MODELLING TO IDENTIFY POTENTIAL DG5's

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INTRODUCTION

Yorkshire Water Services are required by the Director General Water Services to keep a register of properties "at risk" of flooding. It is intended that this register should be completed as part of the Drainage Area Study Programme and a Strategy Group was formed to consider ways of producing the register.

Simulations using hydraulic models will not automatically identify properties at risk of flooding. Four phases of survey work were identified by Yorkshire Water Services which could provide improved levels of accuracy in the preparation of the "at risk" register from hydraulic models. A pilot study was commissioned so that the procedure could be tested and amended before it is generally adopted.

Wilde Allison were appointed by Yorkshire Water Services to undertake the pilot study on four areas representative of the different geographical locations within the Yorkshire Water region.

Sites Selected for Study

The drainage areas selected by Yorkshire Water for inclusion in the study are shown in the following table.

DETAILS OF THE DRAINAGE AREAS

Drainage System	Population	Area Km^2	Surveyed Sewers (Km)
Cononley	2000	0.2	3
Wath-upon-Dearne	17000	4.5	18
Thorne	6000	1.5	6
Hornsea	12000	3.0	12

The study areas had different characteristics. There were variations in size, topography, land use and significantly, availability of digitised sewer records. A verified hydraulic model was available for each area, but the quality of manhole records and record plans varied. Computerised sewer records were available for Cononley and Hornsea. Paper Records were available for Thorne, but records for Wath upon Dearne in places did not agree with details on the Wallrus model. Thorne and Hornsea have had re-sewerage work undertaken during the past year, but records from the original hydraulic model were used for the study. The sewers in the areas are predominantly combined.

Brief Description of Study Areas

Cononley is a typical Pennine village with a dendritic drainage system. The majority of houses are situated above road level and previous studies had identified that there were no properties where flooding had been recorded.

Wath upon Dearne is built on a hill side which slopes quite steeply to a valley bottom. Drainage down the slope is rapid but sewers running across the slope have flat gradients. Many houses are built below road level and there is potential for flooding of properties.

Thorne is situated on the low lying ground between the River Trent and River Don near to the Humber estuary. The ground level varies between 4m and 6m above ordnance datum and sewer gradients are flat. The downstream end of the sewerage system is below sea level and all sewage has to be pumped to outfalls. Very few properties are built below road level and none have cellars. Areas of confirmed flooding have been identified in the past.

Hornsea is a seaside town on low lying but undulating land. Sewer gradients are generally not a problem. The sewerage system discharges to the sea. The main potential for flooding in the town has been associated with lack of capacity in the sewers rather than operational problems.

YORKSHIRE WATER SERVICES REQUIREMENTS OF STUDY

a) Simulate a 1 in 5 year design storm of 50% summer profile with storm durations of 15, 30, 60 and 120 minutes on the four models listed.

b) Undertake the following appraisals on each model:-

Phase 1 - Desk Top Study

Using local knowledge identify those properties considered to be at risk by means of a desk top study.

Phase 2 - Brief on Site Survey

Where local knowledge is either not available or at sufficient detail, a brief on site inspection to assess the topography should be carried out.
There should be no physical levelling at this stage.

Phase 3 - Partial Survey

Where hydraulic models which have been simplified exhibit surcharging or flooding then levels of intermediate manholes and/or ground levels to be determined, thus locating the flooded area more precisely.

Phase 4 - Full Survey

In areas where there are cellars or properties below the level of the road in which the sewer has been laid and surcharging is predicted, it will be necessary to undertake a full survey of the area to refine the model. Some locations required to be surveyed may be on a private system.

c) Prepare plans at an appropriate scale showing the complete sewer network in the modelled area, together with schematic of the modelled network.

d) Undertake, as appropriate, field surveys to obtain sewer record information to comply with Phase 3 and Phase 4.

It should be noted, however, that the properties identified by the various phases of this study are only 'potentially at risk'. A property is categorised as 'at risk' only if it has actually been affected by flooding more frequently than once in ten years. In order to confirm these details in the study areas, it was necessary to send out flooding questionnaires to relevant properties. Although this was not part of the original brief it was undertaken by YWS agents in specific cases after the main study report from Wilde Allison.

