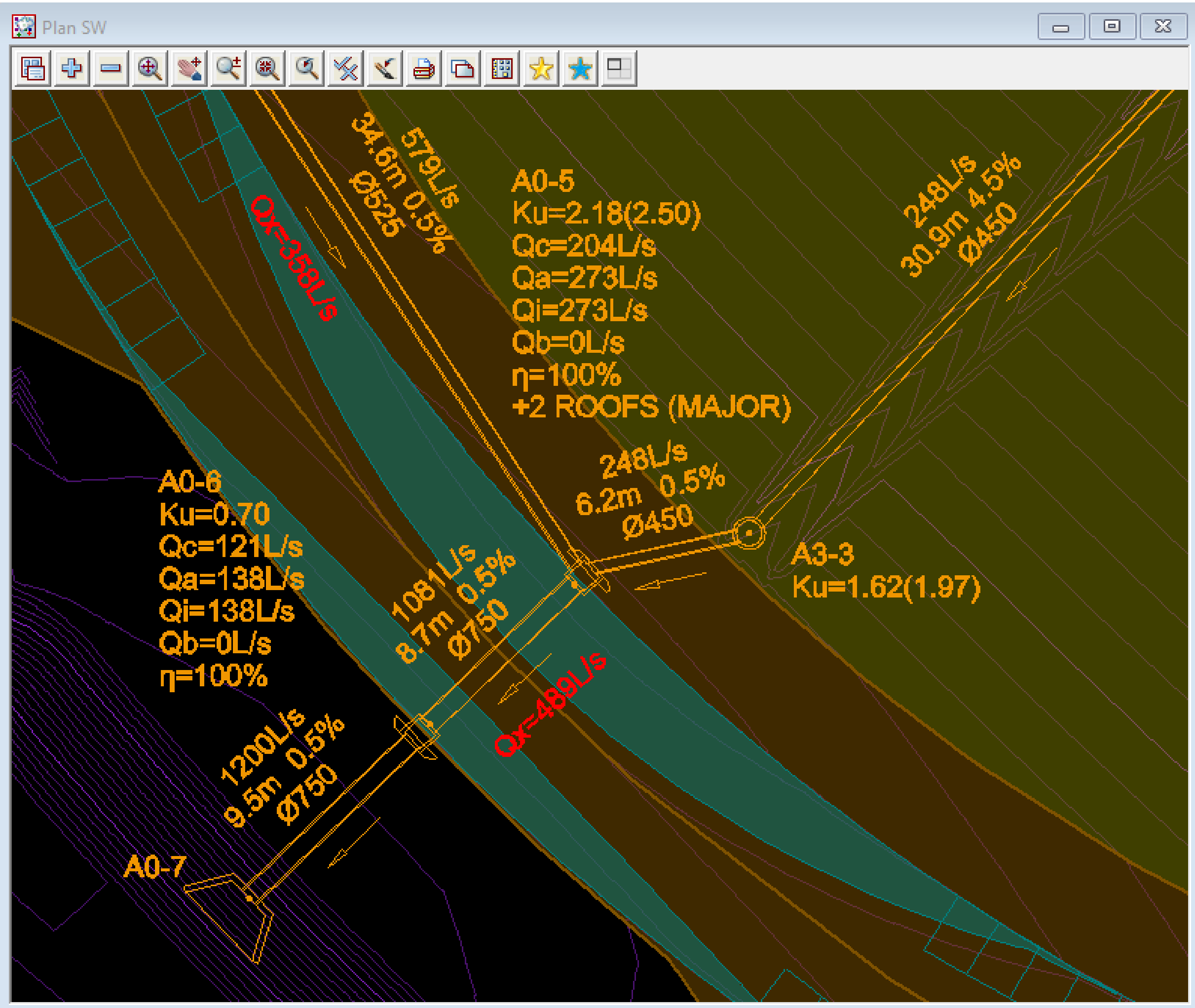
Excess Pipe Flow – Hydraulics for the Rational Method

The Rational Method estimates link flow rate, **Q**, before the HGL is determined. In cases where **Q** is too large to allow the resulting HGL to fit below the link's upstream **Grate RL**, the excess pipe flow rate, **Qx**, is defined as the difference between **Q**, and the lesser flow rate that would allow the HGL to be exactly at the **Grate RL**. As such, **Qx** is a theoretical component of the link flow rate, that must be eradicated, in order for **Q** to be considered reasonable.

