Severn Trent Water ATKINS

Flooding - a returning question

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SYNOPSIS

In July and August 2004, most of the UK experienced very wet weather, with record amounts of rainfall being recorded. During this period, Severn Trent had a significant increase in the number of flooding problems reported to their customer call centre. Over 1,300 internal flooding incidents were recorded plus over 6,000 external flooding cases. Each of these incidents had to be investigated by the Severn Trent flooding team to identify the likely cause and hence allow Severn Trent to take the appropriate action.

As part of the investigation, Severn Trent wanted to establish the storm return period related to each incident. This paper describes how rainfall data, obtained from the Environment Agency (EA) and Met Office, enabled storm return periods to be assigned to individual flooding incidents.

BACKGROUND

August 2004 is accepted as being a very wet month for the UK as a whole. The UK total rainfall for the month was 153.9mm which is double the 1961 – 1990 average! The previous wettest in the series was 1992 when there was 127.7mm of rainfall. There were several notable flooding events across the country throughout the month, with the event in Boscastle dominating the news.

The Severn Trent region was no exception; detailed figures are not available but averages (from CEH Wallingford) suggest that the June to August period was 136% greater than normal ("substantially above average"). Considering that rainfall totals in June and July were relatively close to normal, this shows the overall impact of the August events.

The Severn Trent flooding team generally respond to around 300 to 400 incidents per month from any cause, not just rainfall. In August, there were between 50 and 70 each day which placed an enormous strain on resources. These can include flooding incidents as a result of flows from highway drains and other watercourses.

INTERNAL FLOODING – SEVERN TRENT PROCEDURES

Like all water and sewerage companies, Severn Trent is typically the first call for any flooding incidents that have not been flagged by the EA flood warning system. Any flooding event is very traumatic for the customer and Severn Trent operates a 24 hour call out service to help alleviate some of the problems. Their booklet ("your guide to the Floodcare scheme") describes the process and why flooding may occur. Severn Trent sewers are designed to carry a reasonable amount of sewage from properties and surface water which runs off roads, footpaths and paved areas. The booklet outlines how flooding can also occur for other reasons such as blockages, very heavy rain or the failure of a pumping station.

Following a flooding incident, the field service team performs an initial clean up and also investigates the source of the flooding. If the cause of the flooding problem is not immediately apparent, the cause is investigated and the customer informed of the findings. Should the investigation show that the problem is not public sewer related, they will then help the customer by liaising with the body responsible for dealing with it. If there is a risk of future flooding from the public sewerage system, the booklet outlines how Severn Trent will take reasonable steps to reduce the severity of the problem.

The flooding can be traumatic for the customer and Severn Trent takes a pragmatic approach to resolving the problem and Figure 1 shows examples of the damage that can result.

Figure 1 – Examples of internal flooding damage

If the cause of the problem is a blockage in the public sewer, then the flooding team arranges for it to be cleared. If a heavy rainstorm has caused the public sewer to flood, then Severn Trent will help to clean up and assess whether any remedial work can be carried out. However, if the problem arises in a private sewer or drain, then it is the responsibility of the householder to arrange remedial work. In cases of overland flow, it can be difficult to immediately ascertain the root cause of the flooding.

The customer has recourse to a range of payments under the Guaranteed Standards Scheme (GSS). Severn Trent has introduced a number of payments that exceed the OFWAT requirements for internal and external flooding. These are normally paid automatically and within 14 days of the incident. Exceptions are:

- Flooding due to exceptionally heavy rainfall
- Sewerage charges refunded up to a maximum of £1000
- Flooding as a result of action by the householder
- Garden/driveway flooding as a result of a first time blockage (i.e. no previous incident in past 12 months)

The flooding incidents are investigated by Severn Trent and the results reported in the annual June Returns to OFWAT under the statutory reporting requirements. The June returns include details on the number of properties flooding by overloaded sewers as well as flooding from other causes. These are in addition to the properties on the “At Risk” register. Table 1 summarises the number of flooding incidents since 2000, as given by the OFWAT June Returns.