PILOT STUDY

LEARNING OBJECTIVES

From the practitioners perspective, the pilot study had the following learning objectives:

1 To identify the effectiveness of each stage in providing information regarding properties at risk of flooding.

2 To identify the costs associated with each stage

3 To develop a methodology which would provide the most cost effective way to carry out future studies and which could generally be applied to hydraulic modelling.

4 To identify test and use appropriate technological tools to provide cost effectiveness and a quality product.

PLANNED ACTIVITIES

Objectives 1, 2 and 3 were satisfied by identifying the activities to be carried out, and accurately monitoring work done, costs incurred and benefits gained by carrying out those activities. The activities were initially identified as follows:

PHASE 1 - RUN MODEL AND CARRY OUT DESK TOP STUDY

1 Acquire SSD, Drawings, Sewer Records and Operational Data
1a Visit 1 - identify data available, specify requirement and collect SSD
1b Visit 2 - collect remaining data
2 Convert to WALLRUS
3 Check Videos of CCTV surveys and input silt and roughness
4 Produce PCD
5 Simulate Events
5a without silt, blockages and local roughness modelled
5b with silt, blockages and local roughness modelled
6 Record results on drawings
7 Interrogate O.M.S
8 Compare modelled results with operational data
9 Check results with DC

PHASE 2 - BRIEF ON SITE STUDY

1 Visit all locations of modelled flooding and determine flood routing
2 Identify flood routing on plan
3 Highlight properties at risk

PHASE 3 - PARTIAL SURVEY

1 Identify levels from sewer records, including laterals
2 Survey where cover levels not known
3 Plot Long Sections and indicate hydraulic gradient

PHASE 4 - FULL SURVEY

1 Identify other low spots including private drainage systems, gulleys and cellars
2 Level other low spots
3 Plot Long Sections and indicate hydraulic gradient

THE STUDY PROCESS

PHASE 1 - DESK TOP STUDY

Collection of Data

The following table identifies; the number of manholes within the modelled network, the number of modelled nodes, the number of covers that required levelling and the number of additional pipes required to de-simplify the model. It gives an impression of the quality of data available for each study area:

Drainage Area	No of Manholes within Network	No of Modelled Nodes	No of Covers Requiring Levelling	No of Additional Pipes Required
Cononley	111	109	3	-
Wath-upon-Dearne	560	245	97	
Thorne	231	146	5	4
Hornsea	272	203	-	11

SUMMARY OF MODELLED SYSTEMS

Validation of Data

The accuracy of existing data bases is crucial to the identification of properties at risk of flooding. The first stage of the desk top study was to validate the computerised data sets.

The data of particular importance in this study is related to connectivity and manhole cover levels. Wilde Allison's in house asset database was used to identify the location of any wrong or missing data. The number of covers requiring levelling is given in the previous table. CDR data sets were available for Cononley and Hornsea. The records for Wath and Thorne were digitised as part of the study, a number of inconsistencies between the model and sewer records being found in the Wath study area.

Hydraulic Analysis

The design storms for the prescribed durations as set out in the brief were simulated using WALLRUS software. Simulation times were set to ensure that any flooding or surcharging had ceased before the end of the run.

Surcharging and flood volumes predicted at a particular node varied with the duration of the event and the location of the node within the network. The most onerous cases of surcharging and flooding produced by the simulations were used in the study.

Presentation of Results and Predicted Location of Flooding and Surcharging

SSD files for each model were mapped into the consultants in-house asset management data base. This enabled true representation of the modelled network on both plans and long sections.

WALLRUS output files (PRN files) were imported into the asset data base and the hydraulic performance report was generated, identifying flood volume, surcharge depth and critical duration at each node. The report also indicates where flooding may occur at intermediate manholes within surcharged modelled lengths.

The information was exported to Autocad to be used for the production of plans indicating the location of flooding and surcharging.

Identification of Properties Considered to be "At Risk" in Phase 1

Identification of properties considered to be "at risk" was made from three sources:-

a) the existing DG5 register.
b) local knowledge.
c) data from the WALLRUS (PRN) files.

The locations at which flooding was modelled and at which properties were subsequently demonstrated to be at risk were tabulated.

The number of locations of predicted flooding, where properties were shown not to be at risk were also tabulated.

