USING MURKY DATA TO CLEAN UP WASTEWATER FLOODING

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ABSTRACT (500 WORDS MAXIMUM)

As the saying goes, "You can have data without information, but you cannot have information without data". Many organisations are data rich; however, this data is rarely used to its full potential. This paper will describe how by pairing data with analytics, operational decisions can become more automated. This enables organisations to become better informed and make decisions backed by robust analytical data rather than solely instinct.

The paper will describe examples used in UK Water Authorities to clear up some of the "murky water" from their data - scenarios where various data sources are used in isolation for different problems. This creates a missed opportunity to gain a greater understanding of the broader issues. The approaches linked various data sources and presented them in a manner that allowed Clients to view and understand their data in a more holistic way. Enabling them to better targeted solutions to clear up the real world "murky water" problem of wastewater flooding.

In this paper we will describe how we compiled and analysed 32 years' worth of incident data involving eight million data points across 20 different datasets for 22,000 properties. The project successfully connected and automated the analysis of the data giving the team better ways to target tried and tested solutions, along with opportunities to trial new innovative solutions.

Solutions that will be described include:

- The use of predictive analytics, to target properties that can benefit from prioritising proactive responses;
- Automated logical Feature Manipulation Engine (FME) analysis of historic events to recommend and quantify solutions at a regional level;
- Collation of multiple data sources, and displaying historical data for properties with the use of ruby scripting to optimise the review of properties at an individual property level;
- Analysis of historic events combined with a comparison of property characteristic to identify unique problems that were area specific, such as "Buchan Traps" and the implementation of specific programmes to reduce flooding in these properties.
- Gap analysis to target CCTV and jetting in areas at risk of blockages, backed by data rather than solely reactive instincts;
- Targeted trial of network Fat, Oil and Grease dosing within the network to prevent repeated blockages occurring.
- Network and property analysis for installation of low-cost property level alarms, to gain an early warning of network surcharge, where previously the first signs would be from internal flooding.

This paper will show how even when large volumes of data are available, it is not always used to its full potential and is often lost in poor management or unusable formatting. We will present how different data analytic techniques can be used to optimally target a reduction in wastewater flooding.

The processes utilised by this project can be applied to many other areas with operationally data rich sources to enable improved performance.

KEYWORDS

Analytics, Data Management, Operations, Wastewater Flooding

PRESENTER PROFILE

Rico Parkinson is a Senior 3 Waters Engineer with Stantec, and has recently returned from the United Kingdom, where he had focused on helping local water authorities to reduce wastewater flooding. He has over 12 years' experience and enjoys the knowledge of knowing the work he carries out provides people one of life's necessities.

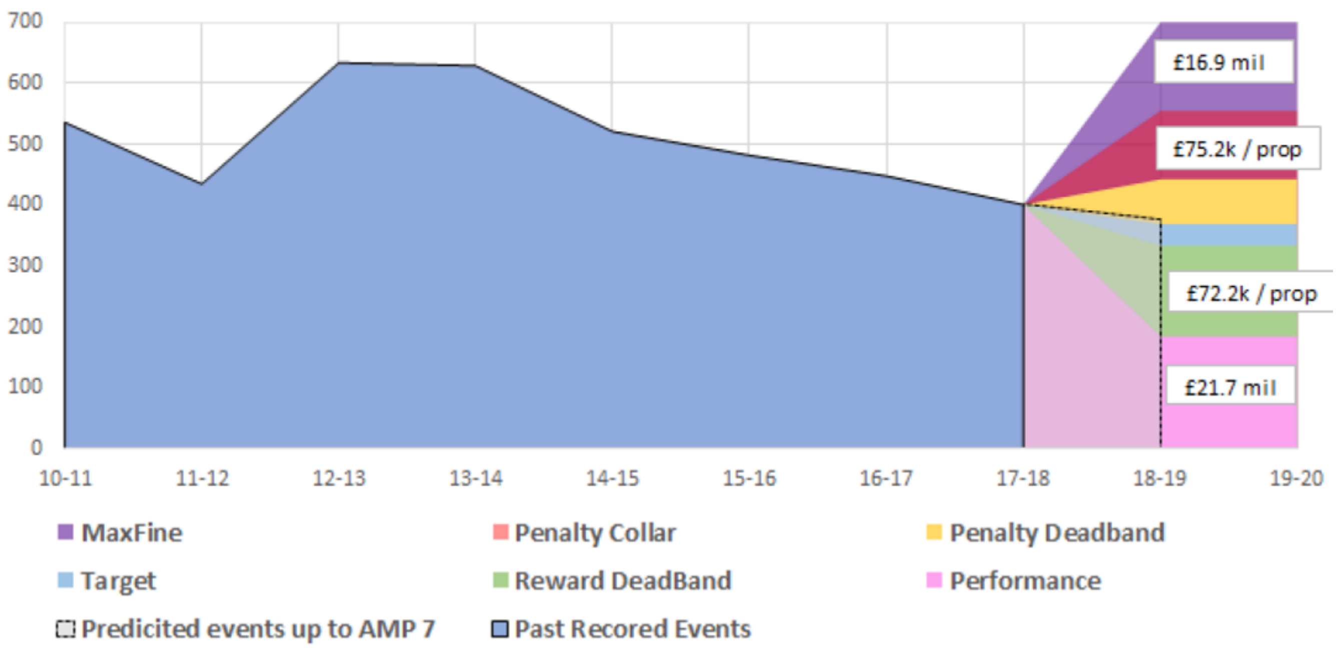
1 INTRODUCTION

In the United Kingdom, internal flooding of properties with sewage can be a more common occurrence than in New Zealand. Many older parts of the country still have combined sewer and stormwater networks, meaning that rainwater can mix with sewage and flood properties either by overwhelming the network during storm surges, or when overland flooding overwhelms a property and causes internal flooding. Other operational issues, such as blockages can also cause internal flooding.

Privately owned UK water authorities manage the supply of water, wastewater and stormwater to and from properties and are tasked with continually reducing the number of internal flooding events that occur within their region. Water authorities set their own targets, penalties and rewards in agreement with the national regulators. The targets in the region of where this work was carried out worked on a total five-year bases (between years 14-15 to 19-20). The resultant maximum penalty was up to approximately NZD$34 million or a potential reward of more than NZD$43 million.

Figure 1 outlines the yearly total of internal flooding incidents that had occurred in the region (Blue), and the number of flooding incidents would need to occur to achieve the varying rewards or penalties in the last two years of the cycle. An example would be if the Water Authority had 550 internal flooding incidents in both the 18-19 and 19-20 year, they would have been fined ~NZD$150,000 for every property over the penalty dead band, and would reach the penalty collar (agreed maximum penalty), totalling a penalty ~NZD34 Million. While if they only had 400 flooding incidents a year in the final two years, they would not reach the point where they would be penalised, they would be with the penalty dead band (above target but below the point of having penalties).