Description	**2000-01**	**2001-02**	**2002-03**	**2003-04**
Overloaded Sewers				
Properties flooded in the year (overloaded sewers)	258	356	295	84
Internal flooding incidents in the year (overloaded sewers)	356	514	328	86
Internal flooding incidents (overloaded sewers attributed to severe weather)	66	64	103	3
Properties where flooding was limited to uninhabited cellars only (overloaded sewers)	14	31	38	3

Table 1 – Numbers of Flooding Incidents (ST – June Returns)

OFWAT recognises that severe weather contributes to flooding incidents and this is reflected in the reporting requirements. As part of the investigation process, Severn Trent typically obtains rainfall data from the EA or Met Office for the flooding incident location. The Met Office provides data on the return period of the event for the point requested. This is based on the rainfall radar records. The EA data is from their rainfall intensity raingauges and then translated into the return period for the event.

In July and August 2004, the number of reported flooding incidents requiring investigation ranged between 50 and 70 each day. This created not only a back log for investigation but also a backlog in obtaining data on the storm return periods. In order to help understand the return period of the events related to the incidents, Severn Trent started to collect rainfall data from the EA and Met Office with whom they had a contract to provide this, for specific dates and flooding locations. However, given the number of incidents not covered, and the number of incidents to be investigated, an additional resource was required.

RAINFALL AND INCIDENT ASSESSMENT

Atkins was appointed to assist in assigning storm return periods to the internal and external flooding incidents. The initial concept was to develop contours for the rainfall events that could be used to interpolate storm return periods for the flooding incidents. Given the volume of incidents and the need to include the results in reporting tables, a relatively simplistic but robust approach had to be adopted. From an initial assessment of the rainfall data provided with the incident data, it became evident that there were insufficient points for any meaningful interpolation. The approach was therefore amended to relate the incident to the nearest raingauge and assign the return period of that event to the flooding incident.

The data assessment showed that there were calls relating to over 1,300 internal flooding incidents in August. These would be due to a number of causes, including overloaded watercourses, blockages, severe weather, flow for third party drains, etc. A data file was provided that included the date and time that the incident was logged with the Severn Trent customer call centre. Table 2 summarises the number of incidents recorded.

	July	August	Total
External	1,925	4,233	6,169
Internal	300	1,050	1,350
Totals	2,225	5,276	7,519

Table 2 – Numbers of Flooding Incidents Reported to Severn Trent

The incidents were not spread evenly through the month. Figure 2 shows the distribution of the internal and external events in August.