PHASE 2 - BRIEF ON-SITE SURVEY

The purpose of the initial site visit was to make an assessment of the extent to which the floodwater discharge predictions made by the WALLRUS model would affect properties in the areas where sewers flood.

A visual appreciation of the topography adjacent to flooding manholes enables the probable path to be taken by the floodwater to be established. If large volumes of floodwater are predicted, a judgement has to be made on the extent to which highways, gardens or properties are in the direct line of overland flow. This enables a list of potentially "at risk" properties to be identified.

These properties are then added to the list of "at risk" properties identified at Phase 1.

PHASE 3 - PARTIAL SURVEY

A WALLRUS model network is usually a simplified version of what actually exists in practice. One pipe in the model may be made up of a series of real pipes of similar diameter and gradient. While this does not cause any problems in the hydraulic analysis of the network, it does mean that WALLRUS can only predict the escape of floodwater at node points. In practice, there may be some intermediate manholes on the modelled pipe with cover levels below the hydraulic gradient. It is from these intermediate manholes that floodwater would escape rather than from the nodes.

In order to accommodate this situation, long sections are needed showing the intermediate manhole cover levels and the hydraulic gradient. Long sections of all modelled sewers were drawn utilising the asset data base and a 'development' Long Section Module.

In some locations intermediate manhole cover levels on surcharged sewers were not available from the sewer records. These had to be obtained by levelling on site. To avoid any errors arising because of subsidence etc, the cover levels of intermediate manholes were related to node cover levels.

In cases where the hydraulic gradient was above an intermediate manhole cover on a surcharging WALLRUS branch, this manhole was made a node point, the model de-simplified and revised simulations made. The recalculated volumes of floodwater and locations were noted. The extent of the de-simplification and number of manholes requiring levelling are shown in the following table

Location	Number of Wallrus Lengths De-simplified	Number of Intermediate Manholes Levelled
Cononley	Nil	3
Wath-Upon-Dearne	21	97
Thorne	4	5
Hornsea	11	Nil

CHANGES REQUIRED TO ORIGINAL MODEL FOR INTERMEDIATE MANHOLES

A further site visit had then to be undertaken to revise the details of the properties "at risk" in the light of the new data.

The site visit followed the pattern of the Phase 2 site visit but special attention was given to those nodes where the revised model produced significantly different volumes of floodwater to the previous model. In situations where the volume had been reduced, some properties identified as being "at risk" at the Phase 2 stage were now deemed not to be "at risk". Similarly, other properties adjacent to intermediate manholes which now exhibited new or increased flooding were added to the list of "at risk" properties.

This addition and removal of properties were tabulated, additions being shown with ticks and removals with a cross.

PHASE 4 - FULL SURVEY

The previous phases identified properties at risk of flooding from the modelled nodes, but failed to identify some properties which may be at risk. These properties are:-

a) Properties below road level where the sewer is surcharged but no flooding is predicted. Typically, the effects in this situation will be flooding from inspection chambers and loss of toilet facilities on ground floor toilets.

b) Properties with cellars which drain directly to the sewer. As the hydraulic gradient rises the cellar floods.

To identify properties in these situations a full survey is necessary where the model predicts surcharged sewers.

Properties situated below road level are readily identified usually but for b) the guidance of the local authority was sought prior to undertaking the survey. Where properties were identified as being in category a) or b), cellar levels, inspection chamber cover levels etc were obtained and marked on the long sections. If these levels were below the hydraulic gradient, the associated properties were marked on the plan as "at risk" of flooding. These properties were also tabulated.

EXPERIENCE GAINED DURING PILOT STUDY

Comments on factors influencing the cost and success of the work done in each phase are set out below.

Phase 1 - Run Model and carry out Desk Top Study

a) Acquire Data

In Wath and Thorne, the lack of computerised data meant that the manhole locations for the modelled network had to be digitised. Although digitisation is carried out at a cost there are subsequent savings in the production of plans and long sections.

The experience gained from Wath is that sewer records should be made available at the start of the study so that there is no need to digitise from small scale plans. Alternatively those areas identified for this type of study should have their records digitised in advance as part of the regional programme.

b) Hydraulic Analysis

A WALLRUS model is necessary to be able to undertake the hydraulic analysis and in the case of the four areas studied, verified models were available. Conversion of data from WASSP files was not necessary for this study but should this be needed for future studies no problems are envisaged.

