PAPER 6

Predictive DG5 at risk register

Presented by

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Predictive DG5 @ Risk Register

Abstract

Properties at risk of flooding from sewers due to hydraulic overload are recorded on a water company's DG5 register and this is based on flooding events that have actually occurred. This approach does not identify the total risk as demonstrated by the fact that new properties come on to the register each year or that a property maybe potentially at a greater risk of flooding than currently indicated on the DG5 registers. Severn Trent Water, Mouchel and InfoTerra Ltd have developed a process based on Source > Pathway > Receptor principles to identifying all properties at risk of sewer flooding. The Source modelling uses a combination of hydraulic modelling outputs and a process for representing un-mapped sewer laterals to determine where water escapes to the surface. The Pathway and Receptor modelling is completed using Mouchel's two dimensional surface routing tool, Flood Risk Mapper (FRM). FRM's functionality uses the flood characteristics, DTM and OS MasterMap data to generate flood paths and identify properties at risk of sewer flooding. This paper describes the process developed during a pilot study, benefits from its application and recommendations for further improvements to the process.

1 Introduction

Severn Trent Water commissioned Mouchel in January 2008 to undertake a pilot study to evaluate the use of flood risk mapping techniques as a tool to quantify future hydraulic sewer flooding risk and the potential locations of these risks within a catchment. Historically sewer flooding caused by hydraulic overload has been identified through the past occurrence of actual flooding events and details of these events are recorded on the 'At Risk' register. Each year a number of locations are removed from the register as a result of interventions, but more locations are added to the register due to an area being exposed to a trigger storm event for the first time or through improved data collection techniques. The impacts of impermeable area creep, climate change and growth can lead to new flooding locations.

This historic approach does not allow the complete flood risk due to hydraulic overload to be quantified and consequently does not allow the business to manage the risk appropriately.

The approach to the quantification of this true hydraulic overload flooding risk is based on a Source > Pathway > Receptor modelling strategy. This approach uses Digital Terrain Model data supplied by InfoTerra Ltd, Ordnance Survey MasterMap, and Severn Trent hydraulic modelling data as inputs to Flood Risk Mapper (FRM), which has been developed by Mouchel over the past three years. FRM has successfully been used to assess "other causes" flood risk as part of PR09 Capital Maintenance planning for a number of large water companies. This work has required the development of more than 2 million flood paths. This paper describes the process developed from the pilot study, benefits from its application and recommendations for further improvements to the process.

2 Objectives

The objective of the pilot study was to evaluate the concept of using flood risk mapping techniques as a tool to assist with the forecasting of future flooding incidents and their likely location within a catchment. The tools and processes developed by this pilot study would then be used to create a 'Predicted DG5 @ Risk Register', which can be used to manage headroom and inform investment strategies in AMP5 and beyond.

3 Methodology

3.1 Overview

The process developed during the pilot study project was based on Source, Pathway and Receptor principles. The objective of these principles is to answer the following questions:

- Source Modelling – Where does the floodwater come from and at what flow rate?
- Pathway Modelling – Where does the flood water travel when it is on the surface?
- Receptor Modelling - What impact does the flood path cause (e.g. number of properties internal flooded or area of A-Road flooded)?

The process developed and the interaction between the different elements is shown on Figure 1. The Source modelling uses the outputs from verified hydraulic models, but accounts for the localised drainage system to ensure the flooding location provides the best possible representation of reality. The Pathway and Receptor elements were completed using the Flood Risk Mapper (FRM) functionality. FRM uses a two dimensional surface routing tool to determine the route(s) of the flood water when it is on the surface and a unique function to quantify the impact of the flooding to individual properties and locations.

