WEST GARFORTH
INTEGRATED URBAN DRAINAGE
PILOT STUDY

FINAL REPORT

Leeds City Council
City of Bradford Metropolitan District Council
Yorkshire Water Services
The Environment Agency
Pennine Water Group (Universities of Sheffield and Bradford)

(November 2006 – April 2008)

1 EXECUTIVE SUMMARY

The West Garforth Drainage Area has a long history of flooding problems, going back to the 1980s and earlier. Many properties were flooded internally in June 2007, during the project period. The backbone of the drainage infrastructure is a system of inadequate culverted watercourses, passing through hundreds of private properties. In the early 1990s – as the sewerage agent of Yorkshire Water Services (YWS) – Leeds City Council designed a trunk surface water sewer scheme to replace the inadequate culvert. This was later shelved by YWS on the basis of a re-appraisal of responsibilities of the sewerage undertaker.

This IUD pilot project was carried out by a partnership involving Leeds City Council, Bradford Metropolitan District Council, Yorkshire Water, the Environment Agency and the Pennine Water Group (Bradford and Sheffield Universities). The fundamental aim is to examine a range of approaches to develop more integrated urban drainage management, including examples of best practice in both technical terms and stakeholder collaboration. It also aims to see whether closer collaboration between agencies could identify innovative and feasible solutions, despite perceived regulatory difficulties.

Shared record data, along with supplementary surveys, was used to build a computer model of the surface water drainage and the model was verified by use of observational data from a new short-term flow survey, along with historic data. Engagement with the residents by means of newsletters and two public meetings also produced a wealth of incident data as well as proposals for remedial measures.

The report shows that, as soon as serious resources are made available for investigating flooding problems and inspecting the condition of culverted watercourses, then opportunities for relatively modest actions become apparent that can have a significant beneficial impact. The simple task of carrying out CCTV survey, for example, necessitated silt and obstruction removal that will have made a real difference. Excavation to construct new manholes for survey access revealed constricted pipe junctions that have now been removed. Investigation of sewer connectivity, for modelling purposes, enabled the explanation and resolution of some long-standing, non-hydraulic, sewer flooding problems.

A significant number of the blockages in culverts and highway drains were caused by services severing them. This is probably a result of the absence of any statutory record of culverts and highway drains that undertakers must consult.

Data sharing between the partners has been largely successful, but a number of issues need to be resolved in order to facilitate the degree of record sharing that will be necessary in order to make the development of genuinely holistic Surface Water Management Plans viable.

Modelling identified six areas in West Garforth with significant flood risk. The use of a design rainfall event with a return period of 2 years indicated that significant flooding would be likely to occur at two of these locations with minor flooding at two others. If a rainfall event with a return interval of 30 years was used significant flooding would be expected at all six areas. Modelling was also used to predict changes in future flood risk. Future rainfall predictions indicated that flood volumes, from a rainfall event with a 30 year return period, would have increased in this catchment by around 50%, by 2085. Flooding would also become more widespread, especially in the south eastern part of the study area.

The expected annual damage (EAD) was calculated taking into account predicted flood volumes from the surface water drainage system and the resultant flood depths. This indicated that current EAD for the study area is £1812K. Predictions of future flood volume, indicated that this would rise to a value of £2216K by 2080. Solutions were ranked by calculating the ratio of EAD reduction against estimated cost, for the solutions examined these ratios ranged from 4.3 to 0.4.

The report describes a number of technically feasible options for reducing flood frequencies, but highlights a number of significant regulatory barriers that are preventing key partners from fully engaging with the promotion of solutions to the flooding problems.

Recommendations for the future of urban drainage systems are made, based on the practical findings made in this study.

An action plan is proposed, based on the lessons learned in this project, with a view to securing positive actions by all stakeholders that will reduce flood risk.

NOTE

This report is the outcome of a research project and should not be taken to represent the official policy of the partner organisations. The recommendations and action plan should not be taken as a commitment to carry out construction works or to expend resources on any other measures.

2 PILOT PROJECT OBJECTIVES

The Integrated Urban Drainage (IUD) pilot projects stem from the wish of Government to further develop their strategy for flood and coastal erosion risk management, 'Making Space for Water' published on 29 July 2004, which highlighted the need for a more integrated approach to urban drainage. In response Defra funded a series of 15 'Integrated Urban Drainage Pilot Projects' with the aim of examining if and how integrated approaches to the management of urban drainage could provide a better means of addressing drainage problems. In West Yorkshire there were two pilot projects: the River Aire Strategic Studies project and the West Garforth project.

The West Garforth IUD pilot project ran from 15th November 2006 to 14th April 2008. The initial objectives of the Project, as set out in the DEFRA Contract were:

1 Confirmation of the status of the drainage assets and provision of working definitions of responsibilities in a simple common format suitable for use by all stakeholders.

2 Development of procedures for application in cases where flooding problems appear to fall outwith the currently accepted operational responsibilities of any competent agency - especially at the interface off public sewers and land drainage flows (for example in multi-owned urban culverts).

3 Development of practical procedures to clearly demonstrate the benefits that assets currently provide to different stakeholders and how future pressures may affect those benefits, so that responsibilities, including those for funding, may be distributed on principles of equity. In addition innovative approaches to the barrier caused by inability to fund solutions will be explored.

These have been broken down into specific Objectives which are shown in **Appendix A**.

The aim of the project is to examine whether closer collaboration between agencies could enable innovative and feasible solutions to be identified and what barriers inhibit effective collaboration.

The problems in this area are typical of those faced in many urban areas. The backbone of the drainage system consists of a series of inadequate culverted watercourses. These culverts – receiving flows from surface water sewers, highway drains and overland run-off – pass through hundreds of private properties. The 'riparian' owners of the culverts have no duty to resolve the capacity issues nor the ability to address maintenance issues. No-one has a statutory duty to inspect or keep records of the culverts. It is clear that any improvements will have to be based on an integrated approach, which manages to build upon the interests and responsibilities of all stakeholders – including local residents, Leeds City Council, Yorkshire Water Services and the Environment Agency - notwithstanding the regulatory or legal obstacles.

