Assessing Pollution from Dual Manholes

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Introduction

This paper reviews the investigation and modelling carried out to provide evidence of the environmental impact resulting from a sewer system with a large number of informal CSOs.

The investigations began following persistent complaints of polluted discharges from the surface water outfall. The problems were reported in both wet weather and dry weather.

The sewer system serves an area of 600 hectares having a population of 24,000. The area has been continuously developed from the 1950's to the present day. The sewerage system was planned and built largely on a separate basis, with foul sewers draining domestic waste water and surface water sewers dealing with rainfall run-off from roads, roofs and other impermeable surfaces.

For reasons of economy at the time of construction, instead of pairs of manholes being constructed, the separate foul and surface water sewers were built with a single manhole with provision for accessing both pipes within a single chamber. This arrangement of separate sewers and dual function manholes is found in many areas of the UK which were developed in the immediate post-war years.

In many of the manholes the access to the surface water sewer is sealed so that there is no risk of flows passing between the systems. A preliminary survey showed however that in a significant number of manholes the seal had either been removed, or in some cases had never been present. Evidence of surcharge levels in some of these manholes confirmed that in storm conditions foul flows had been passing to the surface water system. The open surface water sewer accesses could therefore act as combined sewer overflows, though this was not their intended function.

The preliminary survey demonstrated that many unrecorded open accesses existed and that a manhole-by-manhole survey would be required to identify them all.

Discussions on the approach to be taken in evaluating the problem focused on two alternatives:

- installation of a water sampler at the outfall of the system to quantify the amount of pollution leaving the system,
- modelling to allow the interaction of the foul and surface water systems to be better understood.

Since it was already clear that a problem existed, it was agreed that modelling would be the better approach since through developing a better understanding of the mechanisms causing the pollution, better and more economical solutions to the problem could be developed.

Site Investigation

Although at this early stage the mechanisms behind the problem were not understood, it was thought likely that problems would be widely distributed around the catchment and that the effects the model was to replicate would be fairly minor in nature. Consequently the need for a detailed and sensitive model was indicated.

The first priority was to identify the locations of all the open accesses to the surface water systems, and this was achieved through comprehensive manhole survey. A total of 186 open access manholes were identified in the catchment. At the same time that the open accesses were identified, sufficient information for detailed model building was also gathered.

The problem of the open accesses manifests itself in wet weather. As mentioned earlier there was also a dry weather pollution problem. None of the open accesses was found to be spilling in dry weather therefore the other possible cause - wrong connections of foul drainage to the surface water sewer - was investigated as part of the manhole survey. The tracing of wrong connections was done by testing the small base-flow in the surface water system for evidence of sewage pollution. Tests were carried out at major junctions in the system, working upstream from the outfall and this allowed whole branches to be eliminated from the search very quickly. A test which could be carried out on site and give instant results was required, so that the survey team could rapidly make logical deductions from the results and move quickly on up the system. For this reason on-site chemical tests were considered preferable to bio-chemical analysis in the laboratory.

The testing revealed over 150 dwellings from which the foul drainage was connected to the surface water sewer.

A flow survey was commissioned to provide data for model verification. A total of 30 flow monitors and 6 rain-gauges were installed for a period of 7 weeks. From the data gathered, three storm events and two dry weather days were selected to provide verification data.

A comprehensive impermeability survey was carried to assess the extent and connectivity of roads and roofs within the catchment.

Model Building and Verification

The site survey data was compiled within a graphical database which allowed easy access and checking of the data. Routines within the database were used to generate the model data files. In deciding the extent of the model and the level of simplification to be applied, the locations of all the open accesses were identified, together with the more usual considerations, to ensure that the model would properly represent all the features of the sewer system which might affect the performance of the informal CSOs.

Of particular concern was the modelling of the open accesses and the associated manholes themselves. It was assumed that flow through the open access could possibly take place in either direction, foul to SW or SW to foul, or even in both directions at different stages of an event.