No recent CCTV videos were available. Roughness and silt levels were determined from videos made at the time of the production of the hydraulic model. If it is considered that roughness and siltation are important factors in the modelling of a sewerage system then these should be obtained.

c) Producing Drawings

In the absence of computerised data, results of the WALLRUS analysis have to be added to the drawing by hand. This is effective if there is no requirement to continue to the subsequent phases of the study and there is no concern about intermediate low spots.

Phase 2 - Brief on Site Survey

This Phase of the work was generally straight forward and no problems occurred.

Phase 3 - Partial Survey

The extent of this work depends largely on the standard of the sewer record drawings and detail in the model. At Wath upon Dearne, only those manholes which were model nodes had been levelled. Another 97 intermediate manholes had to be levelled on surcharged sewers. At Hornsea, all required levels were on the plans or in the model.

Phase 4 - Full Survey

The amount of work required at this stage is related to the ground profile and the extent of cellars. With undulating ground there is a strong possibility that cover levels of private connections to surcharging lengths will be lower than the WALLRUS node levels. On the other hand, there were no low spots in Thorne because of the flat topography.

ANALYSIS OF RESULTS

At the start of the study a number of positively identified properties at risk of flooding were included on the DG5 register. These were added to as a result of the initial simulations and site visits to give the total for the combined Phases 1 and 2. After the de-simplification of the model and the subsequent simulation a further site visit was carried out. Properties were added or removed at this stage to give the total for Phase 3. Low spots including cellars and local drainage systems were levelled and the register was adjusted to give the final total.

The following tables summarise the costs and benefits of each phase. The number of flooding pipes according to WALLRUS is shown above each table.

The cumulative number of properties at risk includes both those identified during the study and those already on the DG5 register. Phase 1 and 2 are combined because Phase 1 simply indicates areas worthy of a Phase 2 visit.

The number of extra properties identified during each phase is shown, along with the number of properties excluded during the phase.

A summary of the cumulative cost is shown for each phase, along with the cost incurred is shown in the following table:

COSTS AND BENEFITS

	CONONLEY	WATH	THORNE	HORNSEA
EXISTING DG5 No of Properties Identified	NIL	2	1	23
PHASES 1 & 2 Cost No of Properties Added	2117 3	7358 41	3362 13	2934 56
PHASE 3 Cost No of Properties Added or Removed	1240 NIL	6757 NIL	2174 NIL	2517 9
PHASE 4 Cost No of Properties Added	963 1	1564 NIL	871 NIL	1090 3

Discussion

A desk top study alone would result in an underestimation of flooding and cannot be relied upon without the addition of site visits. The work carried out in Phase 2 identifies the vast majority of properties at risk. However, where there is undulating ground together with over simplification of models and/or properties lying below modelled ground levels where sewers surcharge, Phases 3 and 4 will add or subtract from the list of properties identified in Phase 2.

In all cases the model predicted more locations of flooding than had confirmed properties at risk. It can be concluded that a site survey is essential

Simplified models require a greater degree of analysis and a greater degree of site survey.

The need for a full survey (phase 4) cannot be pre-determined it is dependent on the property and the occurrence of surcharging within the network.

The cost of identifying individual properties at risk ranged between £32 per property and £580 per property for Phases 1 and 2, £57 and £926 for Phases 1, 2 and 3 and £66 per property and £878 per property for Phases 1, 2, 3 and 4.

The significant increase in cost occurs between Phases 2 and 3 and results principally from the duplication of a site visit. However the costs of Phases 3 and 4 were limited during the study because of the availability of software to produce accurate long sections. Without this software the sections would require significant manual input with resultant additional cost.

Given the availability of software and computerised sewer record data, long sections can readily be produced as part of Phase 1. This leads to a process by which the requirements of a single site visit can be determined in better knowledge of the circumstances and after any necessary model de-simplification has been carried out. The recommended process is set out below.

RECOMMENDED PROCEDURE FOR IDENTIFYING PROPERTIES AT RISK OF FLOODING

The next table sets out the original procedure for carrying out the study against that recommended as a result of experience gained during the study.