A genuinely integrated approach should increase the likelihood of implementation and the development methodology could be emulated elsewhere in the UK. At the very least, this study of the feasibility of integrated solutions should help identify where the real obstacles are and will maybe identify the need for amendments of regulations or statutes. It is important to emphasize that this project is essentially a 'study' – not a 'scheme'. The lessons derived should be relevant for the whole country, not just West Garforth. There is no guarantee that any of the optional solutions will be implemented.

UK drainage responsibilities are split between many different individuals and organisations: The responsibilities are not even joined up – there are some aspects of drainage that are no-one's responsibility. The status (and ownership) of the drainage assets in West Garforth is similarly diverse, as shown on **Figure 1**. A consequence is that, although the problems of West Garforth are typical of many urban areas, no organisation seems to be responsible for resolving them.

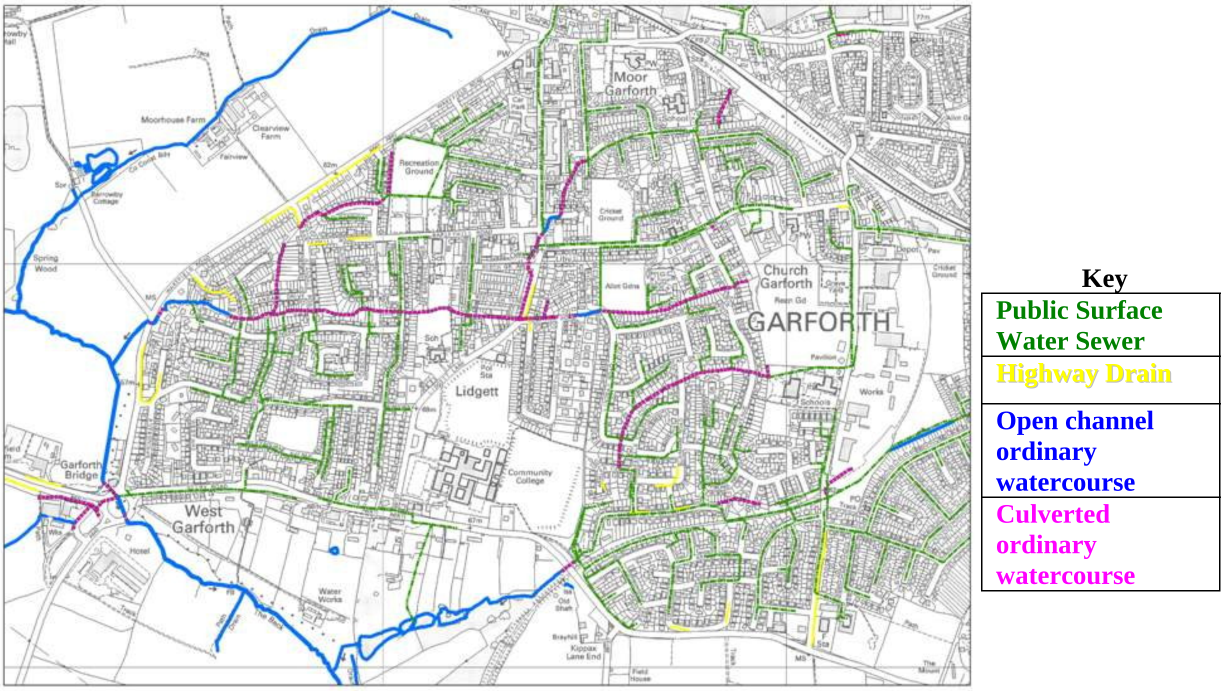


Figure 1 – The West Garforth drainage infrastructure

Within West Garforth there are currently residents whose lives are severely impacted because their homes or streets are subject to inundation. There is also a wider group of residents whose environment – e.g. parks or streetscape - could be affected by the proposed responses to flooding. Flooding in this community is a cause for wider concern also, insofar as many residents currently unaffected consider that the problem is increasing. They anticipate that flooding could become worse as a consequence of climate change and new building development in the area.

West Garforth has grown substantially since the 1950s. The open channel watercourses have been covered over or culverted in a piecemeal fashion and new drainage infrastructure has been connected, seemingly without regard to capacity limitations. This situation is a failing of historical planning regimes. The current Planning Policy Statement 25 (PPS25, Development and Flood Risk) now places a duty on planning authorities to take flood risk into account in the preparation of development plans and the determination of new planning applications.

Although PPS25 and its implementation should result in no additional problems, it should be recognised that planners are not flood risk engineers and water management is but one of a long list of planning requirements. This highlights the need for appointing experienced staff to advise planning authorities on flood risk and mitigation methods. Planning authorities need to acquire a corporate memory of flood risk issues for specific locations. This is especially necessary to facilitate an adaptive approach to coping with climate change.

3 APPROACH/METHOD ADOPTED BY THE PILOT PROJECT

The West Garforth study area is situated to the East of Leeds and consists mainly of low-density residential development. There is a long history of flooding problems, going back to the 1980s and earlier. The area suffered particularly badly during August 1997, Autumn 2000, August and December 2002, August 2004, winter 2005, and summer 2007 (during the study).

The cause of this flooding has in the past been attributed to the surface water drainage system. The bulk of the flow entering the culverts is from public surface water sewers and highway drains. The previous funding strategy for West Garforth was based on the assumption that the overall solution should consist of a trunk sewer scheme. Leeds City Council as agents for Yorkshire Water Services modelled the drainage system in the early 1990s and a trunk surface water sewer scheme to replace the inadequate culvert was developed. This scheme was abandoned on the basis of a re-appraisal of responsibilities by the sewerage undertaker in the late 1990s.

Whilst a solution to this problem is technically feasible, and the seriousness of the flooding problem is acknowledged, there are clearly issues relating to the legal status of the drainage assets, the level of acceptable risk and organisational responsibility. In this respect, West Garforth provides a typical ‘pilot’ for many urban locations at risk of flooding across the UK. The current study aims to identify the causes of the repeated flooding and then to propose individual solutions that may not normally be considered by any of the partners in isolation..

Approach to Partnering

The West Garforth pilot project was led by Leeds City Council, supported by Bradford Metropolitan District Council, the Environment Agency, Yorkshire Water Services and the Pennine Water Group (a University based research group at Bradford and Sheffield).