During the storm analysis, **12d Model** reports **!PROBLEM** messages in the ***Output Window***, for all links where **Qx** remains, like so:

!PROBLEM: Pipe "A0-5" to "A0-6" - US pit HGL of pipe reached the network minimum upstream grate level (see Qx messages above for location). Unable to re-route excess pipe flow (Qx) of 0.4885 cumecs in pipe ... All flow forced into pipe and the US pit and pipe hgls will be greater than that reported.

All links with **Qx** remaining, are also set with an attribute – "calculated excess flow" – which is automatically labelled **in red** via the standard *Water Plan Plot* PPFs installed with **12d Model**, like so:



*In link "A0-5 to A0-6" crossing the road, **Q** is estimated as 1081 L/s, which includes a **Qx** of 489 L/s, which does not fit in the pipe system, and must be eradicated.*

Eradicating **Qx** from your models is critically important. It can be achieved automatically with one of two different techniques:

1) Allow **12d Model** to re-size and re-grade the links so that the HGL fits below the **Freeboard limit** at all nodes. To allow this, turn on **Modify pipe sizes** and **Modify pipe inverts** on the **Main** tab of the **Analysis** panel. This is the typical solution when designing a proposed model for a minor storm event. This technique will only work on links with unlocked sizes and inverts.

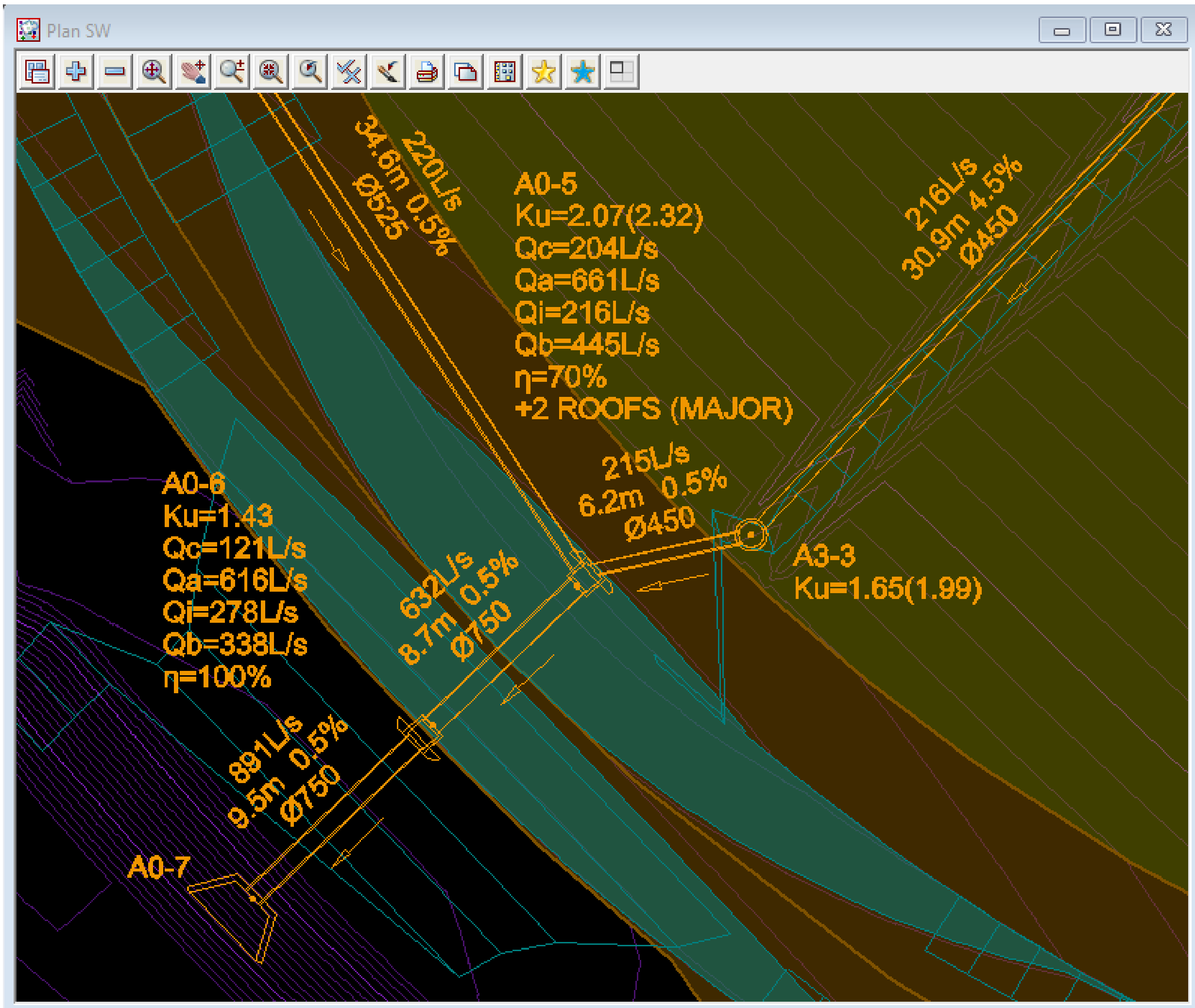
2) Allow **12d Model** to reduce the inlet efficiency, **η**, at certain inlets, so that the HGL just fits below the **Grate RL** at all nodes. To allow this, set a **Qx routing increment** (in cumecs) that is greater than zero, on the **Main** tab of the **Analysis** panel. This is the typical solution when analysing an existing model, or checking a proposed model for a major storm event. This technique requires a suitable **Overland flow model** and **Consider bypass flows** turned on. For more details, read on …

