# Using ICM modelling to fully understand the problem (a case study)

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## 1 Introduction

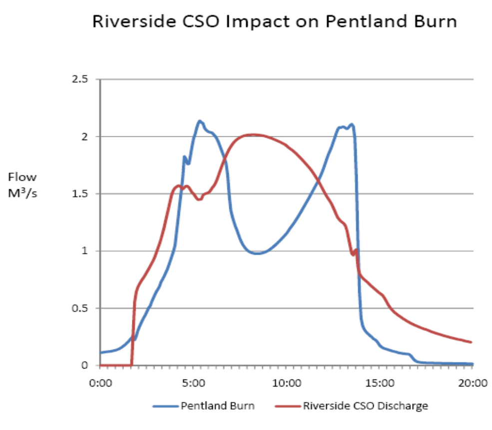
As engineers, we need to understand which tools are best suited to analyse certain problems. As the capabilities and speed of wastewater networks modelling software increases the more frequent application of 2D meshing and Integrated Catchment Modelling will be promoted as standard practise to understand overland flooding problems. However in today's financial climate we need to balance what is appropriate and get best value for money. In most cases resolution of flooding can be obtained by use of a 1D model. But in certain cases when engineering experience indicates that there are multiple complex mechanism involved then the software abilities are invaluable to the understanding of flood mechanism and resolutions of problems.

This paper discusses the reported flooding issues and how best to model the interaction between watercourses and the sewer systems in a problem area in the Southside of Glasgow, to give an enhanced understanding of the flood mechanism.

## 2 Catchment Needs

### Water Quality Derived Solution

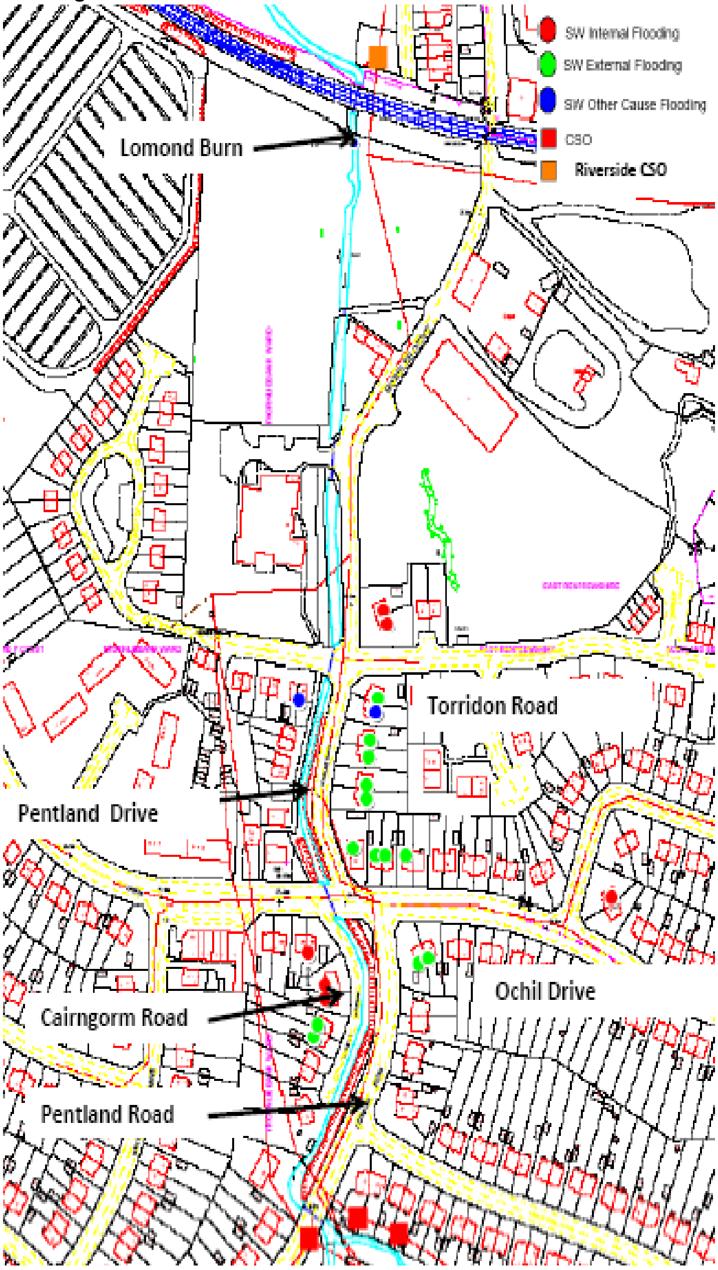
The problem area is in the upper reaches of the Glasgow, Shieldhall catchment. The area is generally valley shaped with the ground profile inclined towards Pentland Burn situated at the bottom of the valley. The sewerage network generally follows the profile of the valley then joins together into one main trunk sewer at the site of an old WwTW, which is now disused. This sewer connects to the South Side No1 Trunk Sewer which takes flow to the Shieldhall WwTW. To protect the downstream area from flooding, a Hydrobrake with online storage has been installed on this sewer with the upstream Riverside CSO acting as a relief point. The Hydrobrake is a significant control point having a pass forward flow of 250 l/s which is 0.6 x Formula A. There is 2250m$^3$ of online storage which is quickly utilised during storm events and the CSO discharges significant volumes to the Pentland Burn. This has been identified as a water quality need during the Scottish Water Strategic Review 2010 (SR10) UID and Flooding Study and requires13,000m$^3$ of storage to meet water quality objectives.