An initial delay occurred whilst a Partnership Agreement was developed and signed. It would be helpful for such IUD collaborative ventures, if a national standard Agreement existed.

The project was managed by a Steering Group – shared with the River Aire Strategic Studies project - consisting of representatives from each of the four key organisations. Engineering staff from Leeds CC, YWS and the EA supplied local knowledge and record information, whilst the Pennine Water Group supplied modelling and stakeholder engagement expertise. A West Garforth resident was later co-opted onto the Steering Group.

At an initial start-up meeting the Steering Group agreed to meet on a three-monthly basis. All decisions would be made via a vote of the named representative of each organisation. An affected resident from West Garforth was also invited to attend the steering group meetings and played an active part in the study. The steering group meetings were supplement by more frequent meetings focussing on specific tasks listed in Appendix A.

An appraisal of the performance of the West Garforth surface water drainage system was presented to stakeholders, both in the form of a report and oral presentation at a workshop. At the workshop an additional presentation on improvement measures from other sites in the UK and overseas were presented. An outcome from the workshop was a range of potential improvement measures for the key identified flooding locations. These measures were then assessed and the findings reported to the stakeholders in a further workshop.

The framework for establishing the partnership approach recognised the importance of benchmarking the current stakeholder positions. The present impasse arises from issues relating to the legal status of the drainage assets (even though the Council, Yorkshire Water Services and the residents do not dispute the status), rather than because of any disagreement about the seriousness of the flooding.

Roles and Responsibilities

The Council has riparian owner responsibilities for those lengths of open channel or culverted watercourse that pass through land that it owns. In West Garforth, this means mainly those lengths of culvert that pass under adopted highways. As the highway authority, it provides a system of highway gullies and drains. These drains normally connect into the public sewers or into the local watercourses. The highway authority's principal duty in law is to ensure that the highway is safely passable. It is not required to show that its drainage system does not contribute to flooding or that water from the highway is conducted safely away from properties.

The Council has permissive powers, but no duty and no specific budget, to carry out flood alleviation works (under s.14 of the Land Drainage Act, 1991) in connection with ‘ordinary watercourses’. Previously, the Council has tended to use these powers in cases where a community is affected by flooding, and where the solution is beyond the simple maintenance work that it would be reasonable to expect a riparian owner to carry out. In the past, the Council has been reluctant to use its permissive powers to construct a flood defence scheme here, on the grounds that it would essentially consist of a pipe acting as an interceptor sewer, picking up all the connecting public sewers.

The Environment Agency has similar permissive powers to carry out flood alleviation works in connection with ‘main rivers’. It considered a request to ‘enmain’ the West Garforth culverts, but was not satisfied that they had the status of watercourses:

> “The Environment Agency’s view is that surface water from the developed areas at Garforth discharges to local artificial land drainage systems that have not been upgraded to accommodate the increased flows. The criteria for enmainment do not include the enmainment of sewerage systems so we are unable to recommend enmainment in this case.”
>
> *(EA to LCC, 7 April 2005)*

Yorkshire Water Services has a duty under the Water Industry Act 1991 (s.94) to provide, improve and extend a system of public sewers so as to ensure that an area is and continues to be effectually drained. The sewerage undertaker and highway authority have rights to discharge surface water flows into the culverted watercourse and are not responsible for any lack of capacity (or for the element of 'land drainage flows' in the culvert);

In 2003-04, the Council and several residents independently appealed to OFWAT, claiming that YW had a duty under the Water Industry Act, 1991, s.94, to *“ensure that the area is and continues to be effectually drained”* and that this was not being complied with in West Garforth. OFWAT did not accept this appeal (Response in **Appendix B)**

The riparian owners (the owners of the land that the watercourses – culverted or otherwise - run through) are responsible for ensuring that watercourses are free of impediments to flow. They have no duty, however, to upsize inadequate culverts. In practice, riparian owners of culverts often have no means of accessing the culverts under their land and have neither the resources nor the powers to construct comprehensive improvement works.

Method of Analysis

Data Collection

This section details the data and models used to support the activities undertaken for the IUD study. Data was collected to describe the historical development of the West Garforth surface drainage system, to identify key drainage assets and their ownership and to describe and understand historical flooding incidents. Numerical models were used to gain understanding of the existing drainage system. These models were built from data collected from YWS' sewer asset database and very limited site surveys and calibrated using data collected during a short term flow survey carried out during the project. Confidence in its predictive performance was enhanced by comparison with historical flooding records obtained from LCC and the public. The aim of this part of the project was to develop modelling tools, within a limited budget, so as to define system performance. This would provide the information on the risks of flooding and on how the surface water drainage system operated to the different stakeholders. Given this information and understanding of how the system operated it was hoped that potential collaborative solutions would then be proposed and then their performance be predicted.

As part of the effort to understand the drainage system of West Garforth, the project partners have pooled their GIS records of the drainage assets: public sewers, private drains, culverted and open-channel watercourses, highway drains and highway gullies. Data was received from YWS and LCC Following the major flood events of 2004 and 2005, the City Council formulated a £1.1m flood action plan, which included the GPS mapping of all highway gullies. This exercise was brought forward in West Garforth (1236 gullies) to assist the study.

Leeds City Council drainage record data was supplied in ArcGIS format and Yorkshire Water Services statutory sewer map data was supplied in MapInfo format. Conversion between formats is readily achieved using the Universal Translator of MapInfo.

No information existed about the current condition of the privately owned culverted watercourses. A major CCTV survey of all the culverts was undertaken (funded 50%:50% by the study and the Council). This revealed that many of the culverts (which had not been surveyed for decades) were silted to varying degrees and obstructed by services.

System performance modelling

The surface water drainage system for the study area is split into two separate systems, therefore for assessment of system performance two small Infoworks models were used. The first model, in the northern part of the study area, was based on the geometry data from an existing Wallrus model, plus data from the CCTV survey, it was converted into Infoworks and re-calibrated using the recent flow survey data. It was then used to assess system performance and the proposed solutions in the northern part of the catchment. The second Infoworks model was built mainly using information of the asset geometry contained in YWS sewer asset and LCC culvert databases. This was supplemented by data supplied by LCC surveyors based on instructions from the model builders. The model was validated using a flow survey carried out by a YWS framework contractor on behalf of the project team. Flow monitors were installed on 2nd July 2007 and rainfall, water level and discharge data collected for a period of 14 weeks. Three significant rainfall events were recorded. The Infoworks models are verified according to the WaPUG code of practice for hydraulic models. This was considered to produce models that are a reasonable representation of the drainage system, though care must be taken in interpreting results from such a small model. A matrix of design storms with return periods from 2 to 100 years has been used to assess the critical duration for each return period for both models.

