)	The weighting factor *x* is used to adjust the bias between inflow and outflow rate and allows for flow attenuation. The weighting factor is usually in the range 0 *x* 0.5 (Davis and Sorensen, 1969). A recommended starting value is 0.2.	dimensionless	real 0 *x* 1	0
Generic				
Storage constant (*k*)	When using linear routing (*m* = 1), the units of the storage constant *k* are in seconds and the wave travel time is equal to k times the number of divisions. When using non-linear routing (*m* 1), a starting value could be calculated using Equation XX in the scientific reference guide.	*k* units	real 0	0
Storage exponent (*m*)	If *m=1*, linear (Muskingum) routing is implied, otherwise non-linear routing is implied. m=0.74 is a good starting value for a natural channel.	time-steps	real 0 < *m* 1	0 time-steps

Piecewise storage function

Flow travel time can also be set using a piecewise linear function. This describes a series of relationships between reach index flow rate versus travel time. The data points can be entered manually or imported from a .CSV file, the format of which is shown in Table 2. See the SRG for details: Link storage routing - SRG.

To get hydraulically valid results, the maximum travel time can not be more than the timestep divided by the inflow bias (x) per division. For example in a daily model, if you have three divisions and x = 1, the maximum travel time can be no more than 3 days. If x = 0.5 the maximum travel time could not be any more than 6 days

Figure 3. Storage routing link, Piecewise

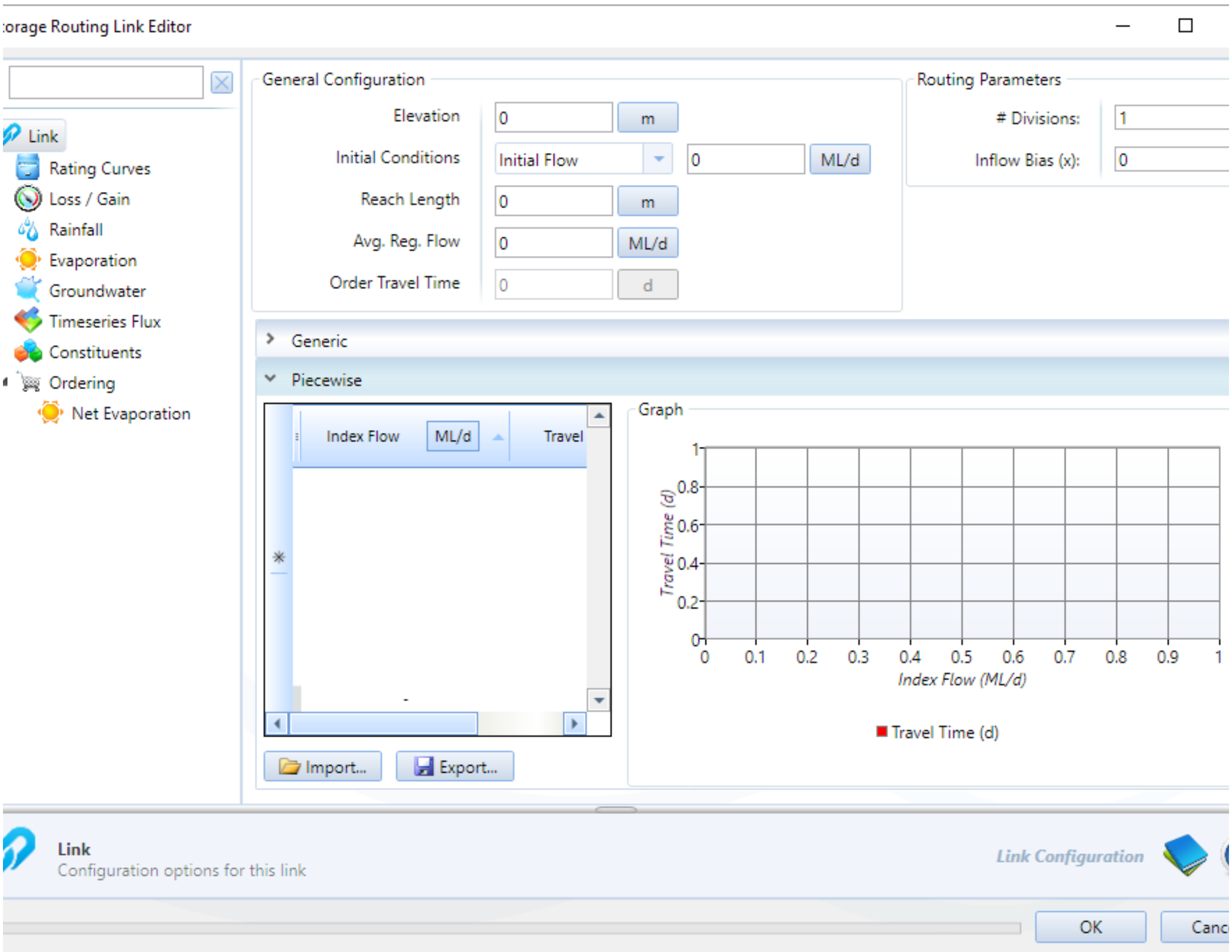


Table 2. Storage routing link, Travel time (data file format)