Figure 1: Internal Flooding History and Target



While the water authority, was able to track, inspect and monitor the number of flooding incidents occurring they also had several fractioned mechanisms for trying to reduce repeat flooding. These were as follows:

- Flood Mitigation – this was a process where the operations team reviewed a property after the property floods and looked to prevent a repeat flooding incident by the installation of small value solutions. For properties with uncertainty of the root causes of the flooding, the engineering team was brought in to assess the property to propose or verify a solution. These solutions were funded from operational budgets.

- DG5 solutions - this is where if a hydraulic overload was recorded as the potential cause, the Engineering team would review the hydraulic model and storm event for the area confirm the cause. If confirmed as hydraulic overload, the engineering team would then prepare a solution. These solutions were typically funded through capital budgets and were typically storage solutions.

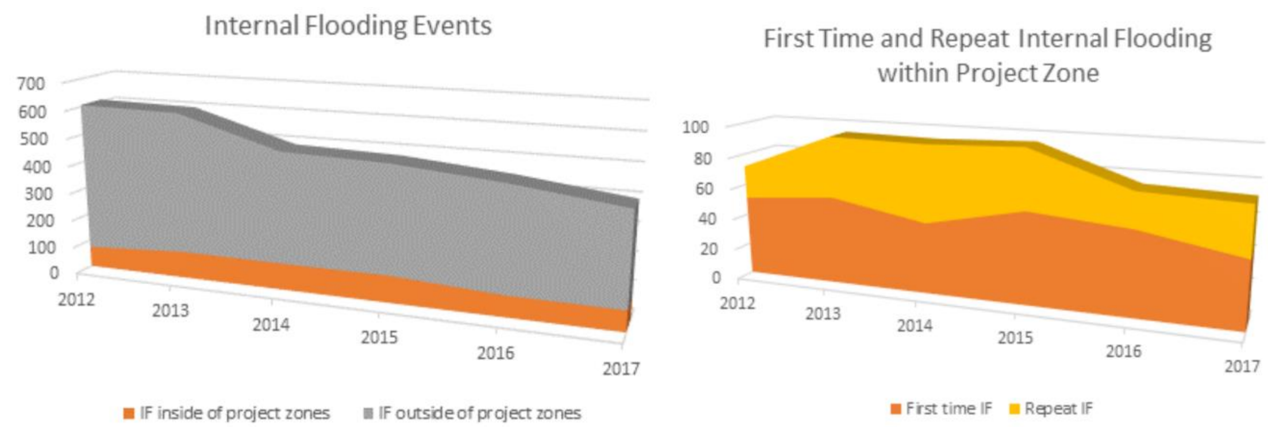
- Flooding Investigations - when internal flooding occurred, a flooding investigation team would go to site, confirm that internal flooding occurred, and that sewage was present. If no sewage was found to be present, the team would investigate into the root cause of the flooding, to determine if the cause was the water authority’s responsibility or if it was caused by another party such as if overland flows originated from other areas such as highways.

These teams all collected data on events and investigations, and recorded them and the solutions in different databases, through simple GIS recording systems, master GIS systems, spreadsheets with many teams able to access, spreadsheets with restricted access, customer services databases (CSMS) to record conversations with customers and sewer incident reporting forms (SIRF) database.

Through proactive analysis into the history and trends of internal flooding by the water authority’s flooding investigation team, they identified 10 key zones which accounted for an almost 20% of all internal flooding, these were considered hotspots. This project was then created to focus on reducing internal flooding in these areas in addition to the normal processes that were described above. This was the “Flood Reduction Project”, in which we were tasked to look at alternative methods, innovations, more holistic approaches to reduce internal flooding for these zones.

To better understand the reason for this project, the following two graphs highlight the issues presented in these areas. The overall internal floodingincidents for the water authority were trending down, while the number within the 10 zones was remaining constant, and even the number of repeat flooding was remaining reasonably steady, indicating that the current process of trying to prevent repeat flooding after the events was having little effect in these 10 areas.

Figure 2: Internal Flooding within project zone and break down



This paper will outline the different solutions that were used to help reduce internal flooding, from purely data focused solutions to improved operational processes backed by robust data analysis.

2 DISCUSSION

Before any decision could be made as to what could be carried out, a greater understanding of the areas had to be gained, which allowed us to quantify the potential cost and benefits that could be achieved overall for the zones.

To achieve this understanding, the first step was to confirm the various databases, their sources, their reliability, what they were used for and how they could be related to other data sources and how we might be able to interrogate them.

While many of the databases were collected accurately by the various teams, many fields were blank or had been interpolated for past data points when the information wasn't collected at the time. This varying accuracy of the data combined with the Central GIS holding only slimmed down information from several databases, meant care was needed when analysing and using the information.

As part of our interrogation, we had to be in constant communication with the operational teams that collected the data, and the data teams that managed and centralised the data. This duel communication identified a tension between the operational teams wanting to focus on recent and memorable flooding events with a customer focus, and the data teams focusing on properties with a high number of previous events with historic flooding issues, we needed to manage this tension throughout the entire project.

With various parts of the water authority's business focusing on different aspects and accuracies of the data, we identified several risks in the data sources but also identified opportunities to connect, automate decision processes and optimise the use of different knowledge and information that was being collected.

A summary of the main datasets used in this project in various ways is outline below in Table 1:

Table 1: Data Source Summary

Data Source Abbreviation	Data Source Title	Description
SIRF	Sewer Incident Reporting Form	Completed when a sewer incident occurs, generated by operational teams and updated if further information is confirmed on site, slimmed down data available on central GIS database.
CSMS	Customer Services Management System	Completed when a customer calls, generated by the customer care team, it was a record of all correspondence with customer, slimmed down data available on central GIS database.
MIMS	Maintenance records	Database to record all operational activities, both reactional and planned works. Only available for work carried out after 2012. Includes, repairs and cleaning.
CCTV	Sewer CCTV programme.	Recorded when and where CCTV has been carried out, with conditions and faults sometimes mapped.

Asset Data	Pipe and manhole data	Recorded asset information such and depth and size of pipe and manhole. Limited accuracy in some areas.
Flood Mit	Progress records of flood mit properties	Recorded the reviews, installed solutions and progress of various flood mitigation properties. For several solutions, such as "flood doors", this was the only record of where they were installed.
Basements	Recorded list of properties with basements	GIS layer to identify if a property has a basement, based on word searches within other databases. Confirmed basements but does not capture all basements.
Address Points	Property identification	GIS layer that identifies properties in a unique manner. Various databases use differing attributes to identify the exact locations, this data was used to centralise point of reference for property identification.
ADF Location	Anti-Flood Device Locations	GIS layer identifying the location of non-pumped Anti-Flood Device (AFD).
Maintained Feature Nodes	Maintained Feature Nodes	Maintenance schedule and location for assets e.g. jetting and inspection programme
DG5 Points	Hydraulic overload properties	Properties identified as being previously or currently at risk of flooding due to hydraulic overload.
Pump stations and catchments	Pump Station locations and catchments	Pump station and Pumped AFD locations, and catchment boundaries.