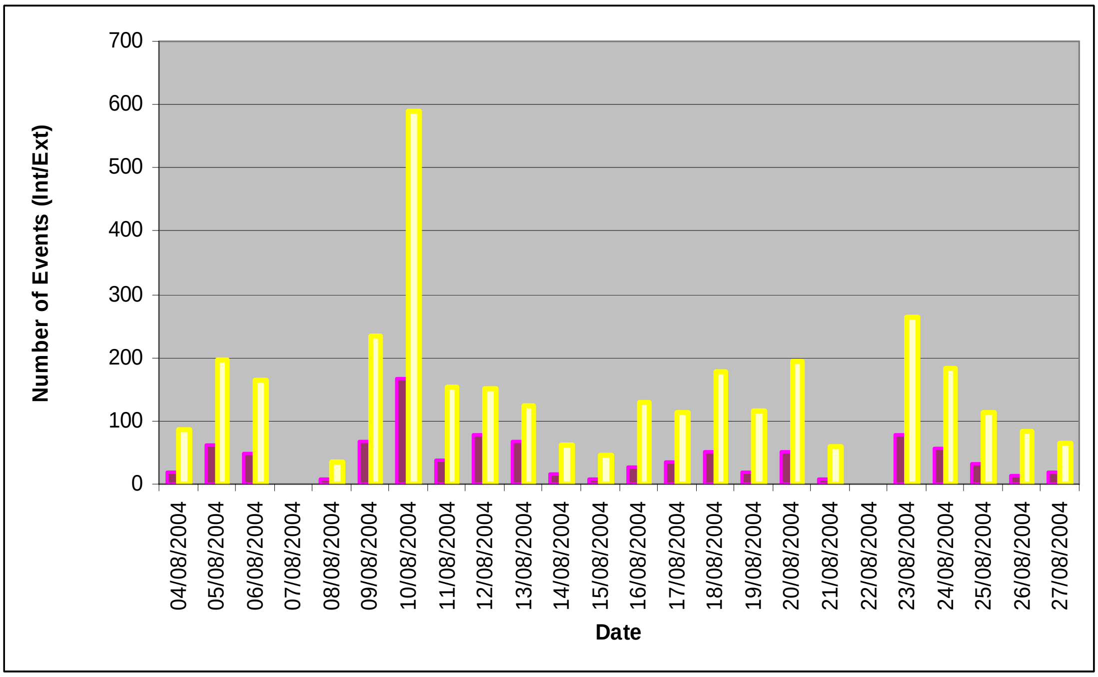

Figure 2 – Number of Reported Flooding Incidents in August 2004

Although the data file included some location details, inconsistencies in the spelling of street names created problems in geocoding the individual incidents. This was a particular problem for the external incidents where only some general regions were stated. Following some data cleaning, the incident locations were geocoded. This then allowed an initial overview of the flooding locations. It became evident that the sites were very scattered across the Severn Trent region. Severn Trent is divided into 345 individual Drainage areas (DAPs). Out of the 345 DAP areas 261 had at least one internal flooding incident. However, 48 DAP areas contained 50% of the incidents. The flooding incidents were also compared to existing locations on the Severn Trent DG5 register and other known problem areas. This showed that 255 of the incident locations were already known problem locations.

The main element of the study was to establish the return periods of the storms recorded. Severn Trent provided an initial data set from Met Office reports and EA raingauges. Most of the Met Office data was from rainfall radar and for a specific location. The Met Office classified their initial reports with low confidence and as the study progressed, they were replaced by high confidence reports. However, the timing in the receipt of data made it problematic to include in the analyses.

The EA data included both the rainfall data and the return periods for the storms. A check on the return period calculations was done and confirmed that they were appropriate. The Flood Estimation Handbook was used for the return period calculations.

The analysis for the August incident was performed on a rain set that included 411 rain events. Starting from this set, the data were divided into daily groups and plotted in MapInfo along with the incident location for the same day. Table 3 summarises the number of raingauges with rainfall events available for each day along with the number of internal and external flooding incidents. Long duration events (spanning two days) were considered to relate to the following day's incident.

Event Date	Raingauges with Rainfall Events	Internal Incidents	External Incidents
04/08/2004	13	18	86
05/08/2004	59	63	197
06/08/2004	9	49	163
08/08/2004	6	8	34
09/08/2004	62	68	234
10/08/2004	77	166	589
11/08/2004	23	38	154
12/08/2004	41	79	152
13/08/2004	16	66	123
14/08/2004	2	15	62
15/08/2004	1	7	46
16/08/2004	9	28	128
17/08/2004	13	34	114
18/08/2004	18	51	179
19/08/2004	6	20	116
20/08/2004	20	51	194
21/08/2004	4	7	58
23/08/2004	30	78	263
24/08/2004	15	57	182
25/08/2004	13	32	113
26/08/2004	3	14	84
27/08/2004	5	18	64

Table 3 – Rainfall and Flooding Incidents

It should be noted that about 60% of the August internal incidents were on seven days in August and hence there are some days omitted from Table 3 as there was little or no rain recorded. This does not affect the overall results as there were only 54 (5%) out of the total 1,046 internal incidents and 326 (8.5%) out of 3,794 external incidents are on these days. A check with other publicly available data confirmed that little or no rain was recorded over the Severn Trent area on those days.

For the days with rain data available, an assessment was completed to establish how close the incidents were to the raingauges. A buffer grid was generated using Vertical Mapper in MapInfo. This grid allowed the distance of each incident point from the nearest available raingauge to be calculated.

Figure 2 shows an example of the procedure adopted. The creation of the buffer grid ensures that every point is associated to the nearest raingauge. The intersection of the buffer grid cantered from each rainfall point coincides with Thiessen polygon boundaries.