The reported flooding immediately upstream of the Riverside CSO would appear to be relate to this significant control, however the level of the relief weir compared to the ground levels around the reported flooding would suggests otherwise, and the CSO should be able to relieve the system without causing flooding. Looking at the position of the outfall on the watercourse and the effect of the large discharge flow (2m$^3$/s during a 30 year design storm) on the narrow channel watercourse, this suggests the watercourse itself may not be large enough to handle the additional spill flows from the CSO during storm events. This interaction between the two systems was suspected during the 2008 verification events but could not be replicated. The hydrographs shown here from the integrated model clearly show that as CSO discharges increase to the watercourse the upstream river flows significantly reduce with depths increasing upstream and utilising available flood plain storage. This increase in river depths causes the depth of water over the relief weir to increase as well and eventually the weir can become drowned with further increased surcharging in upstream sewer network.

**Reported Flooding Problems**

The Pentland Drive / Ochil Drive area of Shieldhall has had several reported flooding events but it has been difficult to isolate a specific rainfall return period causing the flooding. A review of rainfall indicated that short duration high intensity events did stress the sewerage network, as to be expected, but there were recorded flooding events where the rainfall could be described as intense long duration events rather than extreme short periods of rainfall. This lack of a clearly defined flood mechanism occurring with varying rainfall events suggested to MWH that the adjacent Pentland Burn was having a significant impact on how rainfall were received by the catchment and that the sewerage network and catchment interacted to give a complex flooding issue.




**The Ochil Drive, Torridon Avenue and Pentland Drive:** Flooding locations are recorded as external flooding, and the sewer 1D model does indicate numerous flood locations however these are quiet distant from the actual recorded flood locations during a M10 year return period storms. The photo shows the extent of flooding from the August 08 events and shows significant sewer surcharging and overland flow paths.

**Cairngorm Road:** Flooding locations are recorded as internal flooding and local flood volumes would suggest flooding could occur but the severity, amount of properties affected are not replicated with 1D models during M10 year return period. The ICM model shows that flooding turns into overland flow which flows towards Cairngorm Road which then ponds behind a river flood defence wall and subsequently cause Internal flooding.

## 3 Modelling the Interaction

### River Interactions

The burn was surveyed throughout this area giving cross sections at key points along the watercourse to be used in building the burn into the model. Four flow monitors and one depth monitor were installed along the burn reach at strategic locations so that the burns hydrological catchment data could be calibrated against observed data. This was undertaken at the same time as the sewer system verification flow survey so that any interaction between the two systems could be fully replicated in the model. The main Shieldhall catchment model has been left in InfoWorks CS due to the need for water quality modelling of the sewer system. This meant the original calibration of the burn model was undertaken in ISIS and then exported into InfoWorks CS as upstream inflows. The model was then imported into InfoWorks ICM and the burn catchment details were defined directly into the integrated model so that the flooding within this area could be understood at a more refined level.

