Understanding sewer infiltration in a chalk catchment: East Shefford case study

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Introduction

Thames Water's (TWUL) East Shefford STW catchment serves Lambourn and a number of smaller villages in the Lambourn Valley, located on the highly permeable chalk of the Berkshire Downs. The sewerage system comprises a number of small gravity networks joined by pumped rising mains (Figure 1). The River Lambourn is an internationally important ephemeral chalk stream (designated Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC)).

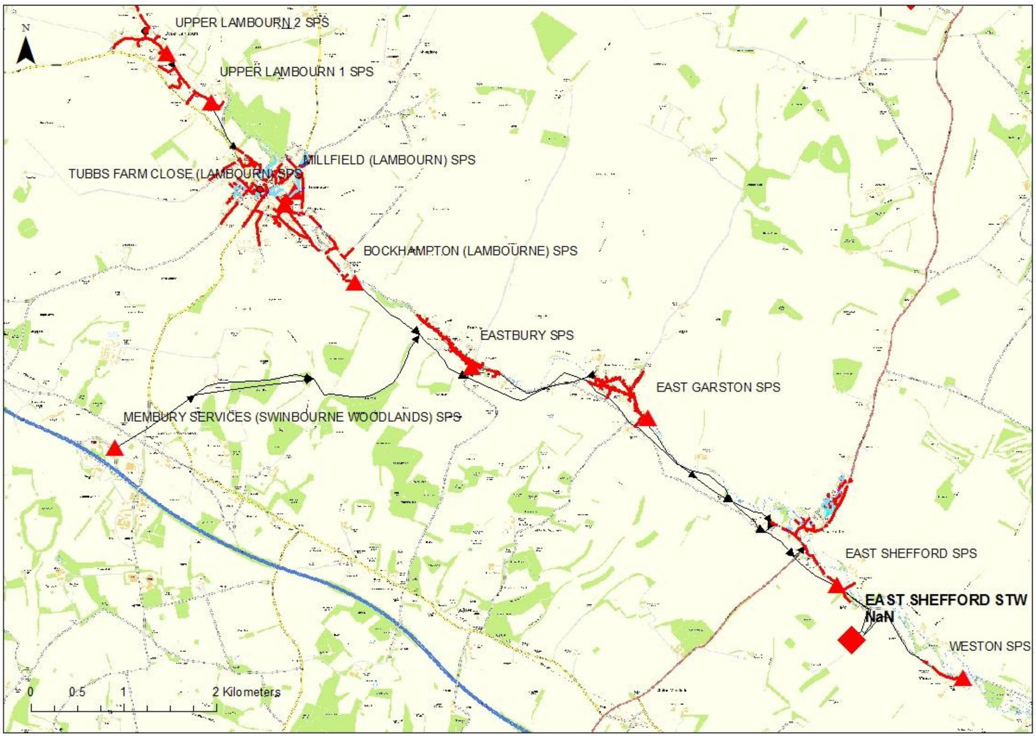

Figure 1: Sewer network in the Lambourn valley

The valley is susceptible to natural groundwater emergence, resulting in the upstream migration of the source of River Lambourn; high stream flow and associated river flooding; activation of springs; flooding of underground structures such as basements; and infiltration into sewers. Groundwater flooding tends to last for weeks or months, in comparison with 'flashier' pluvial or fluvial events. Infiltration can overwhelm sewer capacity potentially causing property flooding, with associated problems (material damages, customer complaints and poor publicity, public health issues). There has been extensive use of a storm overflow with the potential for environmental pollution of the ecologically sensitive chalk stream. Continuous tankering has been required over several months during wet winters to mitigate the effect of large infiltration volumes that compromised the storage and conveyance capacity of the system.