ORIGINAL AND RECOMMENDED PROCEDURES FOR IDENTIFYING PROPERTIES AT RISK OF FLOODING

ORIGINALLY PROPOSED PROCEDURE	RECOMMENDED PROCEDURE
PHASE 1 - RUN MODEL AND CARRY OUT DESK TOP STUDY	PHASE 1 - COLLECT DATA AND CARRY OUT DESK TOP STUDY
1 Acquire SSD, Drawings, Sewer Records and Operational Data 1a Visit 1 - identify data available, specify requirement and collect SSD 1b Visit 2 - collect remaining data	1 Acquire SSD, Drawings, Sewer Records and Operational Data 1a Visit 1 - collect SSD, computerised data and 1:1250 plans 1b Visit 2 - collect remaining data
2 Convert to WALLRUS	2 Convert to WALLRUS (if necessary)
3 Check Videos of CCTV surveys and input silt and roughness	3 Check Videos (if taken since verification) for roughness and amend
4 Produce PCD	4 Produce RED file for WALLRUS
5 Simulate Events 5a without silt, blockages and local roughness modelled 5b with silt, blockages and local roughness modelled	5a or 5b Simulate events on WALLRUS
6 Record results on drawings	6 Digitise sewer records for modelled system where necessary
	7 Plot plans and long sections showing flooding and surcharge.
	8 Identify low spots and check for missing cover levels on long sections
	9 Level missing covers/low spots on surcharging sewers.
	10 Re-plot long sections and de-simplify model where necessary.
7 Interrogate O.M.S	11 Re simulate events and re-plot plans and long sections to identify real locations of flooding.
8 Compare modelled results with operational data	12 Compare modelled results with operational data
9 Check results with DC	13 Check results with DC
	14 Assess requirements of site visit.

ORIGINALLY PROPOSED PROCEDURE	RECOMMENDED PROCEDURE	
PHASE 2 - BRIEF ON SITE STUDY	PHASE 2 - ON SITE STUDY	
1 Visit all locations of modelled flooding and determine flood routing	VISIT TYPE A	VISIT TYPE B
2 Identify flood routing on plan	Visit all locations of modelled flooding to assess routing.	Visit all locations of modelled flooding to assess routing. Identify and level other low spots including private drainage systems, gulleys and cellars on surcharging sewers.
3 Highlight properties at risk	Plot plans showing flooding, surcharge, flood routing and properties at risk.	Plot long sections identifying hydraulic gradient in relation to low spots. Plot plans showing flooding, surcharge, flood routing and properties at risk.
PHASE 3 - PARTIAL SURVEY		
1 Identify levels from sewer records, including laterals		
2 Survey where cover levels not known		
3 Plot Long Sections and indicate hydraulic gradient		
PHASE 4 - FULL SURVEY		
1 Identify other low spots including private drainage systems, gulleys and cellars		
2 Level other low spots		
3 Plot Long Sections and indicate hydraulic gradient		

The next table compares the cost of adopting the recommended procedure compared with that of using the original methodology.

Drainage Area	Cost of Current Study	Cost of Recommended Procedure	Cost Saving
Cononley	4,320.00	3,562.00	758.00
Wath-upon-Dearne	15,679.00	11,333.00	4,346.00
Thorne	6,407.00	5,092.00	1,315.00
Hornsea	6,544.00	5,104.00	1,440.00
TOTAL	32,950.00	25,091.00	7,859.00

COMPARISON OF COSTS OF CURRENT STUDY AND RECOMMENDED PROCEDURE

It is evident that there is a cost saving for each study if the recommended procedure is adopted.

MAIN STUDY

The pilot study was completed in the four months to November 1992. In December 1992 estimates were requested for a second study. Costings were produced for a number of drainage areas of varying size, population, land use and data quality. From these 8 were selected and the studies were completed during February and March 1993.

The recommended procedures were adopted and the final report was produced at 86% of the estimated cost.

The reason for this cost saving was not due to over-cautious estimating but to the enhancements to the asset data base made during the intervening period. In addition to the inclusion of the long section routine in the data base menu system, improvements to the hydraulic model management system had been made. Reports comparing the model with the real system were produced allowing greater direction to be applied to de-simplification and data collection.