2.1 DATA ANALYTICS

It became apparent at the start of this project that the water authority held a large amount of data describing the detail of historic flooding, however this data was split across many data sources that didn't necessarily link together. The project team decided the best way for the water authority to get the most out of the data available to them was to develop a process that would link these datasets together and utilise it in various ways. This section will focus on some of the more analytical tools and processes used in the project.

2.1.1 CATCHMENT ROOT CAUSE ANALYSIS

With the initial brief of the project being simplified to, "target to reduce the internal flooding incidents in these 10 areas to zero by whatever way possible within this amount of money". First, we had to understand the areas and their hotspots (areas of clustered internal flooding), their unique trends and reasons for flooding occurring to help identify appropriate solutions that could be used.

Examples of what these initial assessments looked like were:

- Old towns centres, with large amounts of unmapped sewers that cross between properties, making blockages more likely to cause internal flooding due to the inability to regularly inspect or clean pipes due to limited access point. An example of one such town is shown in below in Figure 3, where the high number of private caused internal flooding indicating a high number of unmapped sewers.

- Seaside towns with high seasonal populations and high level of Food Service Establishment (FSE) discharging Fat, Oils and Grease (FOG) such as fish and chips shops, creating a higher than average number of FOG caused internal flooding.

- Areas that are subjected to tidal locking from rivers, causing potential discharge restrictions of combined sewer overflows (CSO), identified by large portions of hydraulic overload flooding occurring on storm events not expected to cause hydraulic overload.

- Areas subjected to large amounts of tidally influenced infiltration causing network capacity issues, identified through a high number of regular hydraulic overload event.

Figure 3: Old Town Centre Root Cause Review Example

After these area summaries were carried out, we were able to identify that in some case high proportions of properties were repeating for some areas and further improvements to the operational responses could help to reduce flooding in some instances.

2.1.2 PREDICTIVE ANALYTICS

Certain flooding was identified as being potentially avoidable, or at least the impact able to be reduced, by the early arrival of operational teams in response to customer callouts. A project objective was to develop a prioritisation system following a customer call, that improved on the current response systems. The current system applied a P1/P2/P3 response based on the customer conversation with the call operator.

- P1 Customer reports Internal Flood or Pollution - 2 hours target

- P2 Customer reports external flood - 4 hours target

- P3 No flood reported by customer - 6 hours target

In some cases, the situation may escalate from no flooding to an Internal flood after the call is made. It is also possible for the customer to exaggerate or simply fail to correctly communicate the situation. The goal of this work was to try and improve the Water Authority's diagnosis whilst still fully respecting the information provided. The intention of the work was not cause the Operational response teams more effort but to focus their efforts better.

Data about every property in the water authority that has experienced a sewer incident was examined, including an assessment of its closest sewers and the elevations of the sewers. Statistical analysis of the data led to the conclusion that the allocation of P1s according to the customer reporting pollution or internal flooding could not be improved, as internal flooding had already occurred. However, the allocation of P2s could be improved to potentially prevent internal flooding.

A simple formula was created to express the risk of a call from a particular property escalating to an internal flood (L). The formula considers the customer's information, the incident history of the property, the characteristics of the nearest sewer and the presence of basements. The formula was found to be:

Equation 1: Properties risk of escalating to an internal flooding

Probability = L/(L+1) where

L = Exp[-4.9 + 0.5*IFatProperty + 0.6*IFatSewer - 0.1*IncidentatProp + 0.06*MHRel_Elevation + if(Commercial,0.95) +if(FOUL, -0.58) + Proportion_Basement + if(BasementFlag, 2) + if(P3,-0.77)]

The model was created to be entirely independent of what the customer is saying. It demonstrated that over half the internal floods could be prioritised in 10% of callouts without even knowing what the customer is saying. For example, if a property had experienced internal flooding before, it was likely still at risk, even if the customer has only identified another sewer problem.

It was found that for the same level of effort, it was estimated that 24 fewer internal flooding incidents a year could potentially be prevented if a selection of P3 (6 hrs) category responses could be re-prioritised to appear in the P2 (4 hr) category. 3 to 4 of these 24 would completely avoid flooding by earlier attendance. The other 20 will benefit from earlier attendance through less impact, possible avoidance if response time was fast enough and would improve customer perception if flooding could not be avoided.

The formula gives every property a probability or a score between 0-1. It was found that a score of 0.3 or above, could have its response changed from P3 (6 hrs) to a P2 (4 hrs), and may achieve a possible internal flooding avoidance. We suggested to the Water Authority that this be carried out by mapping all properties with a score of 0.3 or higher into the customer call centre or dispatch response systems, so that if they rang through the property would be shown to have a high risk, and if the caller description only gave a P3 (6 hrs) response it could be over ruled and a P2 (4 hr) response issued.

2.1.3 AUTOMATED LOGICAL FME ANALYSIS

The traditional process during the flood mitigation work was to review the various data sources individually for each property that was investigated, it was then carried out in a repetitive manner as multiple properties were passed to the Engineering team for review, normally only working on a single property at a time and using the GIS system as a key point of reference for reviewing most data sources. After having to carry out these reviews on thousands of properties with the project zones for this project, meant a new way of decision making was required. Working through the individual steps that were carried out in a traditional review, we were able to replicate this process in an automated way to predict a possible solution.

This decision automation was carried out using a series of FME (feature manipulation engine) workspaces to analyse the data. There were 10 workspaces in total, varying in complexity, completing simple tasks like cutting the data to the required length of time as considered appropriate history for a property, to completing more complicated tasks like making mitigation suggestion based on history and information for a property.

An example of this decision making is outlined below, as for a solution of CCTV and cleaning:

- Search Internals flooding SIRF information of all "Blockage" faults for a property with a data cause code or search comments, for "FOG", "silt" or "roots", if true, YES
- Confirm if the sewer status is "Public" indicating access is likely to be available, if true, YES
- Confirm Pipe ID of past blockage location is on jetting programme, if not true, YES,
- Indicate CCTV solution could be a viable solution that answer YES to all above statements.

The FME is developed by a company called Safe Software. FME can be referred as a Spatial ETL (Extract, Transform and Load) application and can be described as a data warehousing tool that extracts data from a source, transforms it to fit the user's needs, and then loads it into a destination or data warehouse. FME will allow you to extract data from over four hundred and fifty formats, which made it very useful in this project, where we had multiple data sources in varying formats.