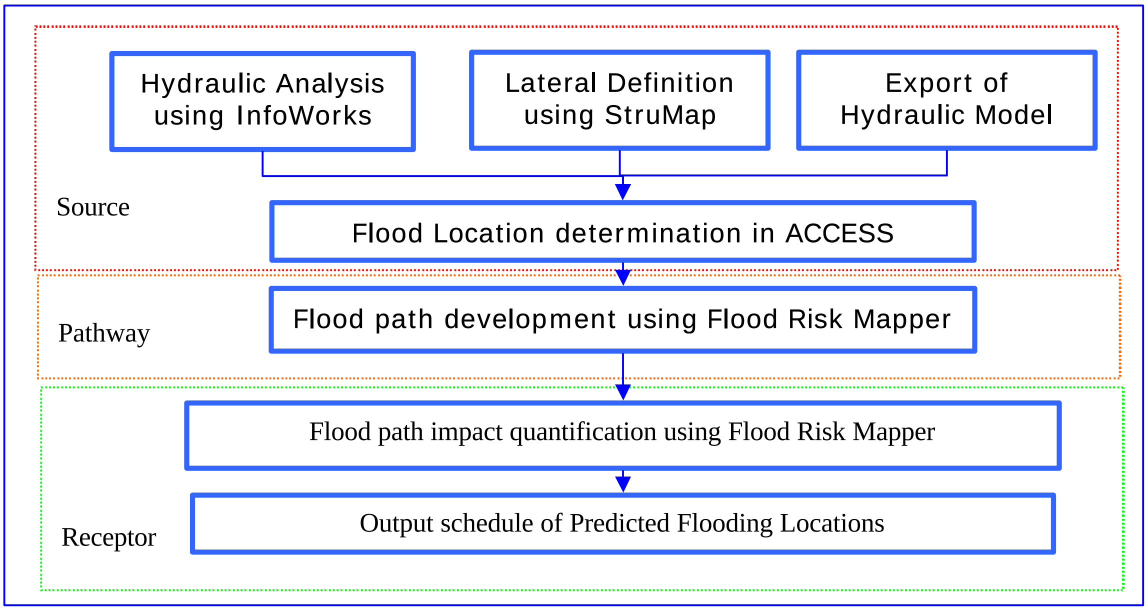

Figure 1. Predictive DG5 process map.

3.2 Pilot Study Catchment

The drainage area selected for the pilot study was Evington, which is situated to the east of Leicester and covers an area of 26 km^2. Figure 2 demonstrate the catchment is urban in nature and is subject to a number of known flooding problems, which will be used to validate the predicted flooding locations. The catchment contains approximately 34,000 buildings.

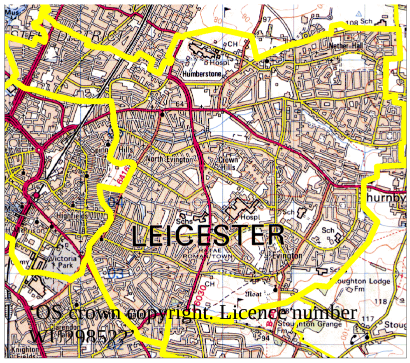

Figure 2. Evington location plan

3.3 Data Inputs

The following data was supplied to complete the project:

- OS MasterMap Topographic Data – This was supplied in .gz format and Flood Risk Mapper was used to convert the files into seamless tables within MapInfo. Flood Risk Mapper provides an efficient tool for converting and managing large quantities of MasterMap data. The data is required for both the lateral definition and development of the flood paths.
- OS MasterMap Address2 Data – Supplied in .gz format and converted into seamless maps. The data contains 1700 different building classifications from dwelling to hospitals. The data is used in the receptor modelling process.
- InfoWorks Model – The hydraulic model was supplied to extract the flooding and surcharge data required for the project. The foul and combined sewerage system is represented within the model and surface water system has been omitted.
- Digital Terrain Model – InfoTerra supplied in 1m resolution LIDAR data. Flood Risk Mapper was used to convert this into the format required to develop the flood paths. The data was used to determine the minimum cover levels on the laterals.

All the data inputs where checked to ensure a complete coverage of the study area and identify any interactions with surrounding Drainage Area's. Further checks were completed for the DTM data set through a visual inspection to identify any obvious problems. Examples of the DTM visualisation are shown in Figure 3 and Figure 4.

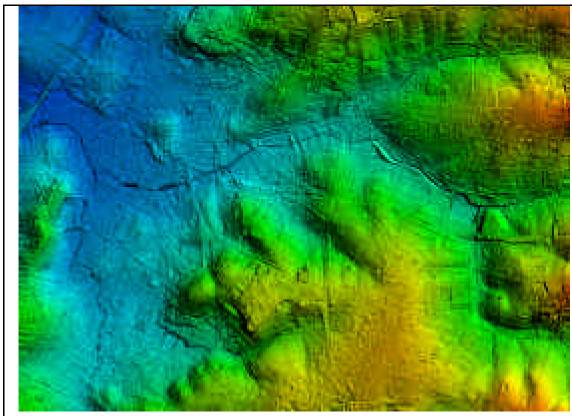

Figure 3. Two dimensional visual inspection of the DTM data.

