CIWEM UDG Conference Paper: Identifying & Addressing Groundwater Infiltration to Sewers

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Synopsis

Southern Water responded to the increased frequency of groundwater infiltration into sewers by initiating a groundwater infiltration reduction programme in 2013. This programme is in accordance with the Regulatory Position Statement published by the Environment Agency in October 2012.

Since 2013, Southern Water repaired or relined over 14km of sewers in more than 15 catchments. It can be difficult to measure the effectiveness of infiltration reduction work because of the variability of weather conditions; however, analysis of data over the last five years suggests that the programme has been successful in reducing sewer flows. The analysis covers periods before and after the repairs, thus quantifying the effectiveness of the repairs. The conclusions of the analysis are supported by experience in the affected villages, where generally incidences of sewer flooding have reduced.

The programme followed a simple but effective approach to prioritising catchments, locating and repairing infiltration. In addition, Southern Water engaged with customers, stakeholders and other agencies about the rehabilitation work as well as their response to sewer flooding when it did occur.

Where discharges to watercourses were still required, the quality of the dilute effluent was improved at critical locations by use of transportable biological treatment units, which Southern Water designed and had built.

In one catchment in Kent, a hydraulic model of the sewer network was built and calibrated using flow data from wet weather conditions and also dry weather conditions. The model also considered groundwater levels along the sewer lengths. The model was used to identify the most appropriate locations for controlled discharges to minimise both sewer flooding and discharges to watercourses. Investigation of the potential for a controlled discharge is proceeding.

Throughout the programme, Southern Water has engaged the Environment Agency about planned and completed work, and the effectiveness of the repairs. This was through regular meetings, conference calls and through the Infiltration Reduction Plans (IRPs). IRPs have been prepared for each of the affected locations, with five now approved by the Environment Agency.

The long-term analysis has been very informative with the techniques developed suitable for rapid assessment of changing conditions informing when and how to respond. Therefore, the analytical approach provides a critical component to enable forecasting.

Drivers for Change

The Southern Water area serves around 4.5 million wastewater customers, covers about 10,500 km^2 and is bounded on three sides by sea. It extends from Kent in the east, through to Hampshire and the Isle of Wight in the south west. The region is bisected by the North and South Downs which are

chalk escarpments. Underlying the Downs is a mixture of Hastings beds, clay, greensands and chalk leading to many spring points and winterbournes which run each winter.

For many years, Southern Water's approach to dealing with groundwater was a combination of reactive use of tankers and over-pumping (through filter and settlement tanks into rivers), and a capital programme of sewer sealing work to protect customers from flooding and loss of their facilities. However, the arrival of the EA Regulatory Position Statement in October 2012 coupled with exceptionally wet winters in 2013/14 and 2014/15, political pressure and the expectations of customers who demand uninterrupted use of their facilities, resulted in a more forward looking planned approach being adopted.

Southern Water is committed to reducing flooding caused by infiltration and demonstrated this by allocating a realistic budget of £12m across Years 4 and 5 of AMP5, for a programme to reduce groundwater infiltration in 17 areas. The winters of 2012/13 and 2013/14 were both very wet. Groundwater flooding was much more extensive in 2013/14, but overall response costs both winters were similar. There was a 60% payback within 12 months for areas where sewer rehabilitation was completed in 2013. A further £10m is committed through AMP6.

This paper describes the key aspects that ensured the success of the programme:

1. having a clear simple approach to reducing groundwater flooding and securing an appropriate budget for investigation and rehabilitation,
2. having a pro-active communication programme,
3. analysing data and using information to support decisions.

Southern Water's Approach

Southern Water has moved from essentially a purely reactive response to groundwater flooding when it happens, to a position where infiltration has been reduced by targeted capital investment. Investment decisions were based on a combination of detailed survey work, coupled with proven analysis of the cost/benefits to give a fairer balance between competing villages. By carrying out remedial work during the 'dry' season, groundwater infiltration has been tackled in a more cost-effective, planned and visible way, where key stakeholders are included in the process. The approach is shown on Figure 1 below.

Flow monitoring is shown as a separate activity because the timing varied to accommodate survey and repairs.