There were many benefits to using FME over the traditional GIS approach for this project which would have been an alternative option, some of the key benefits were:

- The workspace represents a flow of the data where every decision can be scrutinised, this was great for quality assurance.
- Once the workspace is built it can run any number of times.
- The workspaces can be edited making it fully transferable and repeatable in the future.
- The ability to search through free hand fields for key words and phrases allowing a deeper understanding of the source data as many of the count fields were left blank when filled in on site.
- Automated process resulting in hundreds of hours and large budget savings.

2.1.4 DATA COLLATION AND DISPLAY

To help in the decision-making process and to allow us to check the automated solutions with a sensibility check, property cards was created. An example can be seen in Figure 4, these were an innovative visualisation technique that was developed as part of this project. They were not requested as a part of the original scope of the project, however, after creating such a successful data analytics process to automate the procedure of converting a mass of raw data into one neat database, the team wanted to capitalise on this and present the data in a format that would benefit the water authority in more ways than a traditional spreadsheet.

The property card is a collation of all the relevant information that relates to a property pulled from all the datasets mentioned previously in the analysis process. In this project a property card was created for any property within the flood pilot zones deemed as high risk, i.e. all that had experienced internal or external flooding in the past. The cards were developed using the HTML coding language, the same language that is used to create the layout and design of webpages. A benefit of using HTML is that it is highly customisable and can be designed to look however it is desired. It can also be used as a direct output in the FME software that was mentioned earlier, meaning the whole process of going from raw data to property card was a fully automated process. Moreover, as HTML is basically a text document that a web browser then interprets into a visual page, the file size is tiny, making them easy to store or share. Another real benefit of creating a HTML document is the fact that it can be opened on any device that has a web browser installed, this made them ideal for use across any area of the Water Authorities business.

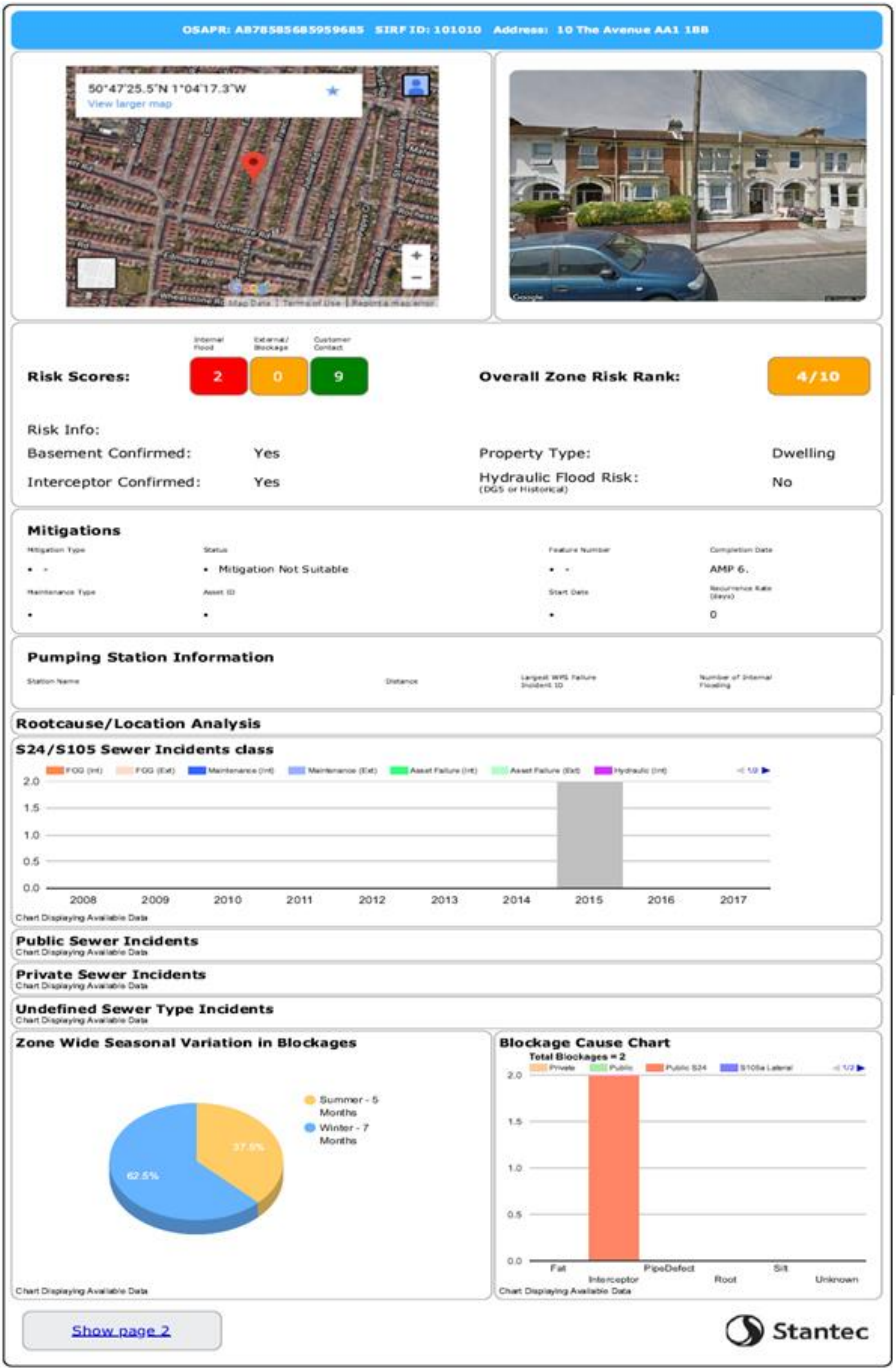
The design of the card was split across two pages. The first page, shown in Figure 4 focused on the background information and historic incidents at the property. The top of page shows the address and other property identifiers commonly used by the water authority. Which is followed by two google maps, one an interactive location map showing the coordinates of the property point and the other a street view image illustrating the exterior of the property.

Below the maps is the risk score that had been calculated for this property, anything in red is an internal flood, orange an external flood or blockage, green is a count of customer contacts and to the right is a zone rank based on the risk score. The next section down explains any previous mitigations that have taken place at this property or any mitigations that are planned in the future. Below this is the pumping station info that shows information relating to the pumping station that serves this particular property.

The next section is a set of up to four charts, which only display if there is relevant data, S24/ S105, Public Sewer, Private Sewer and Undefined Sewer, these charts show a timeline of historic incidents based on the sewer type they took place on. The charts in this section also differentiate the different types of incidents that occurred. The bottom section of the card contains two charts, one shows the seasonal variation in blockages for the zone, helping to identify if there are seasonal trends in the area, and the other shows the cause of the blockages that have occurred at this property.