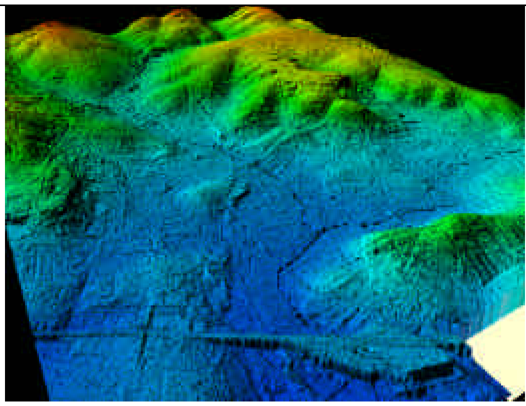

Figure 4. Three dimensional visual inspection of the DTM data.

The accuracy of the DTM in relation to the cover levels in the hydraulic model was checked. The results from this comparison are contained in Table 1 and this demonstrates a good correlation based on the 5 and 95 percentile statistics. The average difference in levels is within the tolerance limits of the DTM data of +/- 150mm.

Table 1. Comparison of DTM and modelled manhole cover levels

Level Difference - Max	6.990 m
Level Difference - Min	-8.406 m
Level Difference - Average	-0.149 m
Level Difference - 5% percentile	-0.480 m
Level Difference - 95% percentile	0.210 m

3.4 Source Modelling – Where does the flooding occur?

The Source modelling used for this project differs from the standard use of a hydraulic model by taking into account low lying laterals and un-modelled sewers within the catchment when identifying flooding locations. Hydraulic models generally contain the main sewers or only those recorded within the sewer records and any predicted flooding will exit from these modelled manholes. This is represented in Figure 5. In reality, flooding due to hydraulic overload can occur from lateral connections where the lateral cover levels are lower than the modelled cover level and this shown in Figure 7.

Figure 5. Predicted flooding location without lateral representation

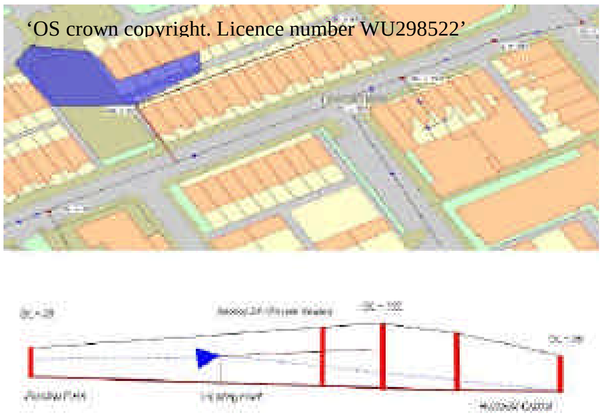

Figure 7. Predicted flooding location with lateral representation.

3.5 'Pseudo' Lateral Definition

Mouchel has developed an expertise in the automated digitisation of private sewer and un-mapped section 24 sewers. The process is based on the using building geometry data from OS MasterMap data to produce a 'pseudo' lateral. Each lateral is then linked to the nearest modelled sewer and the distance is recorded. Analysis of this distance attribute data revealed 98% of the laterals were located within 100m of the nearest sewer.

Further attributes describing the physical and geographic characteristics of the laterals and their position relative to the modelled sewer network were exported to form one of the data inputs to the 'Source Modelling' database. Examples of the outputs from the lateral modelling process compared to section 24 and private sewers already mapped with Severn Trent Water's sewer records (UADMS) are shown in Figure 9 and Figure 11.

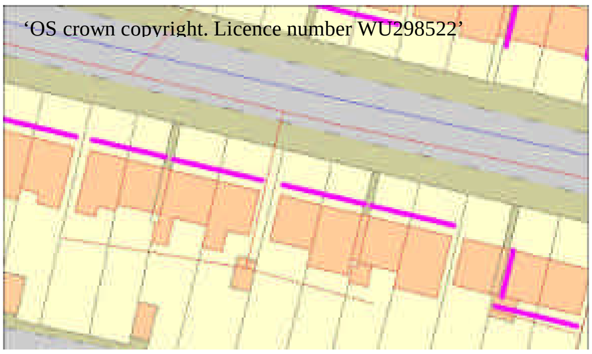

Figure 9. Pseudo laterals from pilot catchment vs UADMS mapped sewers.