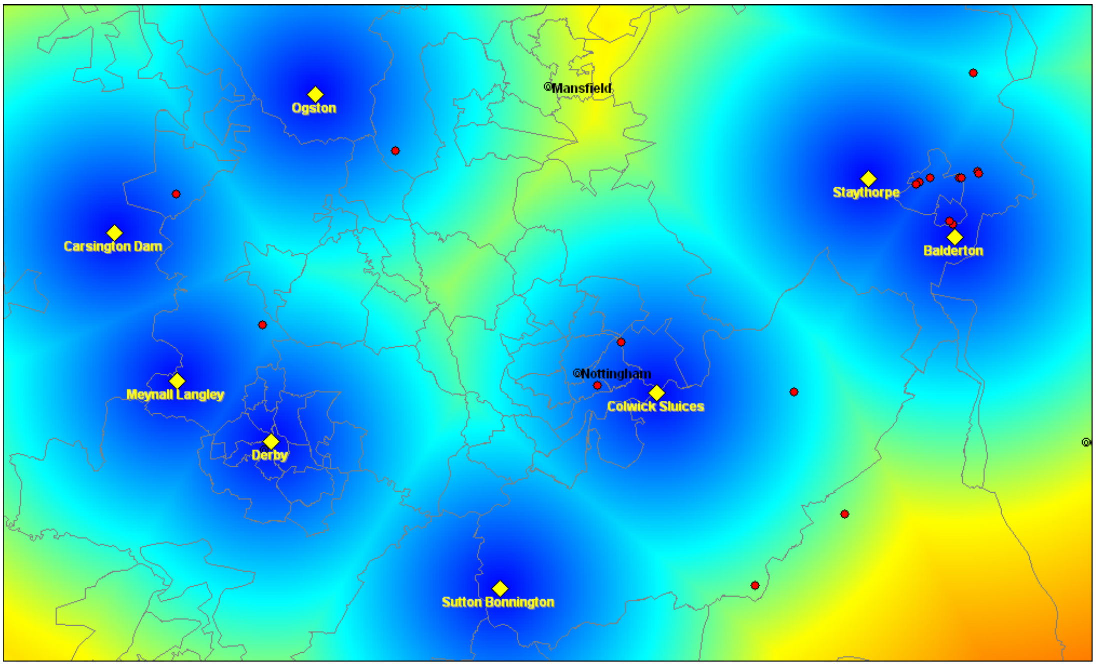

Figure 2 – Example Buffer Grid for Raingauges

Using confidence bands of 2 km, 5 km, 10 km and 20 km, the distance of each incident from a point of rainfall record could be prepared, as shown in Table 4.

Accuracy	Distance	Internal		External	
		No	%	No	%
High	<= 2 km	213	21.5%	341	9.8%
Medium-High	2 - 5 km	248	25.0%	1037	29.9%
Medium	5 - 10 km	268	27.0%	719	20.7%
Low	10 - 20 km	151	15.2%	766	22.1%
Zero	> 20 km	112	11.3%	605	17.4%
Totals		992	100%	3,468	100%

Table 4 – Numbers of Incidents in Distance Bands

Table 4 shows that there was good rain data coverage for the rainy days with about 73% of the internal flooding incidents and 58% of the external incidents geocoded within a radius of 10 km from the nearest source of rain data. On the basis of the data from the closest rain gauge, a return period (from either the EA and Met Office data sources) was assigned to each incident location. The process was performed for each of the rainfall days.

RESULTS

Despite the daily based approach, there were still some uncertainties related to the actual time of the incident. As the incident date and time is the time the call is logged at the call centre, in some cases the incident appeared to occur before the starting time of the closest rain event. Hence the incident is probably not connected to the event, for obvious reasons. In those cases, the event based on the second nearest gauge was assigned. This was done as a manual reassignment. However, it was noted that these incidents could be due to other causes and hence not rainfall related. The data was flagged appropriately so that there was a clear audit trail on where a manual intervention had taken place.

Table 5 presents the number of internal incidents for ranges of return period events, banded on accuracy, according to the distance from the rain gauge.

