Just in time operational management

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ABSTRACT

Despite much effort and many different approaches flooding due to 'other causes' continues to happen. Pollution as a result of sewage escape is also a serious problem. Knowing when problems are developing provides a significant opportunity to intervene before the problem becomes an incident and impacts a customer or the environment.

Monitoring already occurs in the main sewer system, commonly at combined sewer overflows (CSOs) using devices such as 'Hawkeyes'. Analysis of such data undertaken by MWH and IETG has demonstrated that normal and abnormal trends can be recognised to identify when a problem may be present. This can lead to an intervention before the problem turns to an incident.

A 'Just In Time Operational Management' concept being developed by MWH and IETG looks to take this approach further upstream of CSOs. It combines historical analysis and risk assessment to identify the key locations, whilst using a network of low cost monitors to detect abnormal behaviour within the network and alert an operational team to take action before it creates an 'other causes' incident

OUR HISTORICAL CHALLENGE

Sadly, we are all too familiar with the distress caused with property flooding during heavy rain. Water Companies have invested consistently in their sewer systems to reduce the number of properties that are at risk from this type of sewer flooding. They have focussed their efforts on tackling hydraulic capacity with the result that thousands of householders and business no longer face the misery of internal flooding of sewage.

What is equally miserable is when homes flood when the rainfall is low and it some times when it isn't even raining (Figure 1). Water Companies are still measured on their performance of flooding from when sewers collapse, block up (with sediment, fats, grease and roots) or mechanical failure. In technical terms these are known as "other causes" flood incidents because they are occur for reasons other than inadequate sewer capacity. They are proving to be one of the most difficult issues for water companies to manage and require substantial operational investment.

Figure 1 - Trying to unblock a local drain as a result of a blocakge

There is the potential for the number of 'other causes' incidents to increase with the adoption of private sewers. This may have a significant impact in the number of reported incidents to water companies and subsequently Ofwat impacting also on Service Incentive Mechanism scores.

There are two key reasons why 'other causes' creates flooding. Firstly there is very little advanced warning as sewer deterioration and blockages can build up over a period of time unseen. Because of the very large number of sewers they have to manage, water companies cannot inspect them all on a regular basis, thus there is typically no advanced warning of such problems. A water company may only get to know that there's a problem after the flooding has occurred and they are contacted by one of their customers. By this time the damage has usually been done.

Secondly, although there are some common contributing factors, there is a good deal of randomness in these events. We may know that the sewers in Smith Street (for example) are more prone to blockage, but this might result in No 69 flooding one month and No 96 the next. This makes it very difficult for flooding incidents to be predicted, and therefore managed.

For these reasons water companies have often had to rely on their customers to let them know when there is a problem, and then to react as best they can to deal with it. This is not ideal as it is distressing for the customer and costly for the water company.

USING MONITORING TO RECOGNISE AND RECTIFY PROBLEMS

The use of monitors and sensors within the sewer network has been in place for many years. They have been used to not only monitor performance but also control systems using *real time control* e.g: such as in Vienna (Teufel, 2007). Understandably, significant focus has been around the performance of CSOs in both dry and wet weather. Understanding the risk of and preventing the likelihood of pollution from CSOs has been a key focus for water companies. Many have been installing depth monitors to constantly monitor the CSO performance and detect abnormal behaviour (Figure 2). These monitors have successfully helped to identify when the system is not correctly working enabling operational teams to visit the site and take preventative actions, such as removing blockages or silt (Grandison, 2005). Such approaches have helped to reduce pollution incidents by being able to respond quickly to a potential problem.

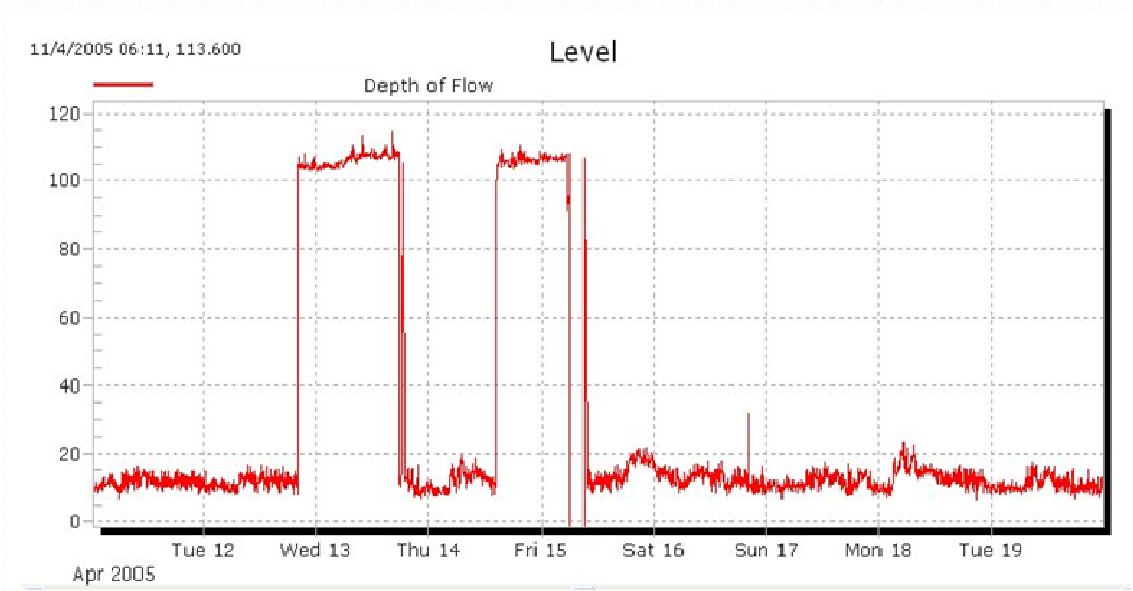

Figure 2 Example of a depth monitor data that detects an increase in levels during dry weather as a result of a downstream blockage

More recently, this approach has been taken further to log the performance of highway gulleys and identify when maintenance is required. Such an approach has been used (A-one and IETG, 2008) to help target the maintenance of gulleys, meaning that gulleys are cleaned when required, rather than on regular cleaning frequency, which may or may not require the cleaning at that time. Using a low cost, 'contact' monitoring system enables the simple identification of gulley performance and needs.