### Overland Interactions

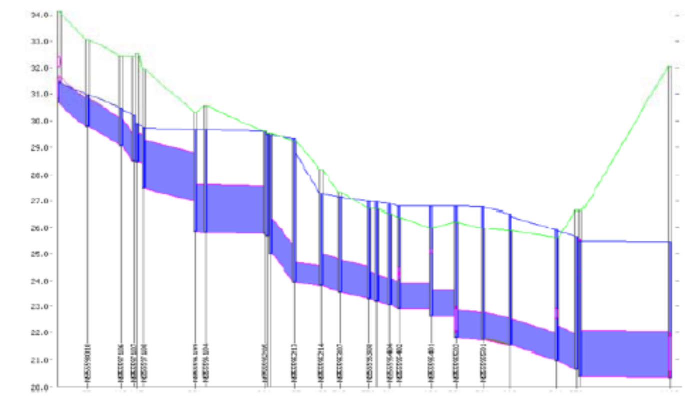
LiDAR data (1m grid +/- 100mm) was also reviewed to understand the overland issues in the area and to produce a 2D mesh to connect the river, sewer system and topography together. Within the original InfoWorks CS model, this involved connecting mesh cells to the river network via 40 dummy nodes to allow the flow within the river channel and on the mesh to interact at a suitable level. Within the InfoWorks ICM model the river reach and 2D mesh was joined along the rivers banks.


2D Modelling Zone Extents

The 2D zone polygon covers an area of 63.8ha and encompasses the area around Pentland Drive, Torridon Avenue, Ochil Drive and 200m to the north of a railway line. This allows the 2D area to include the Riverside overflow and Pentland Burn which would capture interactions of known flood locations, river interactions and ancillaries during investigation of the flooding problem.

As discussed, in general, the area is valley shaped with the ground profile inclined towards Pentland Burn situated at the bottom of the valley. The main trunk sewer in the area also runs parallel with the Pentland Burn. The Pentland Burn flows through the 2D zone polygon from south to north and is joined by a small tributary, prior to the Pentland Burn crossing underneath Pentland Road. The area is mainly residential with an area of industrial estate and grass/ derelict land prior to the Pentland Burn crossing under the railway line. Within the 2D zone polygon, front garden walls and kerb lines were modelled to achieve better representation of the flood paths along Ochil Drive.