Project description and results

Using a sewer model to understand the problem

An existing unverified InfoWorks CS model was available for the foul/combined sewerage system. A three stage calibration / verification process was followed. Initially a dry weather calibration during low groundwater conditions quantified the foul and base infiltration contribution. The STW flow records proved to be the most reliable source of observed data. Secondly, the InfoWorks infiltration module was used to attempt to calibrate infiltration contribution from the chalk aquifer (ground store). This stage met with limited success; the infiltration module struggled to represent the dynamics of the chalk aquifer, even when "dummy" subcatchments were introduced to represent wider areas of the Lambourn valley. An interim work-around used observed borehole levels to drive the infiltration module, and further hydrological investigations were undertaken including a frequency analysis of borehole records. Further development could potentially include a linkage with a dynamic groundwater model.

Using hydrological data to understand the problem

The catchment benefits from a large number of monitored boreholes constructed as part of an aquifer recharge scheme. Long-term hydrometric data (rainfall, borehole and river flows) were analysed against the final effluent flow from the STW to investigate the main trends and influences on the volume of flow in the sewer system. It was clear that flashy response to rainfall is not the primary control on flows at the STW – they also display a longer term seasonal variation that is influenced by groundwater level. Several of the borehole records were found to correlate well with observed final effluent flows from the STW. Scatter plots of groundwater levels against average daily final effluent flow clearly show the level at which groundwater starts to influence the STW flow, and a strong relationship between the two (Figure 2).

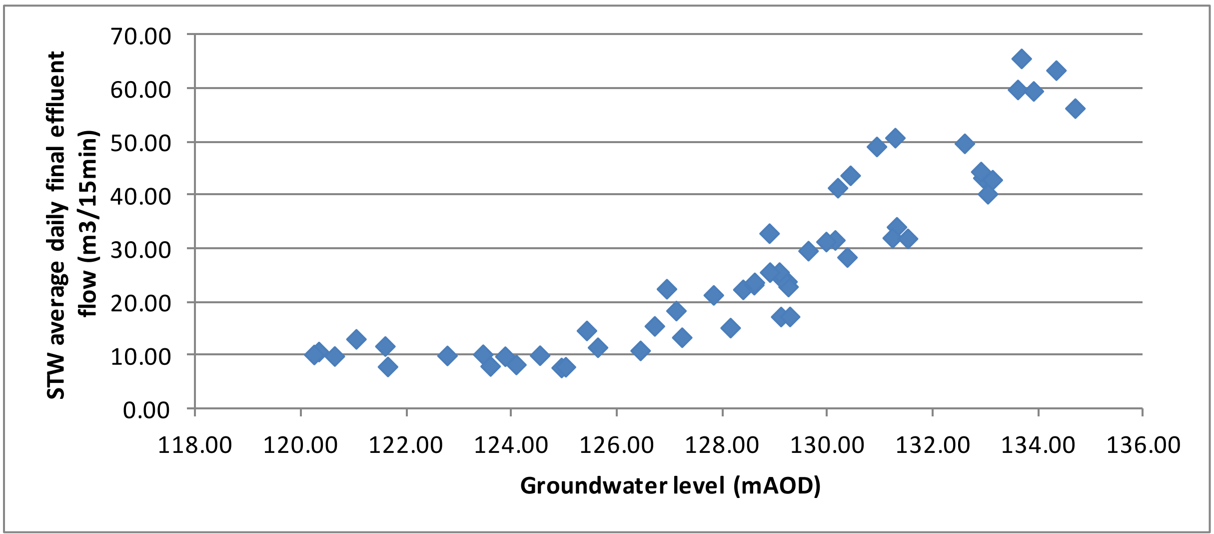

Figure 2: Scatter plot of recorded groundwater levels against STW average daily final effluent flow for Upper Lambourn OBH

The fluvial risk to wastewater assets on the surface was also analysed against the results of a detailed Environment Agency (EA) ISIS model of the River Lambourn. It was found that 84 manholes and one pumping station are at risk of inundation in a 1% probability fluvial event. There was also a good correlation between river flows and final effluent flows but this relationship is not independent of groundwater, which strongly influences river baseflow and STW flow together in the long term.

Quantifying frequency and duration of events

The borehole level data were analysed to establish the frequency and return period of events that have an impact on the system. For each borehole dataset, an annual maximum water level series was extracted (AMAX). Statistical analysis was undertaken to determine the quality of the dataset and the best fit distribution for the data, to develop a frequency curve. Estimated groundwater levels for different return period events could then be extracted from the frequency curve.