The behaviour of the open accesses will vary depending on the hydraulic conditions in the manhole. Under low head conditions, the open accesses act as circular weirs. As head increases a transition point is reached above which orifice control predominates. The discharge characteristics of each of the range of access sizes was calculated from standard weir and orifice equations. These were applied in the model as head/discharge relationships for compound weir/orifice control links between the foul and surface water nodes. In the prototype it is likely that slightly different head/discharge relationships would apply depending on the direction of flow. The model uses the same relationship irrespective of flow direction. Although it would be possible to model the different characteristics by using multiple control links, the lack of data on which to assess the differences, the additional complication, simulation time and risk of instability all suggested that this should only be included if found to be absolutely necessary.

The enforced division of the shared manhole into two separate nodes joined by a control link requires consideration from several points of view. The first consideration relates to hydraulic modelling. Nodes are usually a modelling representation of a manhole. Manholes provide storage volumes within sewer systems. These storage volumes, under surcharged conditions, have an attenuating effect on peak flows and therefore should be accurately modelled. The same effect reduces the speed at which levels in the surcharged system can fluctuate. The surface water nodes in the prototype have no storage volume associated with them however. Initially the surface water nodes were modelled with no storage volume but this resulted in rapid fluctuations in level during simulations and spurious results indicative of modelling instability.

The second matter is relevant if the model is to be used for water quality simulations. In the prototype, if one or other of the sewers surcharges above the level of the open access then flow will spill into the other sewer. This behaviour is adequately replicated in the model. If however both systems become surcharged then the level in the shared manhole will rise above the open access allowing the excess flows to mix within the manhole chamber. As levels then subside, the mixed flow will drain away into one or both systems in varying proportions depending on the balance of spare capacity. In the model under these conditions the head across the control link would be equalised and no flow would occur. Thus the contents of each node will be held isolated one from the other. In the present case this modelling deficiency has been found to be unimportant because in the majority of storm events such heavily surcharged conditions in manholes with open accesses do not arise.

The model was verified to a high standard, for both dry weather flows and storm conditions. In common with many other nominally separate foul systems it was found that the foul sewer was responsive to rainfall.

Evaluating Performance

To evaluate the performance of the system and the implications of the open accesses, the verified model was run with design storms and a selection of events from the annual time series. The results of these simulations showed that the open accesses were indeed acting as CSOs during storms, with a number of the accesses spilling from the foul to the storm system 3 times per year.

The simulations demonstrated that the open accesses in the upstream parts of the sewer system were allowing the surface water sewer to spill into the foul system. The open accesses begin to spill immediately the surface water sewers become overloaded. The excess surface water spilling into the foul sewer then rapidly causes overloading of the foul sewers further downstream, at which point flows spill back from foul to storm.

To provide estimates of the pollutant load being discharged, simulations were carried out using the QSIM water quality module for HydroWorks. Since the model had not been verified for water quality simulation, the default parameters within QSIM were used. The simulations predict that the pollution from the open accesses is in fact a minor component of the total polluting load discharged at the surface water sewer outfall. The main difference between pollution with the accesses open and with them closed is that in the latter case the model predicts no ammonia discharge, this being derived from foul sewage. For the other typical determinands the model predicts a slight increase in pollution if the accesses are closed. This is because the surface water sewers spill more polluting matter into the foul sewer than passes in the reverse direction further downstream.

Trial simulations have shown that although the volumes of spill are not large, simply sealing up the open accesses will lead to unacceptable flooding at a number of locations within the catchment. The model is now being used to determine the most cost effective method of resolving the problems associated with the large number of informal CSOs.

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DISCUSSION

Question **Ron Salinger - Such Salinger Partnership Limited**

What are the origins of dual manholes?

Answer

They were a common design in the 1950's and 60's. We have come across them in the South, East, South West and Midland regions. They were probably used in order to save money. They were probably designed for no surcharge in a 1 in 1 year storm, but have no storage in manhole for enhanced performance in the way that a conventional design would have.