THE SUBTLETIES OF A 10 CUMEC CSO!

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Green Lane Storm Overflow is one of two key CSO's just upstream of the Sewage Treatment Works. It is located at one of the lowest points in the City, adjacent to the River Derwent, and is a critical element of the overall Derby Sewerage Improvement Strategy.

This paper covers the physical realisation of a large strategic CSO, describing the decisions that were made in the sizing and selection of the CSO structure, and considerations in the detailed design & recommendations for improving the general design of CSO's are also discussed.

WHY THE CSO WAS REQUIRED

The new CSO receives flows of up to 10 cumecs from nearly half of the City of Derby providing a significant environmental improvement to the River Derwent. The river quality has been enhanced by reducing the total spill volume by 400,000 cubic metres per annum and screening out sewage debris for the majority of storm events. The existing sewer upon which the CSO was built was actually a surface water sewer, built back in 1936 to offer flood protection to the city centre. As part of the Derby Sewerage Improvement Strategy there was a need to provide an additional major interceptor to receive the storm flows released by the 26 major re-sewerage schemes and to replace 5 unsatisfactory CSO's and 9 other under-performing CSO's. The solution adopted was to convert the existing under utilised surface water sewer, (which was also the receiving sewer for the CSO's), into a new Central Interceptor Sewer and construct a large CSO at it's downstream point. This solution saved over £13M and was key to delivering the completed strategy ahead of the AMP 2 deadline.

The existing surface water sewer discharges directly into a flood relief channel of the River Derwent, which is used for fishing and has a public footpath and cycle way running alongside it. There were regular complaints of aesthetic pollution to the River and the Environment Agency had put a lot of pressure on Severn Trent Water to resolve these problems as part of the Derby Strategy.

At the point where the sewer leaves the built up area of the city it changed from closed pipe to open trapezoidal channel which posed problems for Severn Trent from public safety, visible sewage debris and odour complaints from the adjacent houses. A course 10mm mechanical screen had been installed some 15 years earlier but this did little to control aesthetic pollution and it did not prevent the build up of a foul base flow from the 14 upstream CSO's that were regularly operating in minor storm events and causing the environmental impact on the river. At the same location another large (1.8m dia.) interceptor sewer crossed the open channel at approximately level inverts! This 'clash' had been overcome by a hydraulically modelled 'ramped weir' that passed the second interceptor through the open channel in a 3.0 metre wide by 0.7 metre high stainless steel pipe. The presence of this interceptor has been utilised in the final design to accept the continuation flow from the new CSO

HYDRAULIC DESIGN AND SIZING OF THE CSO

This CSO is unusual due to the magnitude of flows that needed to be allowed for. Hydroworks modelling, using design storm events and ATSR events, generated the predicted flow rates for the various storms as follows:

- 1 year return period storm flows - 6.5 cumecs
- 5 year return period storm flows - 9.8 cumecs
- 20 year return period storm flows - 10.4 cumecs

Choice of Chamber

The basic design of the CSO follows that laid down in FR 0488 and the latest UKWIR WW-01 design guidelines. The two options available were either a stilling pond overflow or a high sided weir overflow chamber. Initial sizing of the CSO chambers and the particular need to achieve the best type of hydraulic control led to the selection of a high sided weir overflow structure with the advantages of a long weir to reduce velocities over the weir. As part of the Derby Strategy it had been decided to limit this CSO to passing forward ‘Formula A’ flows of 473 litres/sec which meant that the 5 year design flow split would be 95%.

UKWIR Equivalent sizing of the chamber

From the river impact assessment it was established that the consent for the CSO would be based on the combined 6mm and 10mm standard for a moderate amenity, even though annual time series modelling had predicted that the number of spill events would be at or below 30 per annum. With the nature of this high profile site it was felt that the higher standards were warranted. It was decided to size the CSO on the new UKWIR design guidelines, which aim to achieve equivalent performance by enlarging the CSO chamber. From the detailed calculations the indicative chamber sizes were established to meet the consent standard as shown in the table below.

Option	K value	Chamber length	SingleWeir length	Incoming pipe diameter
Basic overflow + 6mm screen + 10mm Screens	0.815	39.6m	27.6m	1.8m
6mm equivalent overflow + 10mm screens	3.5	91.4m	63.6m	4.06m
10mm equivalent overflow	3.3	187.0m	130.1m	8.15m