Figure 11. Pseudo laterals from pilot catchment vs UADMS mapped sewers.

UADMS ——— Predicted Laterals ———

The above figures demonstrate the 'pseudo' laterals do not always represent the exact layout of the sewerage system on the ground, but give a better representation compared to the use of property address points to represent the laterals.

3.6 Hydraulic Performance Data

The source process requires flood and surcharge data from a verified hydraulic model. The flooding data was obtained by running the hydraulic model for return periods of 1 in 1, 2, 5, 10, 20 & 40 years. The maximum surcharge level achieved at each manhole for each storm event and flood volumes were extracted from the hydraulic model as inputs to the Source modelling database.

3.7 Flood Location and Flow Rate Determination

The objective of this stage of the process was to identify if flooding will occur from locations identified in the hydraulic model or from the low lying laterals. The determination of the flooding location was undertaken by analysing the modelled sewer characteristics data, the lateral definition information and the hydraulic performance results within an ACCESS database. The decision tree contained in Figure 12 was then applied to identify the lateral and main sewer flooding locations.

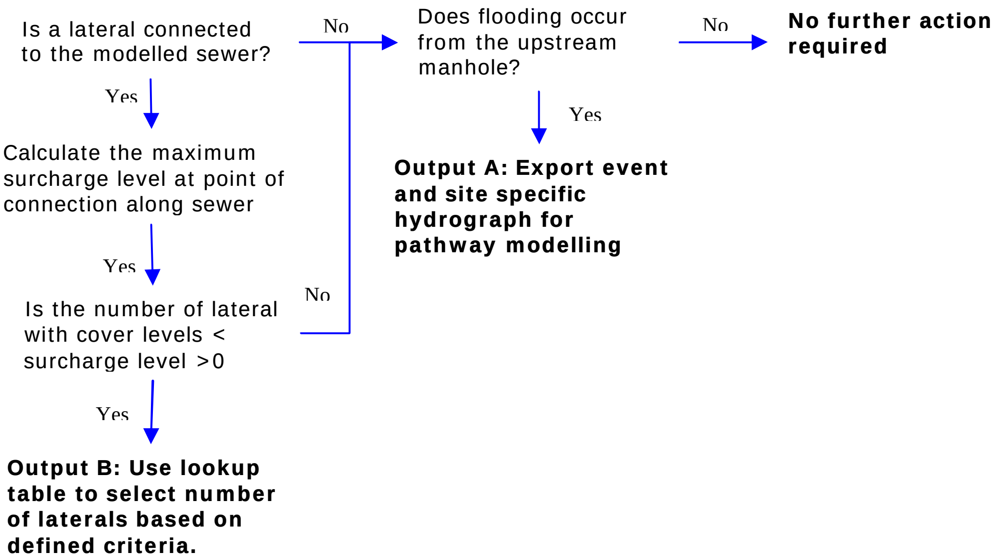

Figure 12. Flooding location decision tree

Further controls were introduced in the Source Modelling database to limit the number of lateral flooding points and flood flow rates. These controls were based on the physical characteristics of the modelled sewer to which the laterals were linked. A standardised time varying lateral flood hydrograph was also developed from analysis of the hydraulic model predicted flooding durations.

Table 2 compares the number of flooding locations derived directly from InfoWorks and those identified using the Source Modelling Database described above. The new approach does identify more flooding locations and this was expected given the increased detail by incorporating un-mapped lateral. The number of InfoWorks derived locations is reduced by about a half due to the flooding being moved to a lateral location.

Table 2. Comparison of Source modelling flooding locations

Storm Event	Number of flooding locations	
	InfoWorks	InfoWorks + Laterals
M1 120min	5	4 + 10
M2 120min	10	5 + 28
M5 120min	32	16 + 57
M10 120min	58	30 + 92
M20 120min	124	57 + 146
M40 120min	139	70 + 191

4 Pathway Modelling – Where does the flood water travel?

4.1 Flood Risk Mapper

The pathway element of the process was completed using Mouchel's Flood Risk Mapper (FRM) software application. FRM performs a two dimensional surface routing simulation accounting for the local relief, as well as local surface characteristics such as surface roughness and infiltration. The simulations are performed over uniform two dimensional grid of square cells and cell size can be varied depending on the DTM resolution and level of accuracy required. The application operates within MapInfo and this makes it very easy for anyone with an intermediate understanding of the GIS package to use the application.