Row	Column (comma-separated)	
	1	2
1	Index flow	Travel time
2 … *n*	*flow*	*day*

Link rating curve

Rating curves (Figure 4) are used to describe the physical characteristics of the reach and convert a flow into a level, ie. they produce an output of level. They can be specified in one of two ways:

- Using the Cross Section Editor to specify a physical cross section, and then generating the rating curve; or
- Directly entering the rating curve - the piecewise linear editor allows you to define relationships with respect to water level, discharge rate, reach width and dead storage. You can define multiple rating curves for a reach, each scheduled to commence on a particular date.

To define a new rating curve directly:

- Right click ***Rating Curve*** and choose ***Add Rating Curve***;
- Today's date will automatically be entered for Start Date. To change this, click the calendar on the right side (see Working with date-pickers);
- Enter the water level, discharge rate, reach width and dead storage; and

- Enter an appropriate value for ***Overbank Flow Level***.

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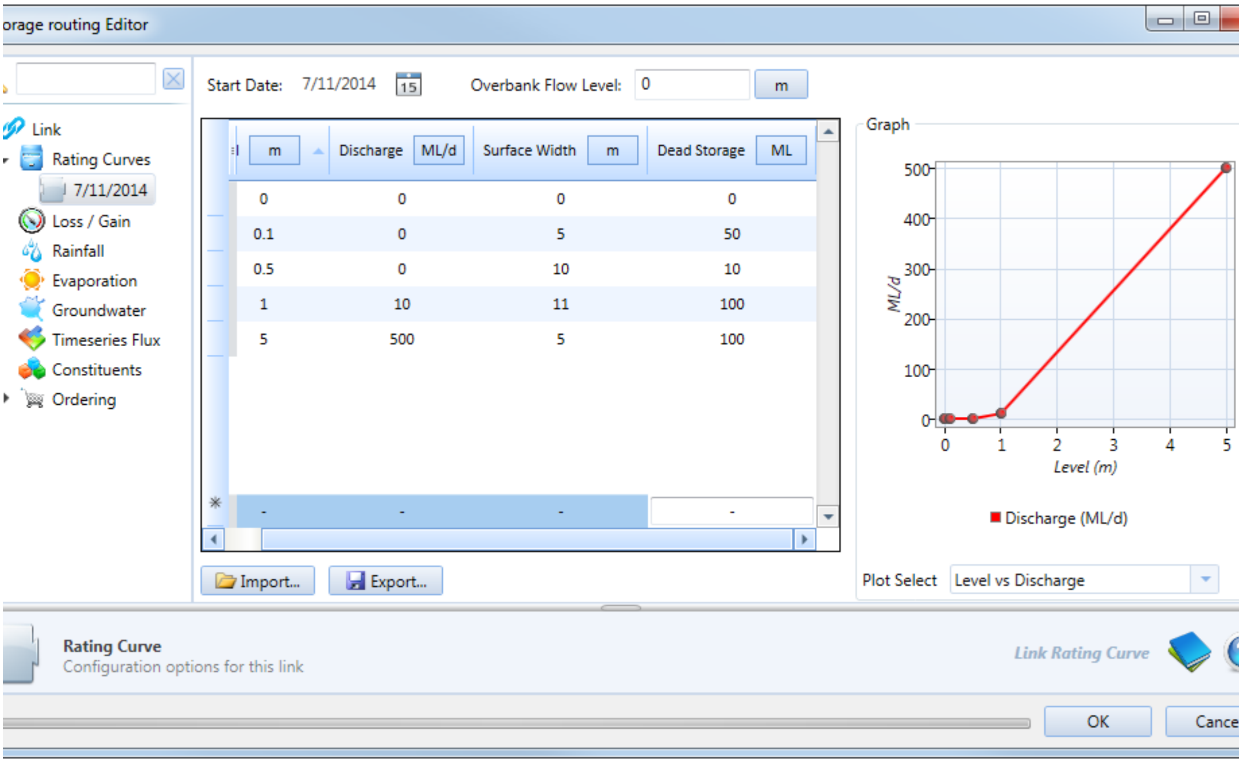
Figure 4. Storage routing link, Rating curve



You can also use the ***Import*** button to import a rating curve from a .CSV file the format of which is shown in Table 3.