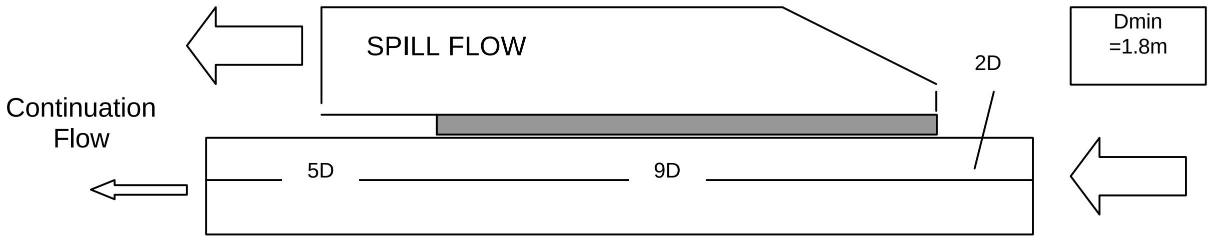
From this it can be seen that the two equivalent overflows would have required extremely large chambers, long weirs and large incoming pipe diameters in order to achieve the ‘equivalent’ performance. Due to this and the particular problems of aesthetic pollution in the river it was decided to proceed with the more robust option of a basic overflow with fine screens.

Basic sizing and screen selection

The existing incoming pipe size was a 2.7 x 2.7 metre box culvert and this dimension was used as the diameter for the incoming pipe. From the basic sizing formula set out in FR 0488 the overflow would be nearly 40 metres long with a 28 metre long weir, however the weir, and more particularly the screens, would be the most critical component of the chamber. A thorough review of all available screening technology was carried out with several site visits to live installations to assess operational performance. It became apparent that to install two separate screens, a 6mm and a 10mm, would over complicate the chamber layout, create more maintenance problems for little extra benefit. The idea of a combined 6mm and 10mm screen was discussed but no manufacturer could offer a tried and tested arrangement. Finally a single 6mm screen was chosen to screen all flows up to the 5 year design spill rate. What was needed was a reliable, preferably non-unique screen that would resolve aesthetic pollution problems and get the approval of the EA and Severn Trent Waters operations.

The screens finally selected were Romag 4mm horizontal bar screens that gave the equivalent performance of 6mm in two directions. The EA were taken to see a similar Romag screen in operation and they agreed in principle to this type of screen at Green Lane. Due to the very high flow rate two in line screens were required. The most important point to note is that the overflow chamber should be designed around the selected screens and that the final weir length was based on the screen manufacturers designed screen weir length, not the theoretical length from FR 0488. For this chamber the screens are 9 metres long with an effective weir length of 8 metres each (16 m total) as opposed to the theoretical length of 28 metres. This design issue has been raised with Prof. Saul and Prof. Balmforth and they have indicated their agreement with this principle.

The oversized incoming sewer was over 200 metres long and it was felt contributed significantly to the requirement to achieve a stilling length on the approach to the weir. Therefore the chamber stilling length was reduced to only 2D. It was also decided to increase the solids collection length from 3D to 5D, thereby maintaining an overall chamber length of 30 metres.



Designing for normal operation and “Failure” mode

1. What should not be overlooked are the smaller storm events. These are what actually cause most of the complaints because of their more frequent occurrence. The ability of the chosen screens to achieve a very high standard for the majority of the events is of prime importance.

2. An important issue is to ensure that that overflow chamber will still operate without damage or consequential flooding during either major storm events or power failure of the mechanical screens. For this overflow the type of screen selected allows flows in excess of the screen capacity to pass over the top of the screen. The chamber and screen mounting system is designed to withstand the full hydraulic forces with the screen completely blinded (power failure) and 20 year spill flow passing over the top. The capacity of the chamber i.e. cross sectional flow area is also designed to accommodate these flows.

Modelling the screens

This overflow chamber was modelled in Hydroworks including the 4mm fine screens. By using the known headloss through the screen and back calculating a coefficient of discharge of 0.34 was derived. When used in the model with a simple weir ancillary it gave a satisfactory simulation of the fine screens.

Scottish Paper storage

For a CSO of this size discharging into an open body of water that often has minimal throughflow it would be expected that full Scottish paper storage should be provided. However the UPM study had shown that the water quality would be satisfactory without additional storage, spill volumes were being halved and a considerable amount of in-pipe storage was being mobilised by constructing the CSO.

DETAILED DESIGN CONSIDERATIONS

The proposed site for the CSO was fairly restricted, with limitations on the amount of land available. Severn Trent already owned the land over the open channel and adjacent landowners were unwilling to sell except at a significant premium. The Highways Agency was also planning to construct a spur road and noise bund right up to the edge of the existing channel. The approach culverts to the CSO are meant to be straight for a minimum length of 25D, however top achieve this we had to use a series of slow radius culverts on a 500 metre radius. Another significant constraint was a high-pressure 27” gas main running parallel to the open channel. The actual site for the chamber had to be chosen to avoid a conflict with this major trunk main.

Problems of levels

A particular difficulty of this CSO chamber design was the fact that there was a very limited fall over the weir into the spill chamber. This problem could not be designed out and the whole CSO chamber has been constructed at a level where normal top water level in the chamber is actually at ground level. The approach culverts also had to be laid with their top surface at ground level and this has necessitated the inclusion of sealed access covers along their length. The top of the CSO chamber itself is some 400mm above ground level. This problem of limited fall can be seen on the chamber cross-section and required careful consideration when sizing the chamber and setting the final weir level. This problem was a significant factor in rejecting the alternative Rotomat screen.