## 4 Flooding Mechanism

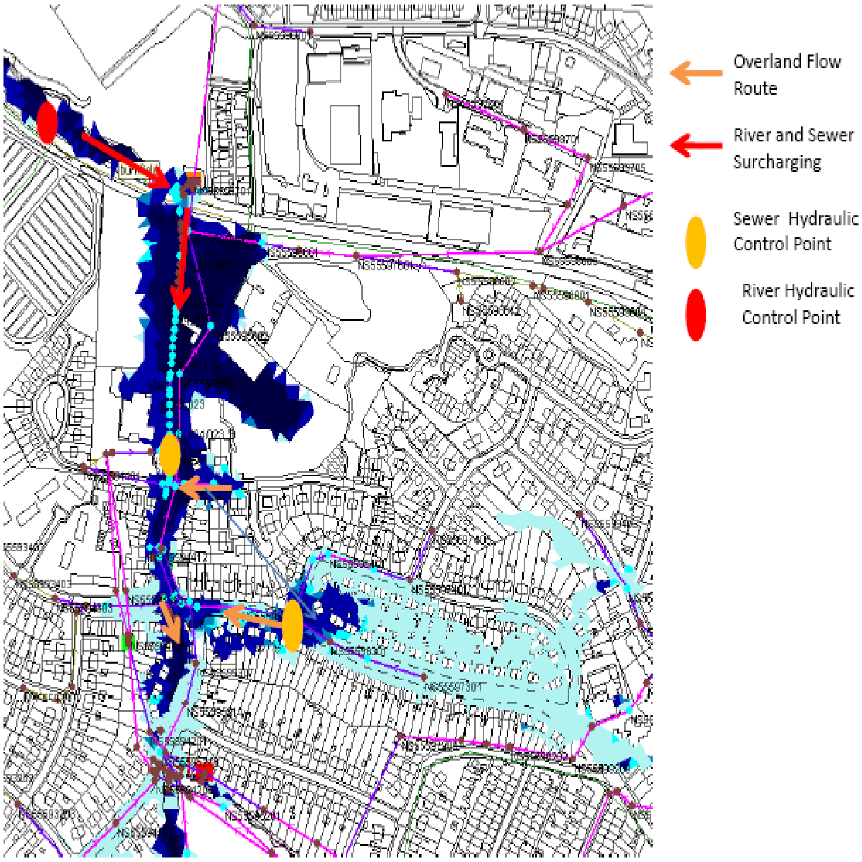

Sewer Long Section from Riverside CSO to Pentland Drive

The analysis of simulation results from the integration of the river system with the sewerage network is indicating that there are three identified flood mechanism within the catchment, two sewer incapacities and one_river incapacity. Each of these controls can cause flooding in their own right however, when conditions are right they interact and compound each other. Matrix analysis of differing returns periods is ongoing but these interactions do lessen the return period of occurrence which goes some way to explain the issue in Pentland Drive.

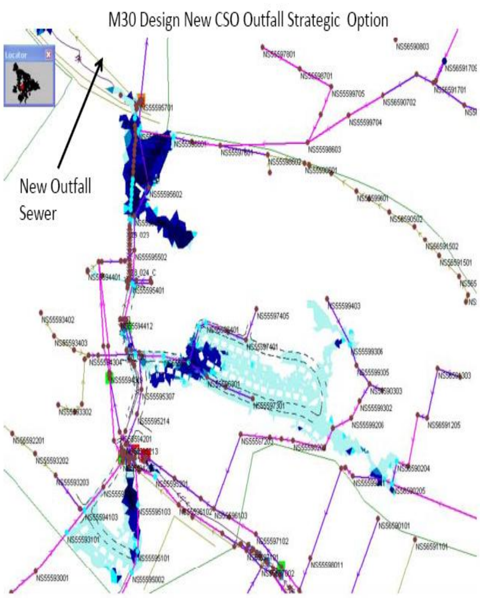
The historical verification for the reported flooding location around Pentland Drive shows that there is predicted flooding at the reported locations which is first predicted at a 1 in 1 return period on Pentland Drive.

The flooding is predicted to occur from the hydraulic throttling at the control Hydrobrake coupled with the incapacity in the sewers between Riverside CSO and the reported flooding area. This is then compounded when the Riverside CSO discharge rate reduces when river flows drown the outfall weir. This can be caused by high river flows or even high discharge rates from the CSO actually drowning out the downstream river channel. This then reduces the ability of the CSO to relieve the main trunk sewer.

This flooding has been predicted in earlier catchment needs analysis but the extent to which the river interacts and reduces the ability of the sewer to be relieved, and its impact further upstream, was not understood.




The 2D mesh has also allowed the overland flooding to be better understood in this steep valley. There are numerous modelled nodes uphill of the reported flooding area that flood during the higher return period events due to local sewer incapacities. The flow runs down the hill in a different route to the underground system causing additional flooding in the basin of the valley. The flooding along Cairngorm Road predominately occurs due to the pooling of the overland flow behind a river flood defence wall where the flood wall actually ponds water on the residential side so that internal flooding occurs before it can spill over the wall into the freely discharging river.




The Pentland Drive and Ochil Drive flooding do have confirmed flooding nodes close to the affected properties which are caused by a localised sewer incapacity. However the ICM has indicated that overland flows further upstream on Ochil Drive, flow towards Cairngorm Road and Pentland Drive and result in the significant flooding experienced here.

The ICM modelling is predicting the flooding mechanism more accurately and therefore the solution developed for this area will take a more holistic approach.

## 5 Proposed Solutions

There have historically been two options proposed for this area, the first option is a 13,000m$^3$ localised storage option which was developed during the SR10 UID and Flooding programme. This scheme would provide water quality improvements with the storage provided also giving flood relief.

A further option was developed following construction of a macro model which enabled analysis of larger catchment wide strategic options. This option was for the Riverside CSO discharge to be passed to a higher dilution watercourse via a 1m diameter sewer 2km in length. This would remove the need for a large storage asset so high up in the catchment and would reduce the significant surcharging upstream at Torridon Avenue and Pentland Drive.

From an initial review of the flood mechanism produced from the ICM model the proposed outline options are still valid but will require enhancements to protect the whole area. However the ICM results strengthen the case for the strategic option developed as this option removes drowned weir scenarios being produced by the river incapacity which is one of the main hydraulic controls. This would not have been established with a 1D model.