Table 3. Storage routing link, Rating curve (data file format)

Row	Column (comma-separated)			
	1	2	3	4
1	Level	Discharge (ML/d)	Surface width (m)	Dead storage (ML)
2 … *n*	*level*	*rate*	*width*	*storage*

where:

level is the storage height in the reach in metres above a datum

rate is the outflow from the reach in the corresponding *level*

width is the surface width of the reach at the corresponding *level*

storage is the dead storage in the reach at the corresponding *level*

There should be at least one row describing the maximum depth at which there is zero flow, and which quantifies the maximum amount of dead storage in the reach. Thereafter, the dead storage volume should remain constant. Table 4 shows an example of this. A depth of 0.5 metres defines the maximum amount of dead storage (100 megalitres), after which the dead storage remains constant. Note that if discharge is 0, then dead storage must be increasing, or it must be equal to the previous value of dead storage.

Table 4. Storage routing link, Rating curve (example)

Level (m)	Discharge (ML/d)	Surface width (m)	Dead storage (ML)

0	0	0	0
0.1	0	5	50
0.5	0	10	100
1	10	11	100
5	500	15	100

To edit an exising rating curve, select the curve from the list of available curves under ***Rating Curve***. Edit the data and click ***OK*** to close the editor. To delete a rating curve, right click the curve from the list and choose ***Delete***.

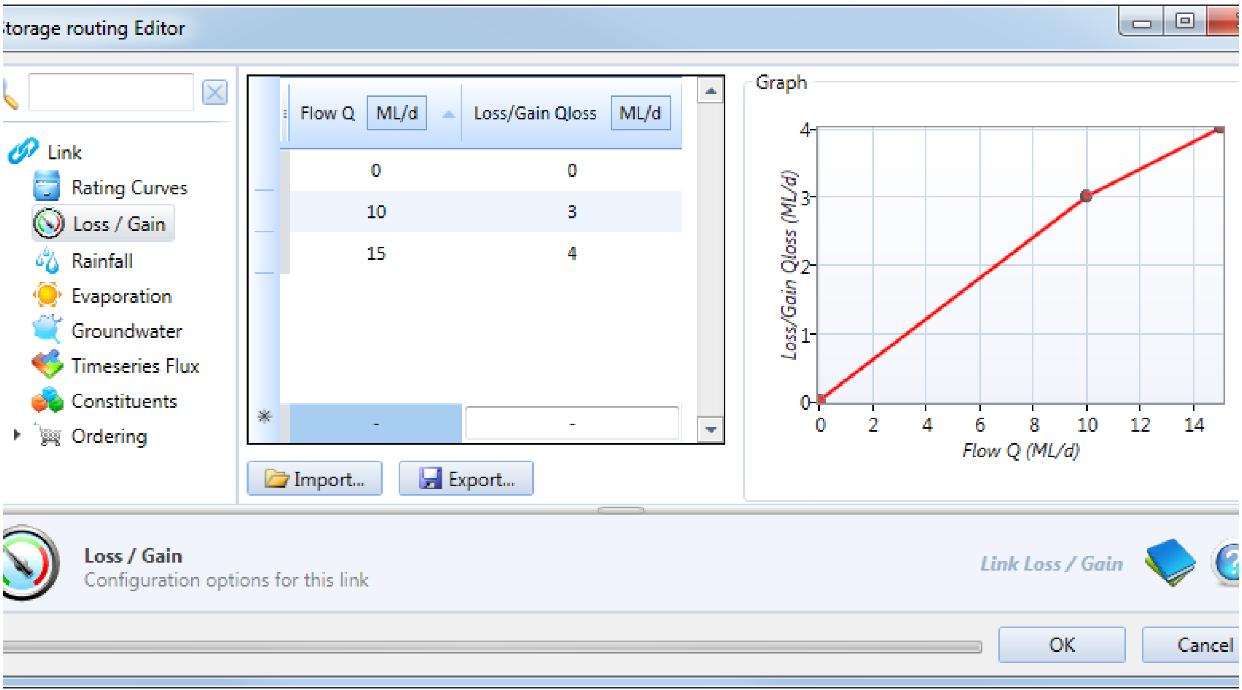
You can also export rating curves to .CSV files by clicking the ***Export*** button.