Page two of the card, was designed to help track the decisions that have been made as part of the project. It includes a table that highlights what decision has been made on each of the possible mitigations and at which stage of the implementation process the project measure has reached. When the data analytics process is run for the first time only the automated mitigation results were populated, then as the property moves through the different stages of review: desktop review, operational review, taken forward and finally implemented, it records the data and person involved in the decisions.

Figure 4: Property Card Example



These property cards have now been taken a step further. A survey was conducted throughout the water company asking the likelihood the cards would be used in the future, with many departments coming back with positive feedback. The main departments which saw a future for the cards were the customer call centre and the response teams. Both teams saw that the cards would give them a great overview of the property on first contact with the customer, allowing them to have a more positive and free flowing interaction without the need to sift through multiple data sets.

Leading from this, the cards were edited slightly to include some additional customer specific information as well as a script of what can and can't be disclosed to the customer. The FME process was then run for all 2.4 million properties in the water company's operational area, with a card being generated for each. The idea being these cards are updated regularly and linked via a simple intranet page to allow for access from anywhere with a web connection.

2.2 JETTING GAP ANALYSIS

Following the catchment cause analysis, further data analysis was carried out to determine if there were potential gaps in the current CCTV and jetting program. This was carried out by identifying the properties that had experienced flooding due to blockages, and the particular pipes identified in the resultant clearing or investigation work. This was then cross referenced with the current CCTV and jetting schedules. This allowed us to identify a list of pipes that could be cleaned as a short-term preventative measure to reduce potential repeat flooding.

Although jetting is a traditional operational solution, the process to identify and view the data to create schedules of further work was carried out in a way outside of the current operational processes. The existing process to create a jetting programme for a pipe was carried out by the operational teams, and the regularity of cleaning was based on experience and knowledge within the team of how frequent issues were occurring. This institutional knowledge can be lost when changes occurred within a team. By carrying out the process with a more data focused approach and running the proposed list and maps past the operational team prior to implementation, it allowed us to remove and include additional pipes either teams believed necessary.

This solution was considered a short-term solution, as the root source of the problems were not being fixed, it simply prevented blockages occurring during the duration of the cleaning. Although CCTV and jetting are considered effective, it comes with a significant and continuing operational cost. Further analysis could have been carried out to optimise the frequency and timing of cleaning based on seasonal trends, or repeatability of blockages in the area. Although not carried out for this project, the opportunity for greater efficiencies on their current cleaning schedules was highlighted to the Water Authority.

2.3 OPERATIONAL SOLUTIONS AND INOVATIONS

Like many organisations, water authorities in the United Kingdom are under pressure to keep operational maintenance cost as low as possible while still achieving various targets. These targets become increasingly harder to achieve as the overall age of their assets increases.

In terms of sewer networks, and the responsibility and ownership of pipes that water authorities must maintain, their assets have had large variations in the past due to legislation changes. They have been given responsibility of particular "shared sewers" within private properties over time, where previously their line of responsibility was simply at the property boundary. This has meant a significant and unknown number of sewers must be maintained, while the assets themselves are aging and becoming harder to maintain.

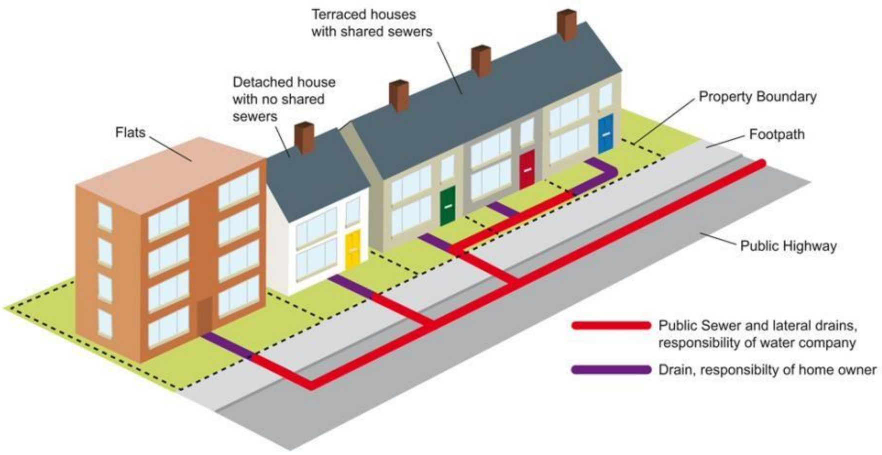
The following sections will outline several practical and operational solutions carried out and explain how they were used within the current operational processes. The goal of many of these solutions was to treat the root cause of the problem proactively or respond reactively more effectively.

2.3.1 MAPPING AND TRACING OF SEWERS

As outlined above, there has been legislation changes in the past that has meant that Water Authorities now must maintain certain "shared sewers" located within private property. The basic reasoning for this, is that if the sewage from one property passes outside of their boundary, the first property no longer can maintain this sewer, so this responsibility has been passed to the Water Authority.

To demonstrate these changes in a simplistic way, the figure below outlines various styles of properties and how ownership of sewer is now assigned. A sewer located within private property but still the responsibility of the Water Authority is considered a "shared sewer", or sometime referred to a Section 24 (S24) or Section 105 (S105) sewer.

Figure 5: Old Town Centre Root Cause Review Example



Although the network in the above image, is reasonably straight forward, in many older areas of towns and cities within the United Kingdom, the sewer alignment can be a lot more complicated. When a flooding occurs on a property with a shared sewer, in many cases the customer won't know or understand the extent of their responsibilities, and an operational response team must make an assessment on site without being able to investigate the sewer in its entirety, or have land ownership details available to them, so assumptions have to be made at the time.

To identify properties where there may be confusion, we carried out a data analysis of not only the flooding history, but all the sewer incident data for a property to identify properties where there were inconsistencies between similar problems and with varying responsibilities assigned to them on a single property. E.g. two flooding events caused by blockages, and one recorded as "Shared Sewer" and another as "Private".

We then reviewed these properties in closer detail to understand if sewers may have been mapped incorrectly, or if there were areas of unmapped sewers. Figure 6 is an example where further detailed investigation found many unmapped sewers and significant complexity as sewers passed from one property to another before leaving private land. The Red sewers are public, brown is previously thought to be "shared sewers" with the green the sewers being identified during further investigation under this project.

Figure 6: Property mapping example location

Once we had identified, and mapped the sewers, we used land ownership and lease holder information to determine the extent of the water authorities' responsibilities. In this case we determined that even though each store had an individual lease, they all had the same ownership, making all these sewers the responsibility of the one landlord. The management company was unaware of this until we discussed with them. Previously internal flooding to several of these properties had been assigned as the responsibly of the Water Authority in the past.