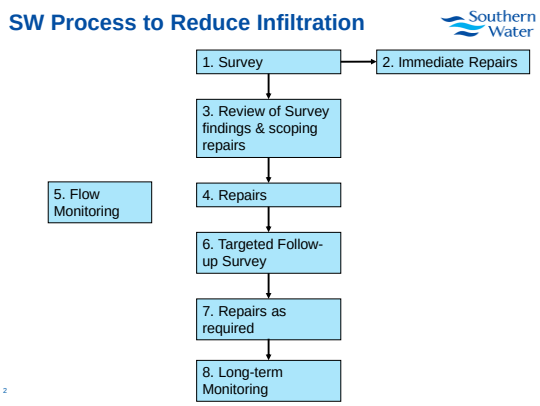

Figure 1 – Southern Water Process to reduce Infiltration

Communication

The EA, in their Regulatory Position Paper (RPS) require water companies which are aware of sewerage systems within their area that are vulnerable to groundwater infiltration and either have a history of overflows being used to relieve pressure on sewers, or where there is a risk of an overflow being required, to submit an Infiltration Reduction Plan (IRP) to the EA. Southern Water is completing IRPs for the 17 worst affected areas and is in the process of getting them approved. Each IRP maps out the local action plan to tackle the problem in a structured way, working in conjunction with other key stakeholders. The approved plans are made available on Southern Water's website for all to see.

The Southern Water team pro-actively engaged the press by providing regular press updates for local publications. In addition Southern Water staff gave several interviews for radio and local television. When letters were sent to customers informing them of planned work or emergency flood response action, stakeholders were always informed prior to letters being posted. Parish councils helped to inform local residents proving an effective way to minimise complaints.

Close working with local flood action groups helped Southern Water understand the local situation better, and when emergency responses were required, they engaged in joint working with highways/ armed forces / blue light services (co-ordinated through COBRA in the 2013/14 winter), including daily conference calls.

During the winter, weekly teleconferences were held within Southern Water to review the groundwater levels and planned responses. Also for the last two winters, weekly calls were held with the Environment Agency to ensure current information was shared.

Analysis Techniques

As the programme progressed, different analytical techniques have been used. The initial approach to quantify non-sewage flows was to plot cumulative percentile flow figures. The shape of the curve gave a quick visual indication of the proportion of the year when flows exceeded DWF, and by how much. This information was helpful for comparing the relative levels of infiltration in different locations, but is not responsive enough to be used for regular monitoring.

When repairs had been carried out, the groundwater levels (EA borehole data) at which tankering or over-pumping was required after repairs was compared with the situation prior to repairs. Generally, this showed that responses were not needed until higher groundwater levels were reached, indicating the success of the repairs. Whilst this is a useful indicator which is quick and easy to measure, it only uses a single point measurement.

The next refinement was to compare pump flow data before and after repairs, which allowed quantification of the benefits of the rehabilitation. Flows in the sewers were compared to groundwater levels to help assess the success of the repairs carried out. Using EA borehole level data and pump run times (as an indicator of flow) scatter diagrams were prepared. An example is shown in Figure 2. Pumping station flows were analysed against groundwater levels over the last five years. This period included data before and after repairs. The data points are shown in Figure 2, together

with linear regression lines (Line A and Line B). These show that for a given groundwater level, sewer flows are reduced after repairs. Or alternatively for a given flow, after repairs, resilience against an additional 3-4m head of groundwater at the reference boreholes has been achieved.

The reference boreholes tend to be on high ground, therefore the variation in groundwater level at the villages in the valleys was far less significant, but this borehole data provided by the EA was used because it is readily available, whereas local groundwater levels are not available digitally.