The main study confirmed the advantages of having computerised sewer record available prior to commencing studies. It also demonstrated that data bases can be used to direct and minimise the amount of site work if used appropriately. This is particularly important when tackling large scale data upgrading exercises as the need for blanket surveys can be eliminated.

The following table shows the estimated and actual costs for the eight studies and the percentage difference:

STUDY AREA	ESTIMATED COST	ACTUAL COST	% DIFFERENCE
Darton and Barugh	6,100	5,935	97.30
Oxenhope	4,200	3,737	88.98
South Emsall and South Kirby	7,650	5,453	71.28
Masborough and Kimberworth	10,550	8,343	79.08
Mosborough	5,000	5,139	102.78
Market Weighton	5,750	5,035	87.57
Harrogate South (Starbeck sub area)	8,200	7,696	93.85
Upper Middlethorpe	5,650	4,401	77.89
TOTAL	53,100	45,739	86.14

CONCLUSION

Following the initial assessment of properties at risk it was felt that the numbers should be refined and that the revised procedure has now been incorporated into the Company's drainage Area Planning Technical Approach for use in all drainage area studies. For those studies completed prior to the introduction of the new methodology a programme of works has been initiated to ensure that all areas in Yorkshire are eventually covered.

It has been found that some verified models were indicating flooding in areas from which no flooding reports had been received. In these areas questionnaires/letter drops have been used to ascertain if there had been flooding which the owner/occupiers had not reported. Where these activities had not produced confirmation of flooding then these properties are not being added to the "at risk" register, but a watching brief is kept on the area by the agent council to determine if or when a flooding incident occurs corresponding to one predicted by the hydraulic model. Consideration is also being given to revisiting the model to ensure that it is truly representing the flow regime in the network.

In conclusion it is believed that the two studies carried out by Wilde Allison have enabled Yorkshire Water to introduce the most cost effective methodology for refining the number of properties on the "at risk" register. The procedure in accepted by the Company's external auditor.

WaPUG Autumn 1993

Questions from Technical Sessions 1, 2 and 3

Technical Session 1 Chairman Andy Eadon Severn Trent Water

Modelling to Identify Potential DG5's
Peter Myerscough Yorkshire Water Services
John Blanksby Wilde Allison

Question Philip Mason Howard Humphries and Partners

Is it not important to visit cellars to check that there is a sewer connection?

Answer

Yes but was not part of the brief. Some properties and cellars appear to be connected to the sewer but actual drainage path is through rear of a property to another part of the system.

Question Richard Long Acer Engineering Ltd

Cellars can flood without being connected, exfiltration from surcharged pipes coming in through cellar walls.

Answer

Yes this has been reported.

Question Martin Osborne Wallingford Software Ltd

On simplification are you saying don't simplify or simplify carefully?

Answer

Simplify carefully.

Question Ian Forbes Thames Water Utilities Ltd

Why did you choose 1 in 5 year summer storms of those particular durations?

Answer

These were defined by the DG as twice in 10 years 1 in 5 year is the interpretation

Question Jon Farrer MW Barber Group

What about operational problems causing flooding i.e. silt roots etc?

Answer

If shown to be an operational problem then rectified and not included on "At Risk" register.

Question Peter Crisp Wessex Water

You say it is a cost effective method but only showed 15% savings on initial estimate, how accurate was the initial estimate and can you support it?

Answer

We compared the cost the cost of the revised methodology with the initial methodology. Additional savings were made by developing software applications.

Question David Wright Consultant

Authors state that properties identified by model analysis are only "potentially at risk", and that it is only if a property has actually been affected by flooding more frequently than once in ten years that it is categorised as " at risk".
Our experience of WALLRUS/SPIDA is such that we have reasonable confidence in its predictions of flooding-location,duration probability etc.
Whether a property floods in any defined period depends completely on whether storms of sufficient severity have actually occurred in the period.
I question the wisdom,therefore, of relying more on historic records for this purpose, than the predictions of a model run with statistically representative storm data.

Answer

A wall built and effectively verified model will give accurate predictions of flooding. In the past recording systems have been poorly maintained. Also occupants do tend to move house so they do not necessarily have the knowledge. Models have been proved correct on numerous occasions when negative responses to enquiries have been received. The standard of model building has improved with time, but this process is being applied to all models, irrespective of age. Therefore it is necessary to have positive confirmation that flooding occurs.