Link losses and gains

Choose ***Loss/Gain*** to specify flux as a function of flow using a piecewise linear editor. By convention, losses are described using positive numbers whereas gains are specified using negative numbers. In other words, a gain is a negative loss.

> **Note:** In the Flow vs Loss/Gain table, flow cannot be negative. Additionally, the values for Loss/Gain Q_{loss} must be increasing (as shown in Figure 5).

Figure 5. Storage routing, Loss/Gain



Link Evaporation

Choose ***Evaporation*** to specify the rate of evaporation per unit of surface area (Figure 6). Typically, this is done using a time series (loaded using Data Sources), the format of which is shown in Table 5. You can also specify the rate of evaporation as a single value or as a function.

Figure 6. Storage routing, Evaporation

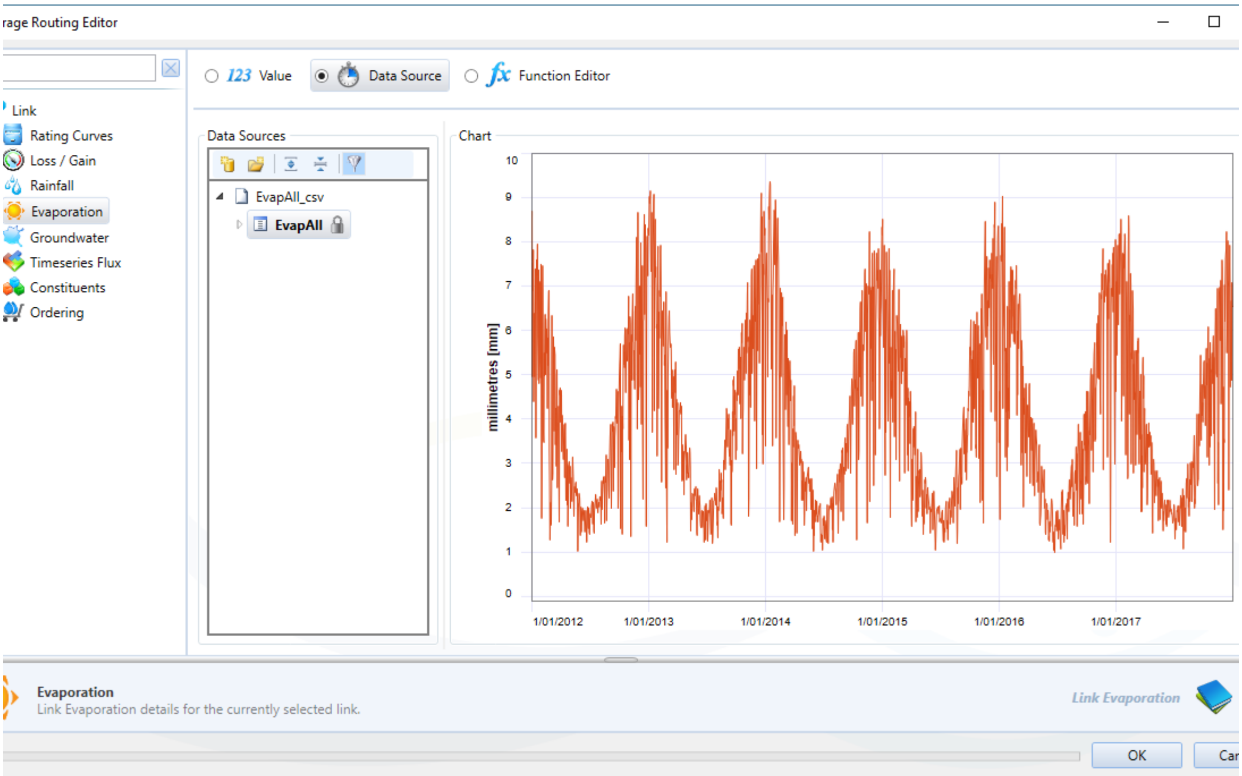


Table 5. Storage routing link, Evaporation (data file format)

Row	Column (comma-separated)	
	1	2
1..n	*time*	*value*

where:

time is the time of obersvation in "dd/mm/yyyy hh:mm:ss" format

value is the evaporation rate in millimetres per time-step

Note: The file format shown in Table 5, as well as the screen shown in Figure 5 can be replicated for Rainfall and Timeseries Flux. The former allows you to specify the rate of precipitation; the latter allows the input of a time series of total water lost or gained on a link. Values can be positive or negative. A negative value denotes water returned to the link (a gain). See also Link losses and gains.

Groundwater

Choose ***Groundwater*** to configure groundwater models on the storage routing link. Refer to Groundwater.