The following topographic information has been collated to assist in the modelling work:

- Leeds CC supplied cover levels for 493 manholes from a historical record database on sewers, culverts and highway drains. This data was used in the building of the second Infoworks model.
- The EA commissioned two ground level surveys using GPS technology. The first used vehicle mounted equipment to measure ground levels at regular intervals along all the significant highways within the study area. The second used 'terrestrial LIDAR' - high-

level vehicle mounted equipment - to measure ground levels, not only along the highways, but also in the gardens and drives adjacent to the highways. Unfortunately this second data set was not processed within the project duration. The data from the first survey was used to estimate flood pathways, surface flood volumes and depths to estimate flood damage costs.
- Leeds CC supplied geological borehole locations and logs from several historical investigations (including the abandoned trunk sewer scheme). This was used to assess the feasibility of building infiltration structures.
- The EA provided LIDAR coverage for the north eastern tip of study area. Supplementary LIDAR survey is ongoing to give complete coverage. This data was not used.

Regular flooding in West Garforth has been documented since the early 1980s. For this study most of the historical flooding data has been provided by Leeds City Council.

The performance of the two Infoworks models was verified using data collected during a 14 week flow survey. The flow monitors were placed throughout both catchments, either at locations in which the effect of major sub-catchments could be assessed (FM07, FM08, FM09, FM10, FM11) of just upstream of locations in which flooding was known to occur (FM01, FM02, FM04, FM05) and at the exit of both catchments (FM03 and FM12), see figure below.

Three rainfall events were selected for comparison of the measured peak flow discharge and water depth against values predicted by the models. In the central model, apart from data from FM07, the difference between the observed and predicted peak discharges during these three rainfall events was between +19% to -10% of the observed values. The difference in the observed and predicted peak water levels was +55mm to -30mm (+14 to -18% of observations). In the case of the branch monitored by FM07, it is a small subcatchment, the discharge and depth was generally over predicted, no flooding was predicted, and therefore no additional modelling resources were expended to improve the validation of this small part of the northern model area.

In the SE model, apart from FM11, the difference between the observed and predicted peak discharges during the three selected rainfall events was between +23% to -3% of the observed values. The difference in the observed and predicted water levels was +30mm to -40mm (+8 to -8% of observations). Flow monitor 11 served a small sub catchment to the south of the area in which no flooding had been observed so the inability to obtain a similar level of verification was not seen as important. The only other point to note was that the model verification was difficult to achieve in the north east part of this catchment due to two larger subcatchments, representing some playing fields and a large industrial area.

Given these figures it was believed that both models would provide reasonable predictive performance. Assuming that the system geometry was correct there was a high confidence in that the location of flooding was being predicted well. This confidence was strengthened from the results of modelling of some historical rainfall events. Observational data was received from members of the public via LCC and as a result of the public meeting on the 25th May 2007 was collated and a series of dates obtained for flooding events in West Garforth for which records of flooded locations were available. The EA were approached and provided 15 minute rainfall data from the two gauges nearest to West Garforth, Leeds; Knostrop (SE32565 31543) and Castleford Wheldale (SE 44399 26489). The data was used to estimate the rainfall depth in the largest rain event observed on each date and using this rainfall depth along with an estimate of duration obtained from FEH tables provided by the EA was a design storm with an appropriate return period and duration was identified. These design events were then used to predict flood locations and this was then compared with observational data. Locations of significant flooding predicted by the model could be linked with observational data of surface flooding. However, there was less confidence in the magnitudes of the predicted flood volumes. The modelling of the surface movement of flood water was highly simplified, due to the small amount of surface topography data. Therefore the predicted flood extent, used to calculated damage costs, has a higher level of uncertainty than the other hydraulic based predictions.