Return Period	High	Med-High	Med-Low	Low	Total	%
> 10	58	68	31	27	184	20.9%
5=R<10	30	13	19	5	67	7.6%
2=R<5	46	22	35	13	116	13.2%
<2	67	123	153	85	428	48.6%
No rain	12	22	30	21	85	9.7%
Total	213	248	268	151	880	100.0%

Table 5 – Numbers of Incidents and Storm Return Periods (Internal)

The table shows that about 20% of the flooding incidents could be related to rainfall events with a return period of more than 1 in 10 years. While some were more than 10 km from the raingauge (and hence low confidence), there was medium or high confidence that the majority of the results would relate to the raingauge. A similar table, as shown in Table 6, was prepared for the external flooding incidents.

Return Period	High	Med-High	Med-Low	Low	Total	%
> 10	139	256	101	94	590	20.6%
5=R<10	78	92	36	20	226	7.9%
2=R<5	35	130	17	122	304	10.6%
<2	71	414	512	404	1,401	48.9%
No rain	18	146	53	126	343	12.0%
Total	341	1,038	719	766	2,864	100.0%

Table 6 – Numbers of Incidents and Storm Return Periods (External)

Overall, the proportion of incidents for external and internal flooding in each return period is similar. The external events have a greater proportion of low confidence as the raingauge data collection was focussed on the internal flooding incidents. More data points would have increased the overall numbers of incidents closer to the raingauges. It should be noted that although about 20% of the incidents were considered to be related to storms with a return period of more than 1 in 10 years, this was only one element in the overall assessment completed by Severn Trent.

SUCCESSIVE STORMS AND OTHER ISSUES

Given the large amount of rainfall over the period, there was a concern that the base flow in the sewers would not have returned to normal before the next storm occurred. The total rainfall required for a 1 in 10 year event was calculated for six selected areas using 24, 48 and 72 hour durations. As would be expected for summer storms, these rainfall totals were rarely exceeded. Another exercise considered the combined return period storms on consecutive days. This identified nine days with consecutive but independent relevant rain events. Overall, this assessment suggested that some incidents were exacerbated by consecutive storms but no real influence could be established.

The approach adopted is simplistic in just taking the closest raingauge and assigning it to the flooding incident. It does not take into account any other meteorological or geographic issues, but was easy to apply and audit. As part of the study, an alternative approach has been also considered in the study. It is based on the generation of interpolated surface from known return period points. The flooding locations were then assigned to interpolated values of the return period.

Different interpolation techniques have been considered and taking into account the number and distribution of the data available a “Natural Neighbour Interpolation” has been used. Natural neighbour interpolation is a geometric estimation technique that uses regions generated around each point in the data. The natural neighbour technique is designed to honour local minimum and maximum values in the point file. This technique thereby enables the creation of accurate surface models from data that is very sparsely distributed or very linear in spatial distribution.

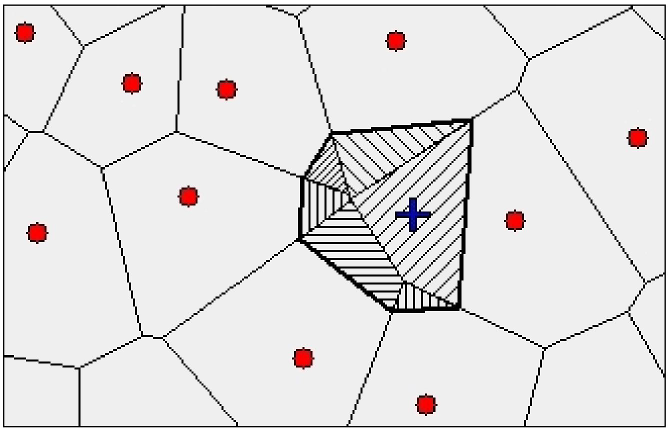

Figure 3 – Natural Neighbour Interpolation Basis

The natural neighbour interpolation makes use of an area-weighting technique to determine a new value for every grid node. As shown in Figure 3, a natural neighbour region is first generated for each data point, based on the polygons. Then, a new natural neighbour region is generated at every node in the new grid which effectively overlies various portions of the surrounding natural neighbour regions defining each point. The new grid value is calculated as the average of the surrounding point values proportionally weighted according to the intersecting area of each point.