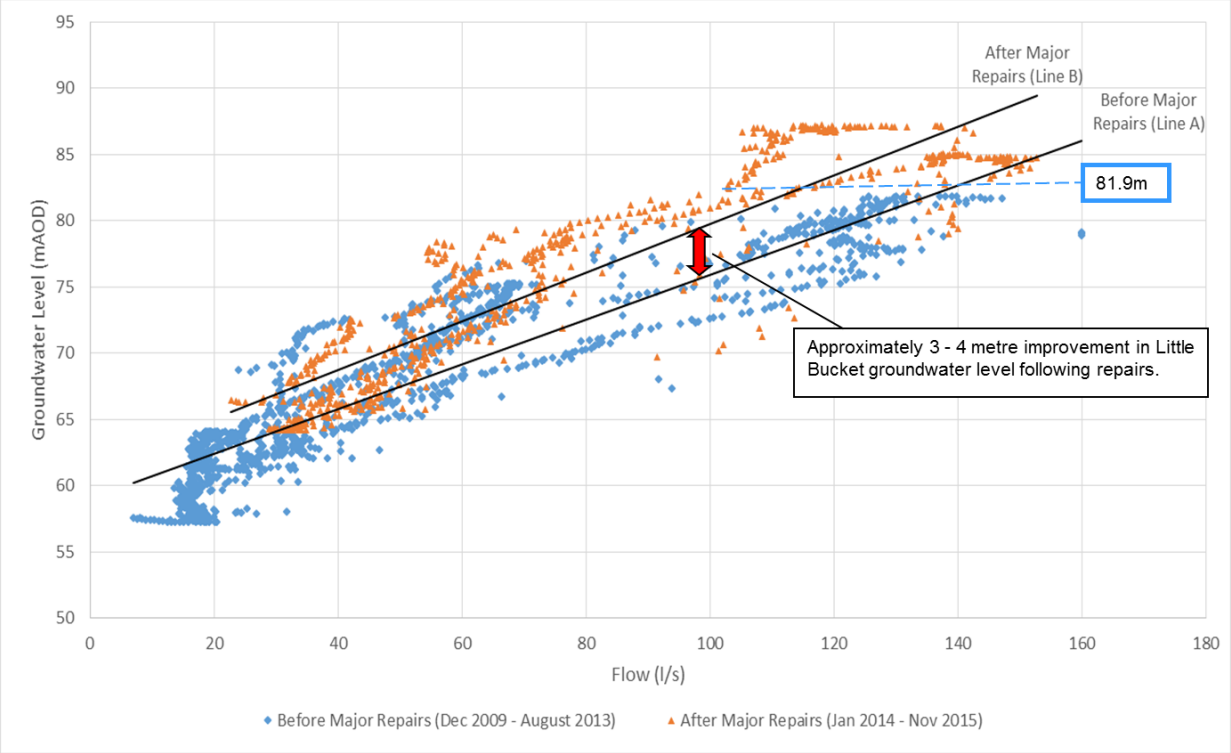

Figure 2 – Flow reduction for given groundwater levels at Nailbourne (Dec 2009 to Nov 2015)

An additional measure of the effectiveness of the repairs, beyond the impact to customers, was financial. The wet winter of 2012/13 served as a baseline for the cost and effort of responding to sewer flooding. During 2013, surveys were carried out in 17 catchments. Comprehensive repairs were completed in six of those catchments during the same year. The winter of 2013/14 was much wetter than the previous winter, but for five of the six locations where repairs had been completed, or substantially completed, the cost and effort of responding to sewer flooding was £1.95m less than it had been the previous winter. Survey and repair costs in 2013 at those locations were £3.3m.
For the remaining eleven locations, where repairs had either not commenced or were not completed, the flood response cost was similar, or greater, than it had been the previous year.

This analysis could be refined by considering the effect of factors such as: rising or falling groundwater levels, evaporation and transpiration rates, soil moisture deficit, etc. However, the scatter diagrams, each of which could be completed easily using readily available data, gave a suitable assessment of the benefits of the repairs given the time restraints of the programme. The EA borehole data is also used in Southern Water's winter weekly reports for predicting likely dates for groundwater flooding which is an essential part of planning for operational responses.

Further Analysis/ Innovations

There is potential for further analysis of groundwater flow and prediction of levels local to sewers, to help forecast likely rates of infiltration for given borehole groundwater levels. To date this level of analysis has only been refined in one catchment – at Nailbourne, in Kent, where £1.7m of surveys and repairs were carried out in 2013. The investment reduced infiltration significantly, however discharges to watercourses were still required in the very wet winter 2013/14. The potential is being investigated for a controlled discharge at a specific location to only be used during periods of high groundwater, when alternatives, such as use of tankers is not viable.

A hydraulic model of the catchment was built and verified using data from wet weather and dry weather flow monitoring. Using historic groundwater level data, rainfall data and river levels, a mesh of groundwater levels was modelled. Infiltration was incorporated into the model. To model the actual situation as closely as possible, infiltration into each sewer length was modelled, taking account of which sewer runs had been repaired. The verified model was used to predict the most appropriate location for a controlled discharge, taking into account locations of historic flooding and optimum discharge location. The optimum solution is when the minimum flow is removed from the sewers, whilst also minimising the number of properties where flooding is predicted.

The Future

The Southern Water groundwater infiltration reduction programme has been successful. However, it is recognised that eliminating infiltration in one part of a sewerage network can result in infiltration occurring in another part of the network. Therefore the long-term monitoring is required to identify increases in non-sewage flows.

Whilst the long-term analyses used have been very useful, they are arguably simplistic. This is because they do not use groundwater levels in the villages where flooding has occurred, also factors such as rising or falling borehole levels, rainfall, temperature and transpiration have not been taken into account, except for the modelling for Nailbourne. There is potential to refine the modelling, but this would need to be cost effective.

Using EA borehole data, prediction of likely dates for groundwater flooding has been automated in the weekly reports produced by Southern Water each winter.