Constituents

Choose ***Constituents*** to configure constituents on the storage routing link. Refer to Constituents - Links.

Timeseries Flux

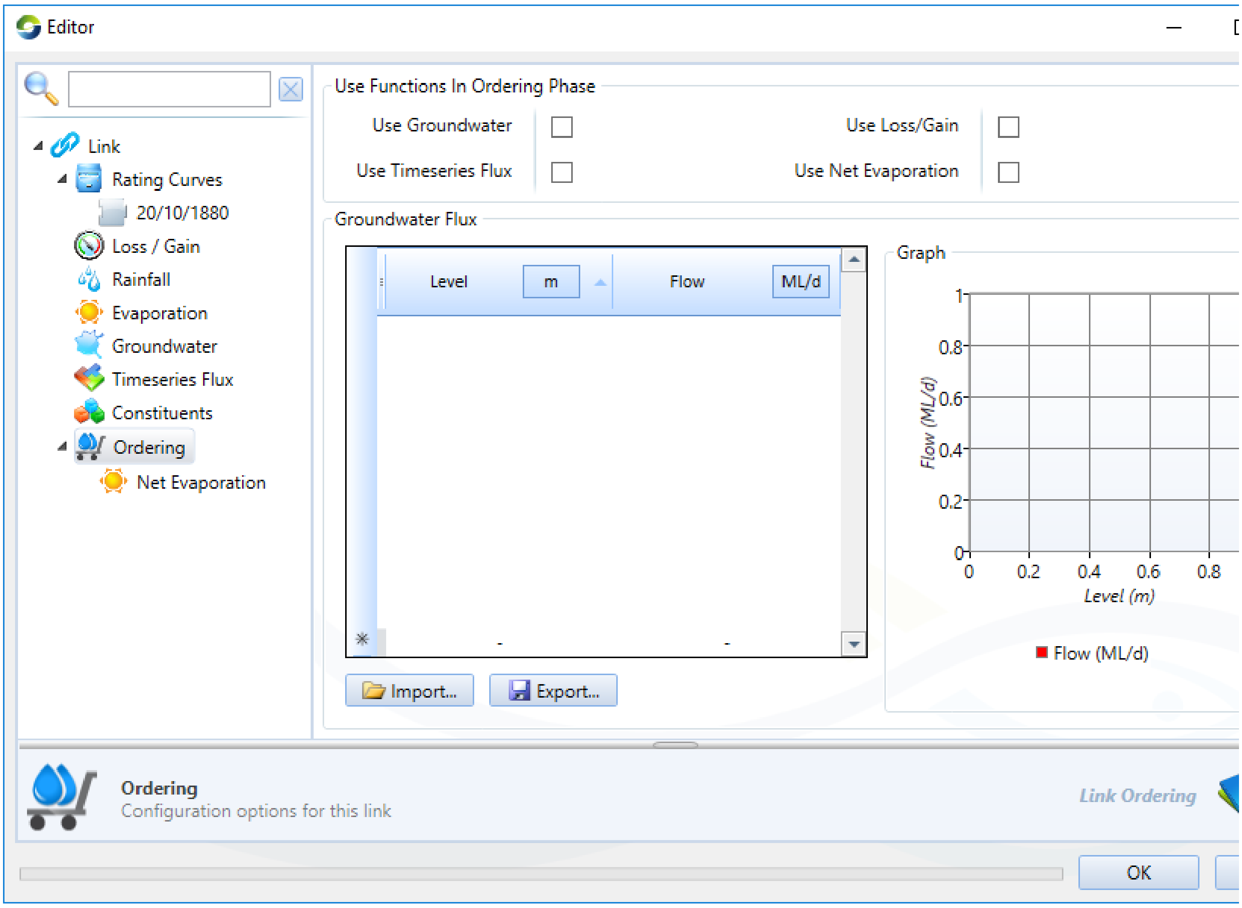
Choose ***Timeseries Flux*** to configure flux as a value, data source or function.

The Timeseries flux can be a loss or a gain, adjustments to orders can be enabled under ordering.

Ordering at links

Choose ***Ordering*** and configure the parameters as shown in Figure 7.

Figure 7. Link (Ordering)



Ownership at links

Ownership must be enabled at the scenario-level (using ***Edit » Ownership***) prior to configuring ownership at storage routing links. Refer to Ownership for details.

References

Davis, C.V., and K.E. Sorensen (1969) *Handbook of Applied Hydraulics*, 3rd Edition, C.V. Davis and K.E. Sorensen (eds). McGraw-Hill.