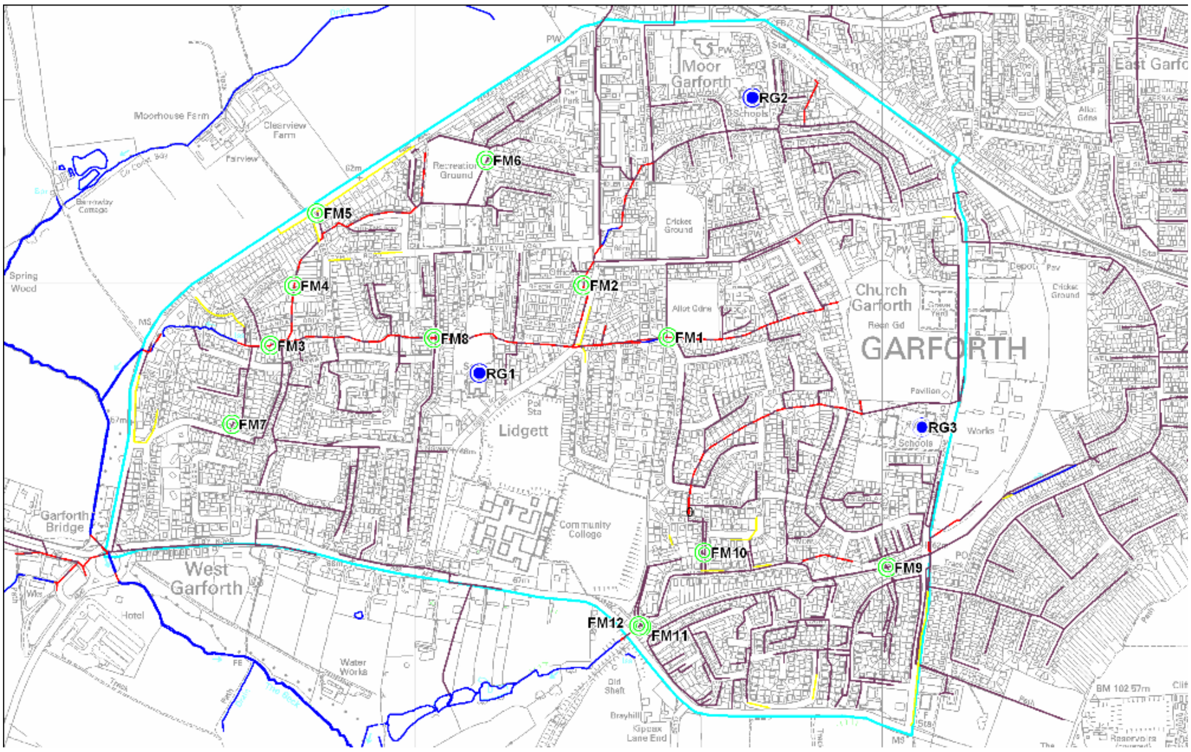


Figure 1B - Location of Flow Monitors – West Garforth (July to September 2007)

Legend:- Flow monitor location Rain gauge Study boundary

Stakeholder Engagement

Stakeholder engagement formed a key element of delivering this project. Two public meetings were organised to discuss the flooding problems. The first meeting aimed to collate residents' experiences of flooding and the second to discuss the findings of the pilot and explore residents' views about different potential responses. As well as collating the information required the meetings aimed to enable, and be seen to enable, residents to be part of the project.

The meetings took place in West Garforth on weekday evenings, on 22nd May and 10th December 2007. Approx 50 members of the Garforth community attended alongside representatives from each organisation involved in the research project. People were invited to attend the public meeting through:

- Letters to those who have suffered from flooding in the West Garforth area
- Information supplied and printed in the local press
- Flyers and posters in shops.

The meetings began with presentations from the IUD partners about flooding problems in West Garforth and potential improvement measures. In the second part of the meetings participants were invited to discuss their experiences of flooding in different neighbourhoods (meeting 1) and to suggest what improvements measures they thought could be located in different parts of the West Garforth (meeting 2). In each case, small group discussions were facilitated by a member of the steering group, assisted by large scale map. In the second meeting, participants were encouraged to place dots on maps to signify different improvements measures for the flood prone areas.

Feedback from the first meeting showed a consensus among residents that the flooding had become worse in the last 5 years with events usually occurring over the summer months, especially July and

August. Likewise flooding was mostly described as resulting from heavy and /or persistent rainfall especially when following a dry spell. The contributing factors identified by the community were the extent of development in the area since the 1960's, the trend to hard landscaping in private property (e.g. driveways instead of lawns) and the areas clay soil.

The interactive sessions led to the two significant outcomes of the public meeting:

- Residents' experiences of flooding led to the Table of Incidents (**Appendix C**). This Table was provided to the modellers to expand upon the information about flooding incidents that had already been provided by the steering group members from their records.
- Residents' ideas about the location of improvement measures led to the Table of suggested improvement measures (**Appendix D**). This Table was provided to the modellers to inform the final selection of improvement measures for the project. The modellers commented that the Table helped to indicate the public acceptability of certain improvement measures, though it needs to be borne in mind that most of the residents who had contributed had suffered flooding.

For the steering group, the meetings provided an important forum through which to exchange information relevant to the pilot, while also managing residents' expectations about what the pilot would achieve. As well as being a valuable source of information, the interactive sessions demonstrated the steering groups' intention to treat the residents as partners with an interest in the project. Identifying a residents' representative to attend steering group meetings was therefore an important output of the first meeting.

The pilot benefited from a newsletter produced by Leeds City Council about the project which accompanied the invitations to the second public meeting. A second newsletter is planned to present the findings of the study. Such follow up communication is important so that the public do not feel that their input has been ignored.

4a FINDINGS OF THE PILOT PROJECT (including RESULTS)

Costs of undertaking the Integrated Urban Drainage Assessment

The project was set up to produce the following deliverables for a total cost of **£75k**:

(a) A hydrological/hydraulic model of the drainage infrastructure in West Garforth to enable modelling of existing system performance and possible improvement measures.

(b) A range of outline improvement measures, using SUDs where appropriate, with different funding models, with the objective of maximising the chances of implementing measures possibly adopted by multiple sponsors.

(c) A report outlining the methodology used to move from a simple, single-sponsor, scheme methodology to one based on a collaborative approach recognising the different responsibilities, interests and capabilities of the various stakeholders. This report would offer techniques transferable to other urban areas faced with flooding problems arising from inadequate culverts or other drainage assets in multiple ownership.

(d) Identification of a preferred mix of solutions.

The individual Work Packages were defined at the start of the project and are shown in **Appendix E.** However, in the spirit of partnership, *additional* services and resources were brought to the project, which increased the 'actual' total cost of the project which are estimated below

		Cost to DEFRA	Actual Cost
WP1	Asset Inventory	£3,872	£34,263
WP2	Historical review	£624	£2,200
WP3	Risk Assessment	£16,212	£38,888
WP4	Attribution of risks/responsibilities	£4,989	£3,233
WP5	Develop options	£13,409	£12,300
WP6	Explore funding options	£2,495	£1,000
WP7	Option selection	£4,989	£7,100
WP8	Stakeholder engagement	£3,118	£12,300
WP9	Methodology report (Final)	£2,183	£3,900
WP10	Project co-ordination and liaison	£9,979	£6,331
Total		**£75,000**	**£121,515**

Project resources

Quantifying Flood Risk

The West Garforth study area is served by two separate surface water drainage systems (Figure 2 & 3). The performance of these systems was simulated using two Infoworks models v7.5 built, calibrated and verified for this study.

The system performance was assessed using design storms with a 1 in 30 year recurrence interval. This was selected after discussions amongst the stakeholders within the project (LCC, YWS and the EA). This recurrence interval was taken to be a reasonable level of risk, given that some stakeholders currently design storms with different recurrence intervals to assess acceptable flood risk.