The ICM model also shows that the option with the localised storage tanks would be at risk of river flooding from the Pentland Burn during long duration events greater than 20 year return period. The river capacity flood mechanism would still exist when storm tanks become full and require relief by discharging to the Pentland Burn.

The ICM process has also identified further consideration of options required including;

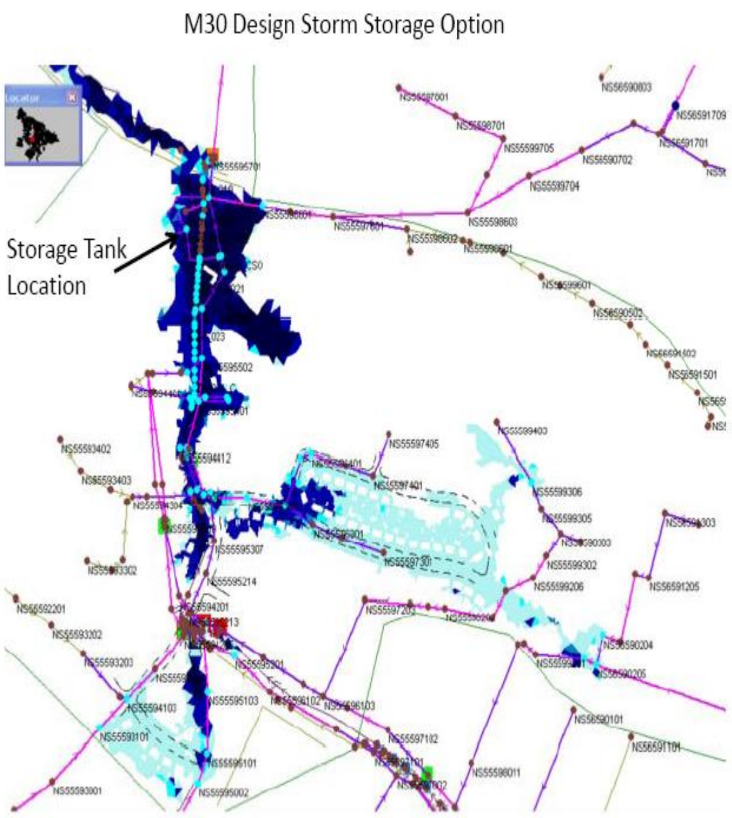
- Review of the river channel capacities
- Future Flood Risk Management measures
- Resolving the upstream sewer network incapacities in Ochil Drive
- Surface Water Management measures
- Reviewing of overland flow routes in Cairngorm Road so that flood defence walls do not compound the flooding issues.

## 6 Use of ICM modelling

For this catchment, MWH have used both the InfoWorks CS and ICM software platforms to gain knowledge and understanding on what advantages each software platform brings to analysis of flooding problems.

River integration on CS caused issues with the modelling of realistic river elements whilst maintaining a stable model for comparison. There was also a requirement to add in dummy nodes to integrate the 2D mesh with the river.

The integration within the ICM platform was easier to achieve and obtain the full benefits from the software but some additional modelling work was required on river elements. If the ICM software had been available at the onset of the project this change in river elements would not have been additional as it was mainly due to conversion between software packages. As the study also required water quality analysis there was a need to maintain a CS model for these simulations.




The results from the ICM software although not reported in this paper did produced similar results to the CS modelling. The ICM modelling will provide more accurate results with the ability of the 2D mesh to merge overland flows into river profiles. But the results from both software platforms would enable any experienced hydraulic engineer the ability to understand the flood mechanism operating in the catchment and allow viable and efficient solutions to be proposed. The ICM software if used from project inception would reduce modelling effort and increase accuracy and result in less risk of human error entering model build tasks.

## 7 Conclusion

The use of InfoWorks CS with 2D mesh and InfoWorks ICM are both useful tools in understanding the full flooding mechanism for this project. It has allowed MWH to visually see the interaction points between the river, sewer and overland flow which has enabled a fuller understanding of the flooding mechanisms within the catchment.

Further analysis is still needed but the early indications would suggest that the strategic option now has significant benefits beyond just sewer network flooding and will perform significantly better and have less flood risk when compared to the localised storage option.

Both these options will entail significant expenditure but the use of a ICM has given considerable robustness to the understanding of the catchment flooding issues and will give SW and there MGSDP partners confidence when promoting a solution for the water quality and flooding issues within the Shieldhall catchment.

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