The FRM simulation engine applies a two dimensional, regular grid method to determine direction, depth and speed at which flow propagates across the surface through application of Manning's equation. Pre-processing of the DTM to fill pits is not required (an advantage over some other surface routing tools that make use of a crude 'rolling ball' method) which means that the filling of depressions is accurately simulated, and the flood path develops over time as it would in reality. Furthermore, because the routing is using a realistic hydraulic simulation technique, the extent of the inundated surfaces are calculated, which provides data for the 'Receptor' stage.

The surface routing algorithm requires the following six properties to be attributed to each cell in the region of flow;

- Inflow
- Elevation grid
- Elevation modification
- Manning's Coefficient
- Saturated Hydraulic Conductivity
- Drainage Coefficient

4.2 Inflow

The Inflow attribute expresses the time varying flood flow rate obtained from the Source modelling process. The attributes are communicated to FRM as a flooding locations and profile tables. The locations table contains coordinates, flooding reference point (this is generally the asset reference from where the flooding occurs), flood flow rate and an event reference to allow continuous simulations of multiple events. The profile table provides the option to use time varying flood flow hydrographs. The hydrographs can consist of variable flow rates over time or a multiplying profile which is used to change the constant flood flow rate contained in the flooding location table.

4.3 Elevation grid

The elevation grid is derived from the Digital Terrain Model (DTM) data and FRM can use resolutions ranging from 0.5m to 10m. This process reduces the files sizes by up to 30%, which aids data storage issues. FRM allows the data to be visualised and modified to incorporate any local features.

Two types of adjustment were made to the elevation grid.

- Road Level Adjustment – The level of all roads was reduced by 100mm to account for kerbs.
- Building Level Adjustment – The level of all the buildings was increased by 5m. This allows the flow to be routed around buildings, but will not account for flood waters entering the buildings, but this can be simulated by changing this single parameter.

4.4 Surface properties

The Surface grid containing information about the underlying ground beneath each grid squares and this allows different simulation parameter to be applied to each surface types. The grid is populated by 'Sampling' the OS MasterMap data to determine the predominant surface type within the grid. MasterMap holds data not only about the layout of surface features, but also about the nature of those features. It has been described as an 'intelligent map'. Thus, for example, surface features such as roads, fields and water bodies can be identified by their respective feature codes. Sampling processes the many feature codes used in MasterMap to a reduced number of surfaces and allows the different simulation properties to be applied to each of the surface types.

The resolution of the grid is critical in the surface routing process as it significantly influences the route the flood paths travel along. The importance of the sampling for the Evington catchment can be demonstrated by the need to represent the alley ways which exist between some terraced properties as show in Figure 13 and Figure 14. The sampling was set up to try and ensure the alleyways were represented in the surface grid and this was achieved at a 1m resolution (Figure 15 and Figure 16). A larger grid would make the representation of this detail more difficult to achieve.

Figure 13. Example of alleyway between terrace properties

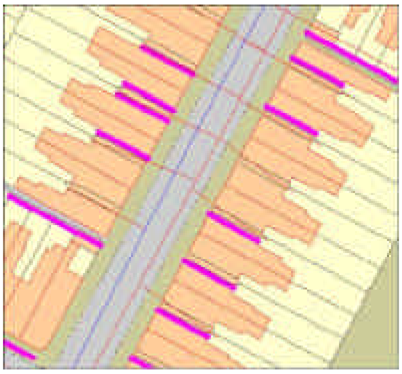

Figure 14. 0S MasterMap

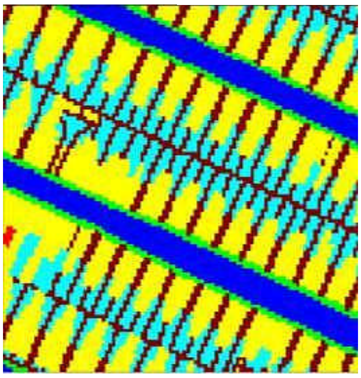

Figure 15. Surface Grid

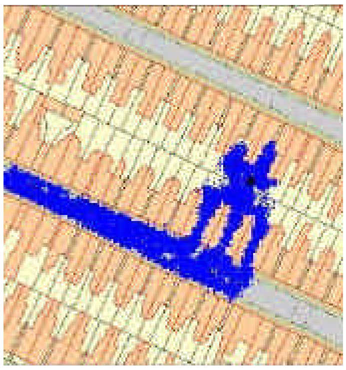

Figure 16. Flood path flowing between buildings

The use of a surface grid allows different hydraulic parameters to be applied to the different surface types. The hydraulic parameters used in the pilot study include:

- Infiltration Rate - A standard infiltration rate was used for each of the surface types. The road infiltration rate reflects typical gully spacing along roads and their operational capacity during a storm event. The rate for open land was equivalent to that of loam over clay and this can range from 0.0005 to 0.005 mm/hour.
- Manning's Roughness – A low Manning's value of 0.015 has been used for roads and paths, but was increased to 0.075 for curtilage and open land to reflect the impact of vegetation and other small structures which decrease the flood path velocity.

- Simulation Duration – The pathway simulation duration was equal to the hydraulic model simulation duration, plus 60 minutes to provide sufficient time for the pathways to achieve their full extent.

These input parameters were derived from engineering principles and then sensitivity tested against the predicted change in service impact as determined from the Receptor modelling process.

5 Receptor Modelling - What impact does the flood path cause?

The Receptor modelling process defines the service impact leading from the flood path. FRM contains the functionality to quantify these service impacts in a user configurable framework. The functionality makes use of the OS MasterMap topographic, Integrated Transport Network and Address2 layers to provide a very detailed assessment of the impact, but it can be configured to provide simple impact summaries (e.g area and depth of flooding).

The service impact framework used in the receptor modelling process for this pilot study is contained in Table 3. The framework can be extended to cover traffic disruption, pollution impact and health and safety impact or specific property type such as schools, hospitals, etc.

Table 3. Receptor modelling criteria

Service Impact	Severity (Depth mm)				Units
	1	2	3	4	
Internal Flooding	0 to 150	151 to 300	300 to 450	>450	No Properties
External Flooding - Curtilage	0 to 150	151 to 300	300 to 450	>450	No Properties
External Flooding – Highway	0 to 150	151 to 300	300 to 450	>450	Area (m^2)
External Flooding – Other	0 to 150	151 to 300	300 to 450	>450	Area (m^2)

The receptor modelling for the pilot study has been configured to provide a summary table of the service impacts predicted by each simulation, plus a detail output of the building flooding locations. The summary table provides the ability to interpret the large quantities of data produced by the process and has been used to assess the results from the different modelling scenarios considered. Detailed information about each building flooded can be exported, including location details, storm return period at which flooding first occurred, type of property and predicted depth of flooding outside the property.

6 Results

6.1 Predicted DG5 at Risk Register

The outputs from the modelling process were a summary of all the flood impacts for the different storm durations as shown in Table 4 and a predicted DG5 at risk property register. The property register details the individual properties at risk of internal flooding, there property use, location, predicted return period of when internal flooding will first occur and predicted depth of flooding.

Table 4.Predicted Flooding Register Summary

ConsequenceMeasure	Severity	G1_M1_120_ FP220min_L	G1_M2_120_ FP220min_L	G1_M5_120_ FP220min_L	G1_M10_120_ FP220min_L	G1_M20_120_ FP220min_L	G1_M40_120_ FP220min_L	Units
FExternal -Highway	0to150Area	2169	5061	8925	14360	28850	45107	Areas
FExternal -Highway	150to300Ar	1870	2072	3409	6497	14429	23415	Areas
FExternal -Highway	300to450Ar	54	910	158	748	2010	3251	Areas
FExternal -Highway	>450Area	66	249	1599	3131	8310	14682	Areas
FExternal-Curtilage	0to150Area	3082	6846	9940	19305	21556	39603	Areas
FExternal-Curtilage	150to300Ar	1043	3447	5985	4351	10009	14749	Areas
FExternal-Curtilage	300to450Ar			193	542	992	2137	Areas
FExternal-Curtilage	>450Area					183	209	Areas
FExternal-Other	0to150Area	5302	8226	14377	25809	33355	46648	Areas
FExternal-Other	150to300Ar	1460	1379	1994	6335	12401	24101	Areas
FExternal-Other	300to450Ar		414	1350	1119	1505	8131	Areas
FExternal-Other	>450Area		41	89	404	2363	3665	Areas
FInternal	0to150	72	113	226	411	602	882	Buildings
FInternal	150to300	5	27	50	57	119	181	Buildings
FInternal	301to450		1	13	13	23	28	Buildings
FInternal	451>				1	9	10	Buildings

The predicted buildings flooding register for the Evington catchment contained a total of 140 building where the flood depth outside the building was greater than 150mm and a high proportion of these are dwellings, but flooding is also predicted at a school and a number of commercial premises.