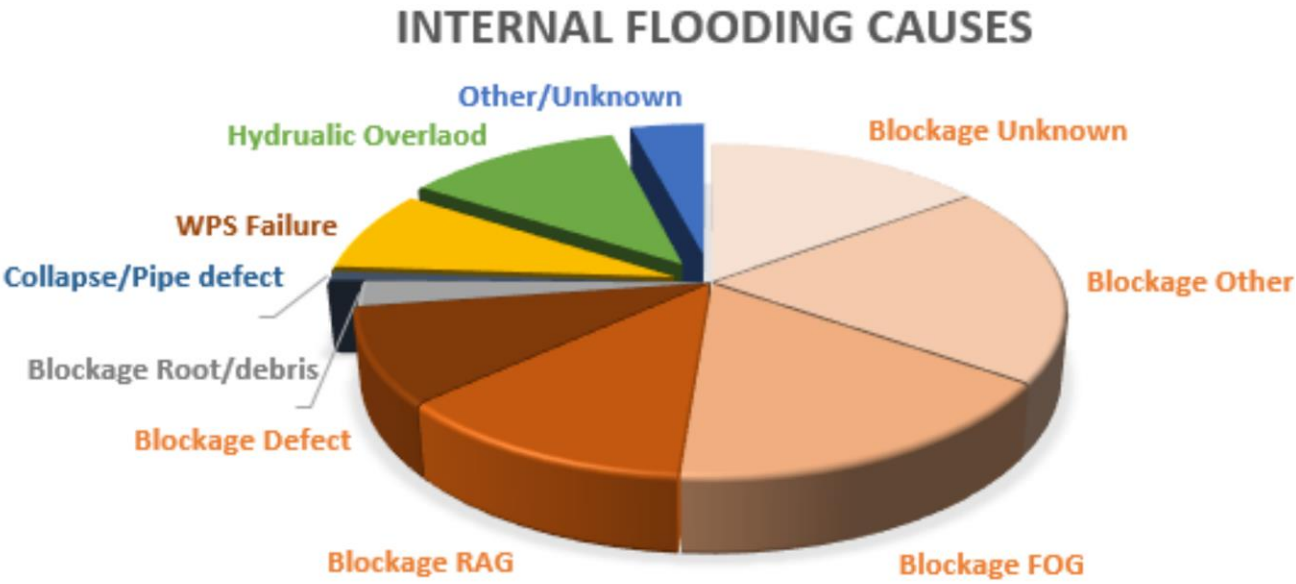
Being able to map the sewer in greater accuracy meant next time there is an issue on any of these properties, the Water Authority could ensure they were not assigned responsibility mistakenly and could avoid a potential penalty.

We carried out similar connectivity survey over several different areas and identified eight past internal flooding' incidents that had been assigned incorrectly as the Water Authorities' responsibility. There are many more unmapped and inaccurately mapped sewers in their network, but carrying out these investigations, in conjunction with a land ownership review, enabled us to highlight a possible method for the Water Authority to achieve a reduction in flooding they were not responsible for. Although this doesn't fix the root cause of the flooding, it would ensure accurate reporting, and a possible reduction.

2.3.2 TARGETED FOG DOSING

A major proportion of internal flooding were due to blockages, these blockages can normally be assigned a root cause based on what is found when clearing the blockage. As seen in Figure 7, FOG (Fat, Oils and Greases) is the leading known contributor toward many blockages that cause internal flooding. Many Water Authorities are aware of this and have large amounts of promotional material, and dedicated teams and events to educate people on, what they should and should not put down their drains, and the impact they can have on themselves or others further downstream.

Figure 7: Cause break down on Internal Flooding's



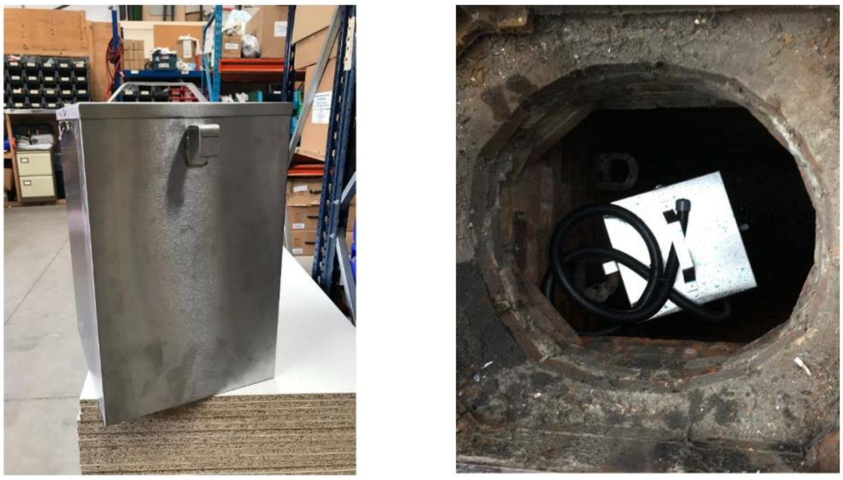
While these educational programs are useful, it is very hard to determine the tangible effect they are having, however it is believed they can have an effect for a moderate duration. For example people will stop putting things down the drain for a while, but after a certain amount of time trends tend to head back towards original level of performance, and it is widely accepted you will never be able to stop the introduction of FOG into the networks completely. It is also widely accepted that certain network properties can cause the FOG blockages, e.g. where there are restrictions in the sewer allowing for FOG to accumulate or where flows from areas with a high density areas of Food Services Establishment's (FSE's) combine with other large sewer flows can have a cooling effect on the FOG, causing it to accumulate in certain locations of a network.

The traditional way to prevent blockages from FOG is to use CCTV to confirm there is a build-up and then high-pressure jet cleaning to remove the FOG. This can be a slow procedure in large diameter sewers and the jet may need to have multiple passes to clear the line, furthermore the normal method is to also have a vacuum trucks at the downstream end to capture the FOG that is dislodged, to prevent it accumulating somewhere else. This means for a large diameter sewer, large volumes may also require a significant number truck movement, possible road closures. An additional risk of high-pressure jet cleaning is that it can cause "blow backs". A blow back is an internal flooding caused by jetting pressure pushing sewerage back up into properties, "blowing" sewage back into a property, having the opposite effect causing what they were trying to prevent.

To try and prevent FOG entering the network, Water Authorities work with FSE's, and traditionally FSE's will install a grease trap to capture the grease, or dosing unit to eliminate the FOG at the source. The problem that Water Authorities face, is that when they are unable to locate the source of the FOG, they have no way to remove it other than Jetting and vacuum trucks. We identified an opportunity to see if in network dosing could be a viable option for Water Authorities at known accumulation point.