With the interpolation, the assessment of the return period of the incident is affected by more than one raingauge measurement. The different time of the rain events is not taken into account in the interpolation. The result of the interpolation of course does not take into account any meteorological or statistical issue and is a simple spatial analysis exercise to consider the influence of more than one rainfall information source on the evaluation of the possible cause of the incident.

This approach confirms the general result of the assessment based on the nearest rain gauge. If Table 7 is compared to Tables 5 and 6, it shows that the analysis made with the interpolation has not produced considerable differences overall. There will be some local changes and a bigger rainfall data set would increase the effectiveness of the approach.

Return Period	Internal		External	
> 10	172	19.5%	622	21.8%
5=R<10	79	9.0%	224	7.8%
2=R<5	107	12.2%	319	11.1%
<2	522	59.3%	1,699	59.3%
Total	880	100.0%	2,864	100.0%

Table 7 – Number of Incidents and Return Periods (Based on Interpolation)

Although the summary result given by this alternative approach is not very different, it is important to take into account the interpolated return period value assessed. Considering the nature of the storms recorded in August, with high intensity and large spatial variability, often, the nearest raingauge method does not give the most appropriate answer about the severity of the storm that caused the incident. If the difference between the return period picked from the nearest raingauge and the interpolated one is large, the influence from another more distant but critical raingauge strongly affects the nature of the incident and this issue should not be neglected.

DISCUSSION

It is accepted that a storm return period is not the same as the flooding return period; but until the rainfall data can be obtained quickly and then applied to an appropriate sewer model, it is a good indication that “severe weather” has occurred, particularly for the larger return period storms.

While OFWAT acknowledges that severe weather has an impact on the number of flooding incidents, it keeps to the definition of the property flooding not more frequently than 1 in 10 years and does not state a definition of “severe weather”. The June Return reporting requirements state that the

Reporters are asked to comment on "the efficacy of the methodologies used and the quality of the data … to identify severe weather events".

The approach adopted used a simplistic relationship between the incident location and the raingauge. There are many other factors that will affect the relationship between flooding and the storm return period. The accuracy of the relationship diminishes with distance and this was fully reflected and reported on. Hence, for Severn Trent, it provided a means to demonstrate where some flooding incidents were associated with severe weather. Given the timing of the study, there were gaps in the rainfall data. As is always the case, more data makes for better assessments and reduces the associated inaccuracies.

What was interesting to note was the number of incidents assigned to low return period storms or even no rain. These in general gave a good indication that they were probably related to "flooding other causes" and timely supply of information can expedite this assessment.

Even though Severn Trent received over 1,300 calls during August, the majority, following investigation, were not public sewer related but were caused by overflowing watercourses, highway drainage problems, etc. These specific investigations by the flooding team reduced the numbers from around 1,300 incidents to 265 actually reported for the whole year. The work with the rainfall data enabled Severn Trent to establish the rainfall return periods and hence appropriate classification when completing the OFWAT reports. Table 8 presents the June return figures for the whole of 2004/05.

Description	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**
Overloaded Sewers					
Properties flooded in the year (overloaded sewers)	258	356	295	84	**226**
Internal flooding incidents in the year (overloaded sewers)	356	514	328	86	**265**
Internal flooding incidents (overloaded sewers attributed to severe weather)	66	64	103	3	**72**
Properties where flooding was limited to uninhabited cellars only (overloaded sewers)	14	31	38	3	**38**

Table 8 – ST Flooding Incidents (June Returns 04/05)

CONCLUSION

The severe weather in August 2004 created a large increase in flooding incidents throughout the Severn Trent region and about 1,300 calls were logged relating to internal incidents. An approach was adopted determine the associated storm return period for a rainfall event so it could be related to either internal or external flooding incidents. Data interpolation techniques were trialled to determine if they would affect the overall results and shown to support the initial findings. The work with the rainfall data enabled Severn Trent to establish the rainfall return periods and hence appropriate classification when completing the OFWAT reports.

The industry will continue to return to flooding issues – questioning both the cause and nature of any solution proposed. However, the impact on the customer and distress that out of sewer flooding creates must be remembered as this is what we are trying to remove.

ACKNOWLEDGEMENTS
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