The critical duration for both catchments was determined by simulating design storms with different durations but a 1 in 30 year recurrence interval, it was seen that the critical duration for both catchments was 90 minutes. To account for climate change a range of design events were created based on the current rainfall with uplifts of 1.05, 1.1 and 1.2 to represent future rainfall at the short (2025), medium (2050) and long term (2085). These uplifts are recommended in DEFRA's *Supplementary Note to Operating Authorities, Climate Change Impacts and Modification of Files Generated Using FEH Parameters* (October 2006). A matrix of design storms with different durations were simulated to identify the critical durations for this catchment at 2025, 2050 and 2085.

The northern part of West Garforth is drained by a system that contains a main east-west culverted watercourse connected to two other culverted watercourses, running in a north-east direction. These culverts then have numerous public sewers and highway drains connected to them. The whole system drains to a single outlet into the Kippax Beck on the western side of the catchment. This outlet was examined on-site with no evidence of surcharging.

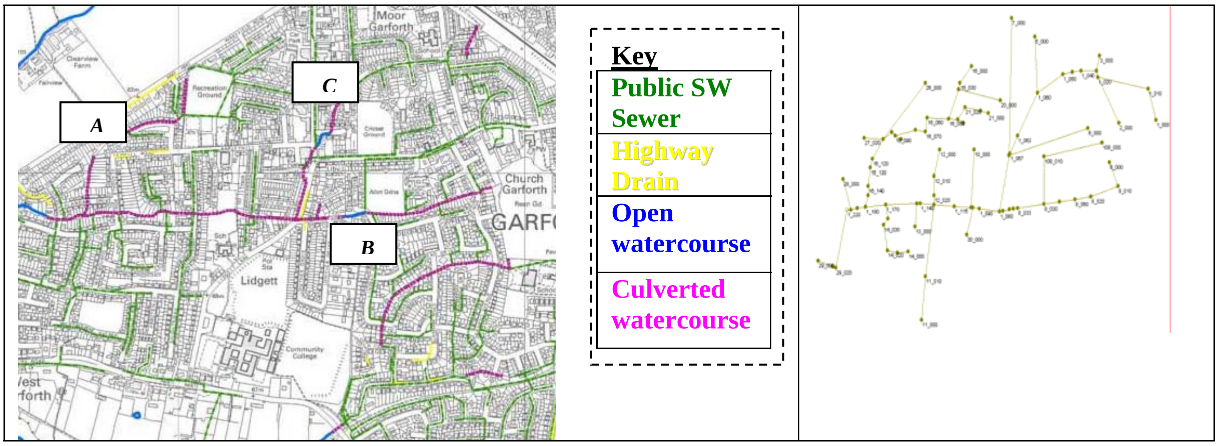


Figure 2 – Schematic of Northern Infoworks model geometry and northern area of West Garforth, showing culverts, sewers and highway grains

During the selected design storm, significant flooding was predicted in three areas, and the water levels in the culvert location "A" were significantly elevated. By examining the change in water levels with time it was seen that the drainage system at the end of each culvert filled quickly causing localised flooding at 3 areas; Recreation Ground/Barley Hill Road "A", Lowther Road "B", and Oak Drive/Station Fields "C", see Figure 2. As the storm progressed both junctions between the main east-west culvert and the other culverts became surcharged resulting in prolonged flooding at the three sites. Proposed responses therefore focused on these sites.

In the southern Infoworks model a main east- west sewer drained other peripheral branches to a single outlet (fig.3) into Kippax Burn. Modelling and visual observation of the outlet in the field indicated that this outlet is unlikely to be surcharged.

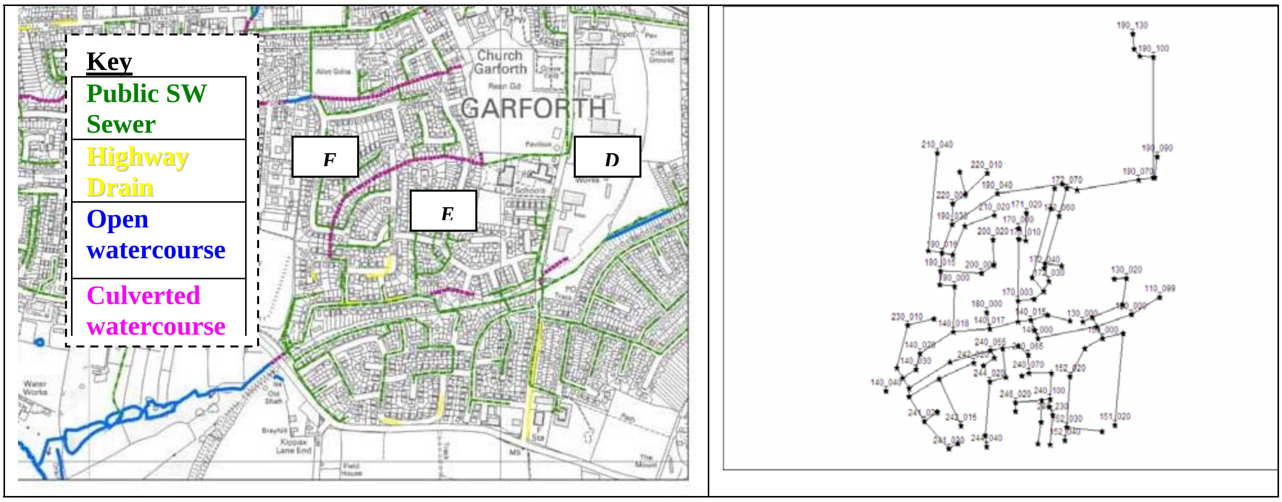
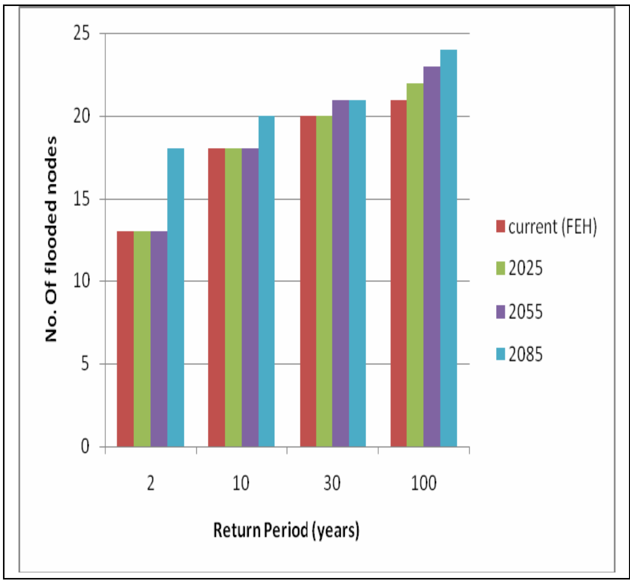


Figure 3 – Schematic of Infoworks model geometry – southern area of West Garforth

Three zones of significant flooding were identified. The most significant was located at Ninelands Lane, "D", which appeared to be caused by draining a large area with a relatively small downstream pipe. This was followed in importance by an area around Richmond Way/Derwent Avenue "E". The pipes in these areas were relatively small (150-300mm) feeding into the 1200mm diameter North-South main sewer. The other zone, Lindsay Road "F", had significantly less flooding, see Figure 3.