Within this project, we implemented a trial of in network dosing units and other alternative dosing techniques to determine their effectiveness. The alternative dosing technique, using tablets was carried out on "Buchan Traps" and will be discussed in a later section of this paper. Photograph 1 shows what an in-network dosing unit looked like. They held a small battery power pump, that would pump a regular pulse of "Stopblox" reagent, which delivers billions of active fat, oil and grease eating microbes into the drain to biologically digest FOG & organic waste. The unit was sized to hold a week's supply of reagent and meant that the operation of filling the units was significantly less than jetting activities and could be carried out by the operational teams.

Photograph 1: An in-network dosing unit.



The trial was in a town centre which is plagued with FOG build-up within the lines and had experienced multiple repeat internal flooding's due to FOG blockages. The town was a seaside town and effected by large seasonal influx of visitor and resultant FOG inflows. The results of a three-month trial over the summer period showed lower levels of FOG built up at critical points, although not to the levels the reagent supplier had anticipated. Photograph 2 & 3 show the change of FOG build up during the three months.

Photograph 2: Results of in network FOG dosing at a manhole over 3 months.

Photograph 3: Results of in network FOG dosing at a secondary manhole.

The effectiveness of the trial can be seen in both manholes, shown by the reduction of hard FOG (shown as black and brown build up) being present at the start and the colour of the FOG build up changing to white (considered fresher build up) and water flows being visible indicating a reduction of the amount of FOG present.

The benefits of this style of solutions for treating known FOG problem areas were found to be:

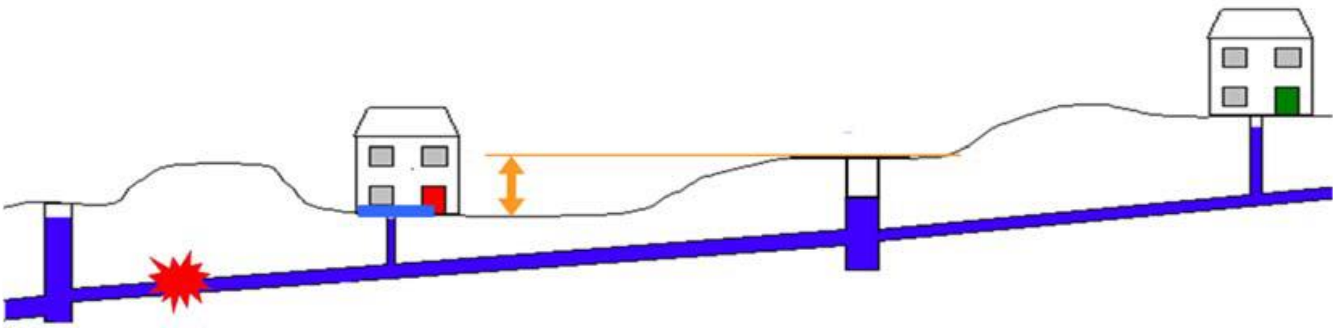
- Seasonally dosing could be carried out to match known season trends.
- It treats the manhole and the pipes downstream of the dosing point, so continued dosing could have a greater effective area than traditional jetting method or dosing upstream of a hard to access sewer could prevent the build-up of FOG in the sewer.
- Access and maintenance in hard to access areas can be more readily achieved compared to traditional jetting methods.
- Removes the risk of additional internal flooding occurring due to "blow backs".

Although not as effective as high-pressure jet cleaning, we recommended the Water Authority consider the use of in network dosing in specific situations where jetting was unable to be achieved due to restrictions to access, such as sewers with known limited access points preventing effective cleaning, or sewers in areas with high traffic management cost associated with gaining access to enable cleaning.

2.3.3 PROPERTY LEVEL ALARMS (PLA'S)

For many properties, when a sewer pipe is blocked, there is no warning of an imminent internal flooding occurring before it occurs. An example of what this might look like is shown in Figure 8, where a property has a toilet or drain in their basement. Although there may be an access points on the sewer or lateral outside the house, if there was a blockage, sewage would spill into the house before spilling outside at the access point as the lower level is within the house.

Figure 8: Properties with a high risk of internal flooding



With properties like this, a solution might previously have been to install an Anti-Flood Device (AFD), which is a can be a simple flap on the lateral sewer, preventing flows flowing back up towards the house. Although many Water Authorities may not install these if they simply pass the flooding along the street to a neighbouring property, i.e. the next similar basement, leaving no suitable solutions available to try and prevent repeat flooding occurring.

As part of this project we looked to see what other solutions might be available for properties like those described above. We discovered that there was a new solution being implement around the United Kingdom, which we grouped under the name "Property Level Alarms" (PLA's). These solutions now exist because recent developments in wireless senor networks were starting to show a significant impact on a broad range of applications relating to sewer monitoring. The convergence of the internet, telecommunications, and novel information technologies now providing vast opportunities for the application of low-cost monitoring solutions which could improve sewer network understanding in real time.

The simple concept of an alarm is to dramatically increase observability and promote responsive rather than reactive management from operation teams. In a nutshell, operational response teams can respond to potential and developing blockages before they impact on customers. The basic operational feature of the alarm is a simple on/off alarm, that triggers when the water level rises within a manhole or chamber, indicating the system is surcharged. Because the alarms do not constantly monitor the level, but only sends a signal when triggered, the expected battery life of the alarm was 10 years. A typical set up of two different suppliers in shown in Photograph 4.

Photograph 4: Property Level alarm installation examples

The location selection for alarms was based on several simple but effective steps which included a desktop study of SIRF/MIMS data, pre-inspection site visits and local knowledge from technicians. In the first trial each alarm was installed on a commercial property and could be monitored remotely through a web portal. The web portal provides an easy to read 'rise and fall' graph which showed any changes happening at the location. The system was also arranged to send a text to the trial design engineers and operational team to allow us to check the accuracy of the alarm when they were triggered.

The alarms were installed on properties that had high chances of repeat flooding based on existing history, and where no other mitigation could be carried out on them. Within a six-month period, we successfully located two blockages. We simply carried out an inspection when surcharge levels were remaining high for more than a few hours, and if a blockage found, called the operational response teams to clear it before flooding occurred. Photograph 5 shows the installed alarm, and the located effect of a blockage before flooding had occurred.

Photograph 5: Example of successful blockage location from a PLA

It was determined that even though blockages could occur very quickly, in most cases there would be a period of fluctuation before flooding would occur, this was observed in the blockage shown above where the water level in the manhole was surcharging and seen to go up and down repetitively.