This has led to substantial savings and a more targeted cleaning programme. An important aspect of the system is that a number of monitors send signals to single hub that then broadcasts to a control centre. This reduces the power demand of the individual monitors. Clever analysis understands true and false readings from the monitors.

JUST IN TIME OPERATIONAL MANAGEMENT CONCEPT

The ability to monitor and predict where flooding occurs within the sewer network, using low cost monitor technology is critical. In 2009, a Knowledge Transfer Network event (Caffor, 2009) highlighted this need as part of an Integrated Urban Water Management assessment looking to the future. Also in a recent research needs review for the Environment Agency, *Research Framework – The Implementation of Integrated Urban Drainage* (Balmforth et al 2009) highlighted the need of low cost monitoring and *just in time operational management (JITOM)*.

JITOM aims to identify a problem before it creates an incident and impacts on the customer. To do this, we need to make the best use of a number of techniques. This can be broken down into monitoring, risk assessment, clever data analysis and operational action.

Monitoring improvements enables area wide and effective data collection

Monitoring until recently has been quite expensive. This can limit the number of monitors that can be installed and left in a network for a long period of time. However, technological advances now mean we can build and install low cost monitors that relay signals to a 'hub', a single local point. These detect the levels in the sewer at set points to identify early signs of a collapse or blockage before a significant event occurs that could lead to major flooding. These sensors are intrinsically safe for use in a sewer environment and importantly have a low energy demand resulting in a long battery life. Data is transmitted via mobile phone networks, although further examples in communications are now becoming available.

These sensors detect the change in depth so it becomes clear when sewers start to behave in an abnormal way (for example when they become full, even though it is not raining). What is more important though is the recording of the depth 'patterns; so that a small amount of rainfall creates clear 'abnormal' behaviour between the different sensors. We can install a network of sensors in areas we know are likely to be more prone to blockage or collapse. Sensor recordings are analysed using artificial intelligence. This effectively means that the sensors 'learn' from each other how the sewerage system responds in different circumstances and are therefore able to detect when something goes wrong.

Understanding the common factors to identify areas and tackle the risk of 'other causes'

For JITOM to work we need to target the parts of the sewer system that are likely to be most problematic. Despite the apparent randomness of blockages, historic evidence suggests that there are some common factors (Erskine, 2009), and typically we are able to identify 'hotspot' areas through careful analysis. For example, small diameter butt jointed sewers laid towards the end of the 19th century are particularly prone to blockage, as debris gets caught on the edges of the joints.

We can therefore assess the likelihood of blockages and collapse by correlating key asset attributes (statistically predicting high likelihood areas, Figure 3) against historic incident records. This provides the confidence we are targeting the right areas. It's also important to understand the sewers that are likely to cause the biggest flood impact, so looking at consequence. A sewer may only impact a single property if it blocks due to the property type, position and relative level. Alternatively it may flood a number of properties creating a more widespread problem. We use consequence mapping to identify where the greatest flood impact can be. Combining the likelihood of problems occurring with the resulting impact gives us a measure of risk.

Figure 3 - Example of a network showing low, medium and high probability sewers

Placing and learning from our monitors

How we establish our network of monitors affects the value of using this new technology and JITOM approach. Too many monitors and the costs are too great, too few and there is a risk of missing important information. Using the latest sewer network modelling software helps to understand where best to place monitors so they can collect the most useful data and understand how the system should perform. As the monitors' record on a continuous basis a large quantity of data is collected, so using this data effectively is important.

Artificial intelligence helps us to automate the analysis of the data we collect so we can quickly identify problems as they occur. This is built on the concept that sewer systems when in a clean state normally behave in a consistent way. Wastewater levels follow dry weather diurnal trends, low at night and peak in the early morning. When it rains, levels rise to a peak during periods of rain and then progressively reduce as rainfall becomes less or stops. A network of monitors will record these patterns. The software understands what the normal 'clean' behaviour is and so it is possible to identify abnormal performance. It is this that creates the alarm that leads to a response. For example, when it rains we would expect all sensors to show similar responses in level, albeit staggered in time as flow progresses down the system. If a particular sensor records a high water level when all other sensors are lower, outside of its expected behaviour, this is likely to be due to a blockage or defect that can then be investigated.

Taking operational action can address the problem

The fundamental part of JITOM is rapid response. If we identify a potential problem early then we have to respond to it quickly, before it develops into something serious. Therefore we will need to rethink how we better manage the deployment of crews with the appropriate tools and techniques to prevent the defect from turning into an incident. The aim is that an operational team turning up on a customer's door step before they even know they have a problem.

CONCLUSIONS

For water company customers this approach could mean a real improvement and finally see the numbers of other flooding causes decrease substantially. Sensor data will also be available to better understand how networks perform, how they deteriorate and when is best to intervene to maintain them on a regular basis. This will help water companies to perform more efficiently, but more importantly it will improve the level of protection against flooding that is given to their customers.

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