Examples of the flood paths developed from the pilot study process using a 40 year storm event are shown in Figure 18 and Figure 20. Explain paper

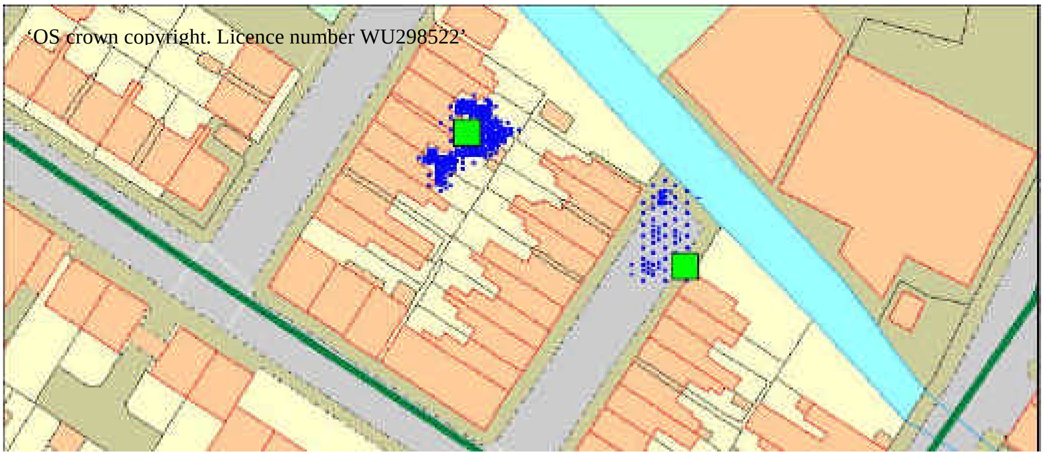

Figure 18. Example flood paths.

Figure 20. Example flood paths.

6.2 Validation

The Predicted DG5 Register was compared with the actual DG5 register for the catchment to validate the approach and this was completed using a series of quantative and geographical analysis techniques.

The predictive DG5 modelling identified 103 properties at risk of internal flooding from storms with a 1 in 20 year return period or less compared to 24 properties on the current register. This indicates a the number of properties at risk of sewerage flooding is four times greater than the existing register. This increase is significant, but it represents only 0.3% of the total number of properties in the catchments and allows further site investigations to be completed to confirm the existence of the risk.

A detailed comparison between the predicted and current DG5 at-risk register was completed and this determine the following statistics:

- Total of 208 current and predicted locations were identified in the catchment as suffering from flooding on storms with a return period equal or less than 1 in 40 years
- 24% of these properties were present on both the existing and predicted registers
- 59% of these properties were contained only on the predicted register.
- 17% of these properties were contained only on the current predicted register.

7 Conclusion

The pilot study has enabled a process to be developed to account for low lying laterals in predicting properties at risk of flooding. The validation against the current DG5 register indicates the process can identify properties currently on the register and those properties/areas at risk of flooding. The criteria used to identify properties at risk of flooding (>150mm outside the property) and the location of the low lying laterals in relation to the sewerage system are crucial to the accuracy of the process.

The process developed does provide sufficient accuracy for strategic planning purposes and targeting further investigations to confirm the existence of the risk.

8 Future Development

The process developed from the pilot study has been improved to account for different storm durations within each of the return periods assessed and the updated process is currently being applied to a further 15 drainage areas across the Severn Trent region. The outputs from these catchments will then be used by a multi objective regression analysis technique to estimate the total number of properties at risk of internal flooding from sewers.

It is the intention to use the outputs from this process to target further investigations to confirm the risk. The investigations will include site surveys and further detailed modelling and feedback gained from this process will be used to further improve the methodology developed from the pilot study.

The use of InfoTerra's high resolution LIDAR data captured from the streets is currently being explored to improve the accuracy of the modelling. This data is currently being captured for those locations where flooding occurs on the highway or at the front of properties and it is hoped to use the data to identify property threshold levels.

FRM is currently being developed inline with the products development plan to provide the following additional functionality; tracking of flood sources, output of surface flow hydrographs for inputs to 1 dimensional hydraulic modelling packages and improved animation.

9 Acknowledgements

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