As described above, the Infoworks models were also used to assess the performance at 2025, 2050 and 2085. Figure 4a and 4b indicates the number of flooded nodes predicted under these future rainfall scenarios for both areas.



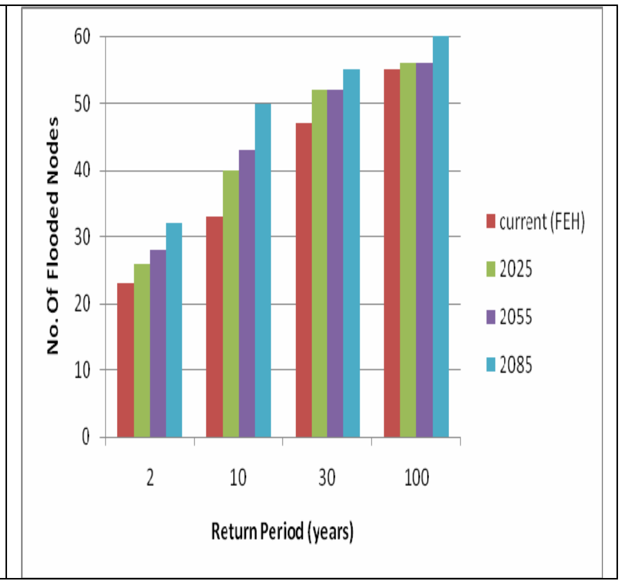


Figure 4a Number of flooded nodes at 2025, 2050 and 2085 Northern area, West Garforth

Figure 4b Number of flooded nodes at 2025, 2050 and 2085 Southern area, West Garforth

In terms of future performance, different patterns are observed in each area. In the northern area, the number of flooded nodes does not increase significantly until 2085. Although the flooded volumes increase in the southern catchment, it can be seen that the number of flooding nodes also increases significantly and consistently.

This indicates that the incidents of flooding will become more widespread and are likely to impact on larger numbers of people and property, many of whom are currently unaware of the likely changes in future risk. In addition, as these results deal only with the parts of the system that were included in the models, there will be a number of other localised areas that will also be flooded in the future.

Responses

The professional stakeholders attended a workshop at which the performance of the system was examined, and a list of potential responses was proposed by examining each of the flooded locations. This list was then compared with the responses and locations that were seen as acceptable based on the results of the second public meeting. There was considerable agreement between the responses suggested by both groups (Appendix D).

The proposed responses could be grouped into those that concerned the more rapid transfer of run-off from flooding locations, temporarily stored excess run-off or disconnected parts of the catchment surface from overloaded parts of the surface water drainage system. The responses examined were:

1. Underground storage
2. Pumping excess flows to alternative locations
3. Surface storage (swales, ponds, wetlands)
4. Enlarge or adding pipes to transfer excess flow to alternative locations
5. Disconnection.

The preferred options from the professional stakeholders contained all but the first two types of response. The modellers could demonstrate that underground storage was technically viable but expensive, so was not included in the final response assessment. It was found that the pumped solution proposed by residents could be achieved with a gravity driven solution so this was examined as it could be provided at significantly less cost. All the other response types (3,4,and 5) suggested by the residents were examined separately and together.

The responses outlined in **Appendix F** were all examined using the Infoworks models for a design storm with a return period of 1 in 30 years, for both current climatic conditions and, if the solution proved viable for conditions in 2085.

Appendix G contains a short description of the effectiveness of the reported responses.

The main areas of flooding were examined separately (**Figure 2 and 3)**. At Lowther Road, it was seen that a combination of removing the adverse pipe gradients, combined with adding a route to the southern outlet was the most effective response.

In the Barley Hill/Queensway area the two options to improve conveyance (an additional outlet/daylighting culvert) do not appear to have a significant impact on flood volumes, although they do reduce the water level in the culvert. The most effective response appears to be the provision of storage at the Recreation Ground. Combining these two responses brought no additional synergistic benefits in terms of flood volumes.

In the Oak Drive/Station Road/Fidler Lane area surface storage and disconnection upstream of Oak Drive were examined. Both responses had significant benefits locally and also at the junction where this branch meets the main east-west culvert and so has benefits for Lowther Road.

In the southern area the flood location at the school on Ninelands Lane was addressed by disconnecting a highly impermeable area just upstream of the school. This had a significant local impact but no impact further down the system.

Flooding in Derwent Avenue and Glebelands was not reduced by disconnecting an upstream area in the main east-west branch this suggested that the problem was a local capacity problem in this branch that could be addressed by upsizing pipes.

All the responses had a cost benefit carried out. The cost of flood damage was estimated by combining the estimated flood volumes from the Infoworks simulations with a simplified topological model of the catchment surface obtained using the GPS ground level survey collected by the EA. This allowed flood depths to be estimated at the six sites, and also the reduction in flood depths after the implementation of the proposed measures. The expected annual flood damage costs (EAD) were estimated based on the work of Penning-Rowsell et al (2005), with response costings using data from YWS and Stovin and Swan (2007). Note that the unit damage costs (flood depth/damage) were not discounted or scaled up into the future and hence the EADs used are underestimates in terms of whole life costs and benefits. It is probable, however, that the relative balance of costs and EAD reduction would be as presented in Table 1.