After this successful trial, these alarms were to be implemented in a wider programme, and the alarms connected straight into the Water Authority's response coordination team. The alarms were each assigned with a site-specific action plan as to what it meant when triggered. These action plans were also to allow for self-clearing of blockages by having a delay on them before notifying the coordination team, the action plans would then describe what actions were required, along with an estimated time of storage available within the relevant network. The estimated cost for installation and implementation for each alarm was ~NZD$2000.

A key aspect of these alarms was to ensure they were installed on properties that had experienced flooding due to blockages rather than any risk of hydraulic overload in the network. As the current operational response team were stretched during storm events, we wanted to ensure the alarms were not given a lower priority during wet weather event.

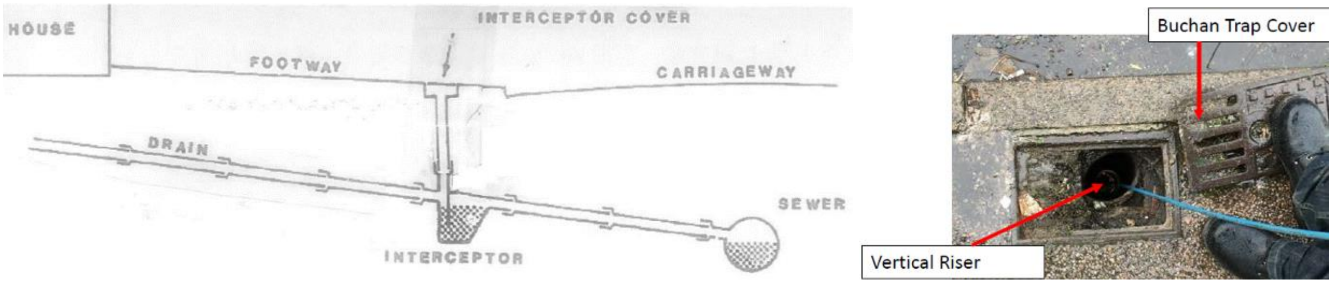
With many of these alarms being in the basements of properties, it meant that cell phone signal could be poor at some locations. These alarms could be installed in various arrangements, to ensure suitable cell phone signal coverage was achieved. By varying the location of the logger and standard aerial or utilising the manhole lids to amplify the aerial where necessary or running an external aerial within a building and basement up to ground level. This flexibility, affordability, durability and reliability made these PLA's a great new tool in the prevention of flooding in previously difficult to manage properties.

2.3.4 BUCHAN TRAPS

An example of where a combination of data analysis tools, root cause identification, optimisation of existing operation approaches and new operational options were able to be carried out on a single cause, was the targeted approached to reducing internal flooding due to "Buchan Trap" blockages.

Buchan Traps are a historic trap installation which some councils utilised during certain periods of growth throughout the last century. They were installed in the past to prevent odours and rodents from entering houses from the sewers. A diagram of what a Buchan Trap looks like can be seen in Figure 9. They were a very prevalent and large contributor to internal flooding within some project areas. They are simply a U-bend trap normally located on the roadside of a property boundary, and therefore the responsibility of the water authority.

Figure 9: Buchan Trap sketch and example



Although these assets were a known issue in some areas, the current approach was to clean them out if they were blocked, and in a significant proportion, particularly properties with basement, this blockage would not be found out until internal flooding had occurred. The reason for blockage occurring could range from debris falling the trap from the street, FOG build up, foreign objects getting lodged in the traps, or breakage of the clay traps themselves. Example of these blockages can be seen in Photograph 6.

Photograph 6: Examples of Buchan Trap blockages

When we carried out the catchment root cause analysis for the various zones, we were able to identify one area that had a large proportion of blockages caused by "Traps". While in the overall Water Authority's flooding causes, this wasn't identified as a major contributor. However, when the area was identified as hot spot of flooding, the analysis identified over 50% of the internal flooding in the town were caused by "Traps".

The various data analysis techniques mentioned earlier, and the FME tool was able to search through the various data bases for each property and identify if a trap had been mentioned, or similar related words, in the same process. Words like "Interceptor", "trap", "buchan", "IC", "BT" were all used to describe these traps in the areas, and easily searched using the flexibility of the FME tool.

Once a list of properties was identified, we then carried out basic property connectivity surveys to capture the following;

- if a trap was still present on the property, the exact location, depth, current condition,
- any sign of FOG or debris build-up within the trap,
- any faults with the trap, such as a cracked riser or missing lid.

This information was then mapped onto the central GIS system, allowing for future operational response teams to identify the location of the trap quickly if there were any future issues on the property.

With this information on current condition we were able to automate a schedule of actions that were then carried out. This involved:

- For shallow trap, less than 1.5m deep and able to cause internal flooding, with easy access to the trap, they were to be removed and replaced with a straight section of pipe.

- For deeper traps, that were found to contain debris, a cleaning schedule was created to get these jetted and vacuumed cleared.

- For deeper traps that were found to have faults in easy to access parts, such as on the risers, a list of repairs was created to ensure that they wouldn't cause blockages in the future.

- For deeper traps with FOG build ups a secondary trial of dosing was carried out, this used a product called "Ecotabs" which could be dropped into the trap and would sit in the liquid within the trap and dissolve, allowing the reagent to digest the FOG build up in the trap.

- Where a troublesome trap was identified, which could not be removed, due to constructability issue, such as being located too close to a wall or building, and the trap had repeatably caused internal flooding, we suggested these were added to the list of properties considered to have property alarm installed on them to ensure they could be identified as needing cleaning urgently to prevent internal flooding.

Because the local area was shown to have such a high risk of internal flooding from blocked traps, we worked with the educational team to determine what a targeted educational campaign for the area could look like, so that team could apply for funding for in the future.

This example of an identified root cause utilised an array of tools and techniques that were used elsewhere in this project to have a greater combined effect. It also shows the that the Water Authority already had all the existing rich data they needed but were unable to identify the problem and its localised extent with the current tools they had available.

3 CONCLUSIONS

With so much data within the many available databases from free to access sources, and from that collected and utilised by the different teams within the Water Authorities, the saying, "You can have data without information, but you cannot have information without data" stands very true.

With so much data available, the Water Authority needed to understand what was achievable in combining their data and what tools were available to determine the information needed to make smarter and more effective decisions.

Even with data inaccuracies, the sometime "Murky" data, we were able to combine and clarify it by utilising supporting data and information on the property. The skills and knowledge to understand the data can enable organisations to become better informed and make decisions backed by robust analytical data rather than instinct alone.

This paper has shown how data can be used to complement existing procedures, to enable optimisation of current processes and responses to achieve a greater outcome.

It also highlighted the need to take many small steps and varying approaches to be able to achieve a greater effect, as there is very rarely a silver bullet to fix complex problems, such as flooding, which can be a result of so many causes. Although there was no silver bullet the data that was available and can be used through modern processes and techniques can be as valuable as gold.

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