Qx routing increment

When link sizes are too small for the estimated Rational Method **Q** values, setting the **Qx routing increment** greater than zero, triggers a special, iterative routing algorithm in the Rational Method hydraulic analysis. This will reduce **η** at certain inlets, in an attempt to eradicate all remaining **Qx** and make the HGL "just" fit below the **Grate RL** of the inlets affected. The **Qx** is eradicated from the links and transformed into increased bypass flow, **Qb**, and increased approach flow, **Qa**, in parts of the overland flow system. At those inlets where **η** is reduced, inlet flow, **Qi**, will also be reduced. In extreme cases, **η** may even be reduced to zero, and **Qi** may be negative, indicating that the inlet is surcharging. Any flow surcharging out the top of the inlet, simply adds to the **Qb** departing the inlet, which may re-enter the underground system further downstream, where there is capacity.

It is recommended that you set the **Qx routing increment** to zero, initially, until you start to see the above mentioned **!PROBLEM** messages in the ***Output Window***, regarding excess flow. If you have several links reporting **Qx**, a recommended *next* value for the **Qx routing increment** is ~10-20% of the largest **Qx** value reported, or 0.01 cumecs, whichever is larger. In general, a larger increment value will yield a faster run time, but may result in routing slightly more **Qx** from the underground system to the overland system, than is necessary.

At each iteration of the algorithm, the most upstream inlets with **Qx** remaining, are determined and adjusted: the **η** is reduced by an amount calculated to reduce **Qi** by no more than the **Qx routing increment**. This local adjustment can potentially have an affect across the entire model, so the HGL is then re-calculated for the entire model, and if any **Qx** still remains in the model, the algorithm continues for another iteration. The algorithm may be thought of as a numerical adjustment to the bypass flows of the model, which in turn are the result of a numerical adjustment to the Rational Method. Technically, both these numerical adjustments represent a departure from the Rational Method in its purest form.



*With a **Qx routing increment** set greater than zero, the inlet efficiency of node "A0-5" has been reduced to 70% and both sag ponds are now bypassing. In general, link flow rates are reduced and overland flow rates are increased across the model. Most importantly, all the **Qx** has been eradicated.*

Limitations of Qx routing

While the *Qx routing* algorithm will achieve its goal most of the time, it is not guaranteed to eradicate all **Qx**, in all cases.

Most commonly, issues arise when the links with **Qx** have a manhole connected immediately upstream. Manholes are not connected to the overland system, and so have no **η** to reduce. Assuming the manhole has a sealed, or bolted-down lid, a possible solution is to manually raise its **Grate RL** slightly and allow the underside of the lid to go under a certain amount of pressure. Alternatively, if the manhole is allowed to surcharge, it can be modelled as an inlet with a connection to the overland system.

Other issues can arise, that also result in some **Qx** remaining in the model, even after automatic *Qx routing*. In some cases, there may be scope for manual adjustments to be made to **η** at selected inlets. Such adjustments can *certainly* eradicate the remaining **Qx**, but perhaps not always with a *realistic* result. Indeed, for the hardest cases, one may be forced to conclude that the complexity of the model is beyond the capability of the Rational Method, and that one should instead consider a hydrograph method using the 12d *Dynamic Drainage* module.