Access and Maintenance

An important factor in the design of any CSO chamber is ensuring that it is safe and relatively easy to maintain. Full length access covers have been provided over the two screens as well as several 1.0m square man access points with retractable handholds. The structure can be easily vented and has good natural light to allow operational staff to inspect the chamber from above and below ground.

Dealing with the continuation and spill flows

It was not possible to achieve the pass forward of full Formula A flows by gravity because of the problems of the existing surface water sewer and second trunk sewer being at a similar invert level. This necessitated the inclusion of a deep pumping station to lift the flows above surcharge levels in the downstream receiving sewer. In order to ensure that the submersible pumps operated with a pumping head a traditional control orifice, 400 x 300mm, was installed between the CSO and the pumping well.

The spill flows pass through a 6 metre wide spillway chamber and into the downstream channel. As part of the strategy the remaining 1400 metres of open channel down to the River Derwent was replaced with 3.4 x 2.4 m box culverts for safety reasons. In addition a new raw water inflow of 50 litres/sec was introduced into the river cut-off channel.

COMPLETION OF THE PROJECT

The project was successfully completed in November 1998 and there have been several major storm events to test the installation. There have been some events that have overtopped the screens and we are currently monitoring the CSO as part of a larger post project flow monitoring for the Derby Strategy. The out-turn cost for the CSO contract was £1.2M which included £200,000 for the twin Romag screens. The whole site has now been landscaped and planted to reduce the maintenance burden and reduce the impact of the new installation on the local residents.

RECOMMENDATIONS FOR FUTURE LARGE CSO'S

With the successful completion of this major CSO project it is possible to raise certain issues that may justify further investigated.

- Should the solids collection length of the CSO be increased even more? Because of the 95% flow split at peak flows there is a considerable quantity of retained screenings that can not effectively get out of the CSO chamber. I would recommend that this length is increased where the flow split is similar to this CSO
- Should scumboards be incorporated into CSO's that include high performance mechanical screens? The advice from the screen manufacturers is not to include a scum board and I would concur with this mainly because it creates a barrier to the effective cleaning of the screen and disturbs the flow patterns within the chamber. If correctly positioned the fine screen should operate effectively without one.
- It is important to get public support for such a project because a 10 cumec CSO does not come along un-noticed!
- The most important part of this CSO are the fine screens. Technology is racing ahead and there are now some really good screens available. The whole design of the CSO should be based around getting the most out of the screens and ensuring that they perform as required. There is very little benefit in oversizing the CSO chamber, as it is unlikely to give any extra benefits.

CONCLUSION

What are the subtleties of a 10 cumec CSO? Can such a structure really be subtle? The challenge has been to fit empirical design approaches to real concrete and steel within a very confined site. This has I believe been successfully achieved, making for a healthier river and satisfied client!

DISCUSSION

Question Adrian Saul University of Sheffield

UKWIR is funding the CSO research group. They are currently looking at several projects, monitoring the performance of CSO screens, trying to address some of the problems you have encountered. 12 screens have been assessed so far and there are 4 screens yet to be tested. All of the Water Utilities will be issued with a draft comparison report.

In HydroWorks you say a discharge coefficient of 0.34 was used. What was the design head? What were the flows that overtopped the screen?

Answer

We are currently monitoring the performance of the new screens in association with the screen manufacturer. We are aware that there is a higher than normal downstream head caused by constraints in the downstream receiving culvert, however only longer term monitoring (depth and flow) will confirm the screen performance.

Question **Adrian Saul** **University of Sheffield**

The longer the length of the CSO chamber the better, however secondary circulation could carry particles back onto the face of the screen. It is this consideration which is leading current research into recommending that a scumboard be included to prevent the screenings from being re-presented onto the screen.

Answer

The need for scumboards was considered, however when this CSO was designed the thinking was that a scumboard could be detrimental to the operation of the screens, which require a through flow across the face of the screen to keep them clean. It would always be possible to retrofit scumboards to these screens if felt appropriate.

Comment **Adrian Saul** **University of Sheffield**

There will soon be a UKWIR CSO Research Group report on the use of scumboards with screens.

Question **Brian Sharman** **North West Water**

You have come up against similar problems to those that we have been having at North West Water, with similar solutions, which is reassuring.

1. What allowances have you made for blinding (de-rating the screens hydraulic capacity)?
2. The solids at the Wigan CSO test facility appear to be different to those at other CSO sites?

Answer

1. A de-rating factor of 1.5 has been used, however I am unaware of the exact method the manufacturer uses in design.
2. We have noted that one of the screens appears to have a higher solids loading than the other, but we will have to await the results of the monitoring exercise before any conclusions can be drawn.