'Tankering thresholds' were defined based on observed groundwater levels at the point when tankers were deployed in 2012/13, and projected back across the borehole records (Figure 3). This allowed estimation of the likelihood of mitigating action having been required in past events. Based on the best available borehole record (49 year record at 14 Park Lane Welford borehole) it was estimated that, on average, mitigating action is likely to be required in the catchment by TWUL approximately once every 7 to 10 years.

The duration of mitigating action for a typical winter groundwater event will depend on the length of the event. It is known from TWUL records that tankering continued for 125 days in 2012/13. Using the 14 Park Lane Welford borehole record an approximate estimate of the the length of tankering in previous events was derived by calculating the number of days that the borehole level was above the 'tankering threshold'. The average tankering period was 17 weeks. This provides a general indicator for estimating the tankering activity into the future.

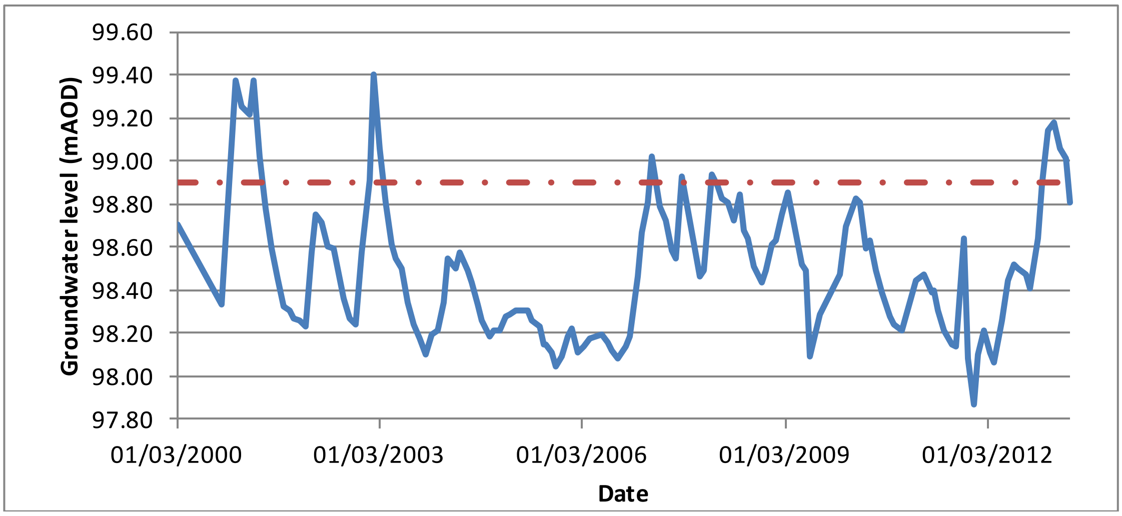

Figure 3: Estimated 'tankering threshold' against observed borehole levels at 14 Park Lane Welford 2000-2013

Understanding operational costs

Data on operational activity such as 'tanker days' or costs was difficult to tie directly to specific assets in Lambourn for the 2012/13 event due to the way tankers are deployed and the way such activity is recorded. Estimates were made by TWUL based on a 24 hour tankering record and general unit costs for callout / hours attended but they are not definitive and TWUL would rather costs were kept confidential.

A methodology for using the frequency analysis to estimate operational activity into the future was described. The average weekly activity of the tankering operation in 2012/13 was estimated at 67 tanker days per week. The average duration of past events above the tankering threshold in the borehole record is estimated at 17 weeks. This allowed calculation of average tanker days per event (1133 tanker days). As it has been estimated that similar events will occur on an average of every 7 years, we could then estimate the total activity over a longer period (for example 50 years) and express this in terms of average annual operational activity over that period (162 tanker days per year).

The calculation is of course approximate but it does give an idea of the order of magnitude of the long-term costs of reactive mitigation techniques in the catchment. A more severe event then 2012/13 (which had a 12 year return period) may well require more operational activity. Note that operational activity provides a conservative estimate of the costs of high infiltration events as it excludes social and environmental costs, power and asset depreciation costs due to extra pumping, and asset management investigation costs. The TWUL "Cost of Failure" framework estimates the cost of flood events at a property level, but is most appropriate to typical sewer flooding events that last for only a short period of time.

Solution development

Mitigating the effects of infiltration will only be achieved through a combination of actions at different scales. Collaboration and partnership with other organisations, e.g. the EA, the Lead Local Flood Authority (West Berkshire Council (WBC)) and local residents, will be essential to the success of any Infiltration Reduction Plan. A number of solutions were discussed in light of the investigation in the catchment.

Sewer relining

Extensive relining was undertaken in Lambourn in 2003, however with limited success. The experience here, and in other catchments, was a driver for the collaboratively funded research undertaken by WRc. It has led to a series of test procedures to assess the performance of lining, joint sealing and grouting techniques to reduce infiltration. TWUL are planning 4km of relining works in the catchment in 2014 and plan to assess its effectiveness by re-analysing STW flows against groundwater levels after the works are complete.

Prevention of fluvial inundation

The ordinary watercourse at Upper Lambourn was identified as likely to benefit from some improvement. It has reduced in capacity over time and is obstructed by poorly constructed culverts at the entrances to properties. Its capacity was exceeded in 2012/13 when the road and manholes flooded. Partnership with WBC may enable some small-scale and relatively low cost improvement works here to increase capacity, with mutual benefit. Areas that would potentially benefit from manhole sealing are Upper Lambourn and Eastbury, particularly Eastbury, where channel conveyance improvements would be more problematic due to the river's SAC status.

Improvements to tankering

If tankering was identified as a cost-effective long term solution for the catchment, it would be beneficial to formalise and improve the infrastructure to make tankering operations less disruptive to customers, and to avoid damage and disruption to roads. The study discusses the potential for improvements to existing locations or alternative locations in the main settlements of the catchment.

Discharge to the watercourse

Utilising the linkage between sewer flows and hydrometric data gives a stronger evidence base for improving emergency discharges. There is strong evidence that the storm overflow at East Garston is only required when there are high river flows/levels in the River Lambourn and high volumes of clean groundwater infiltration to the sewers i.e. the discharge would tend to be very diluted. The quality of the discharge could be improved by:

- Monitoring/sampling of the river downstream of the existing discharge at East Garston during high groundwater flows, to provide quantitative evidence of its effect on river water quality.
- Definition of acceptable dilution levels and the link with river flows at gauges. It would then be possible to estimate the frequency with which the consent would be likely to operate.
- Controls could be put in place to ensure that the correct conditions were in place before a discharge to the watercourse was allowed, for example, a penstock which was only opened when dilution levels and river flows reached certain acceptable levels,
- Suitable polishing or use of more innovative methods such as mobile biological treatment tanks before the effluent was discharged.

Improvement to the flood alert system

A specific flood alert system based on groundwater level thresholds would allow time to plan the operational response, with the outcome that staff and tanker time could be organised more efficiently and coherently. Sharing of data with WBC and EA could reduce overall costs and demonstrate a pro-active approach to managing infiltration.

Property level protection

A property level protection (PLP) scheme may be a viable cost-effective alternative to other solutions. In terms of funding for PLP, there may be partnership opportunities with the EA and WBC, as other sources of flooding are also evident here, which may combine with sewage and therefore require a combination of PLP techniques to fully protect the property.

Conclusion

Action on infiltration by WaSCs has in the past been very reactive, with limited planning or investment for recurrence of the problem. However the last few years have a significant shift in the attitudes of the regulators and other stakeholders towards the issue (e.g. Infiltration Reduction Plans), as well as a move towards collaboration and partnership working to improve flood risk. Analysis of the available hydrometric data for this Chalk catchment provides an invaluable evidence base to support decisions on actions to reduce infiltration, improve strategic planning for flood events, assess the effectiveness of mitigation, and improve the impact of emergency discharges in the future. Such evidence is becoming more important as the emphasis changes from a reactive response to more long-term planning with the advent of Infiltration Reduction Plans.