As can be seen in Table 1, the current EAD for the whole study area is £1812K; the proposed responses (in combinations) have the potential to reduce this to £617K, an almost 2/3rd reduction in damage costs. However, reducing the flood risk to that defined by a 1 in 30 year rainfall event, under current conditions, was not possible at all locations using the selected responses. These responses had been selected after considering their potential effectiveness and cost. The ratio of the current EAD reduction divided by cost was used to rank the solutions in terms of their cost effectiveness. These responses would, however, fail to keep the EAD down, as this will rise steadily to £1056k by 2085.

If no action is taken then the EAD in West Garforth will continue to rise from £1812K to £2216K by 2085. This increase will not be spread equally over the catchment with some areas expected to experience substantial increases in EAD, of the order of 70%.

Flooding locus	EAD £k		Responses	Costs £k	Performance of responses		Residual EAD £k		EAD benefit ratio**		EAD current cost benefit
	Current	2085			Current (years)	2085 (years) ****	Current (£K)	2085 (£K)	Current	2085	EAD reduction/£ spent on response
Lowther Road (A)	373	460	1. Replace local pipes to remove adverse gradients 2. Construct new pipe to take flows south 3. Disconnect some upstream inputs (roofs, rainwater barrels)	390 250	10	5 years	108	200	0.29	0.43	0.41
Oak Drive (B)	228	353	1. Storage at school (pond) 2. Swale along Oak Drive 3. Disconnection (roofs rainwater barrels)	70 150 250*	50	15 years	29	127	0.13	0.36	0.42
Barleyhill/Rec. Ground (C)	107	183	Storage pond at recreation ground	120	30	10 years	23	97	0.21	0.53	0.7
Ninelands Lane (D)	477	695	Disconnect factory hard standing (pond)	110	100	5 years	7	288	0.15	0.41	4.27
Richmond Rd/Glebelands (E)	186	246	Only solution is upsized pipes (disconnection removes little inflow)	220	30	10 years	9	65	0.05	0.26	0.80
Various other areas than above	441	279	Local solutions will be required – these are relatively modest problems currently but will increase by 2085	-	-	-	441	279	-	-	-
Totals	1812	2216	-	1560	-	-	617	1056	0.34	0.48	0.77

Table 1 Responses – expected annual flood damage values and their reductions due to various responses

*Would benefit more than one location
** residual EAD/original EAD (smaller the value, the better)
***Tackle residual EAD using non-structural methods
**** Values for the year 2085 incorporate rainfall uplifts of 20% to allow for climate change.

Benefits and barriers to data sharing

All key project partners shared data (asset geometry data, flood incident data, survey data from LCC and EA surveyors and CCTV survey data) without significant restrictions. However there were difficulties in combining data from each source. The data formats were different, most were in a GIS compatible format so that the data could be spatially located and efficiently used, but significant amounts were not. Some data was in a written format and was particularly difficult to assign to a drainage asset.

Although Yorkshire Water Services already provides the local authority and the Environment Agency with a digital copy of the statutory sewer map (pursuant to the Water Industry Act, 1991, s.200), this is provided on a standalone computer system. This could not be integrated with the Council's own GIS drainage records and it made it difficult to analyse flooding or pollution incidents in a holistic fashion. The prospect of having the ability to view all assets via a single GIS system is regarded by the Council, YWS and the EA to offer significant potential benefits. However, it is also acknowledged by all parties that any such system would have to address issues relating to the frequency of updates, confidence grades and consequently the suitability of the data for different purposes.

An agreement was made to use the project as a pilot for GIS record sharing by the sewerage undertaker and the local authority. This collaborative approach enabled better sharing of information between the partners, without which it would not have been possible to undertake the modelling work, which uses a combination of culvert, highway drain and gully records (Leeds City Council) and the public sewer network (Yorkshire Water Services), together with rainfall data provided by the Environment Agency.

The major data source was YWS' sewer asset database. Whilst this appeared to comprehensively list public surface water sewers and manholes, together with some culverts and highway drains, it did not have geometric information on every asset. Many assets lacked data such as invert and ground levels.

The flood incident data was not always sufficiently comprehensive: specific timing information was sometimes missing and it was difficult to link this data with particular assets. Data on the condition of the assets was also not available at the start of the project.

The above issue concerning the quality of the incident data is particularly important as this data provides the evidence base through which flood prevention measures can be funded. If properties are flooding and it is not being registered then the construction of justified flood prevention measures may be delayed or prevented altogether.

For purposes of the IUD project there is a high level of confidence between the parties and therefore a willingness to share information as far as possible. But in the wider arena this is not necessarily replicated. General confidentiality issues protecting the individual are dealt with under data protection legislation but one outcome of the legislative protection is that the stakeholders which hold that information may be reluctant to share it with other professional stakeholders (and, of course, the public) for fear of contravening that legislation. There is a clear recognition by all the professional stakeholders that the sharing of information gathered on site about individual properties could be illegal and could be damaging to the interests of the property holders.

Yorkshire Water's DG5 register had no records of properties at risk from surface water sewer flooding due to hydraulic incapacity, but partners were informed that – if this had not been the case – sharing the register information would have been problematic. Due to personal data protection reasons, YWS would have declined to share detailed property information for West Garforth (even though the Partnership Agreement contained a confidentiality clause). There is no obligation of the sewerage undertaker to discuss additions to, or removals from the register with other stakeholders.

Thirty-two individual properties were listed as being liable to flood in a report of 1993 by Leeds Main Drainage – acting as the sewerage agent of Yorkshire Water Services.

Even when there is a will to share data there is often a time constraint as advice is sought or the data are checked by legal departments and conditions proposed and accepted. This slows down the process of cooperation as witnessed in the IUD project.

All parties needed to negotiate the tension between their confidentiality obligations to householders and the public benefits of sharing data and understandings about flood vulnerability. When flooding occurs, authorities hear about it from members of the public. It was noted that the current means of collecting information was poor and was unlikely to pick up all flooding incidents.

Benefits and Barriers to Partnership

The success of this project depended on the time to be able to build good relationships both at a personal level and in the more formal forum of joint meetings this enabled the opportunity to develop and extend networks for common benefit. In the past these relationships have failed to develop due to the legal complexities of the many flooding problems. It was recognised to be important to continue to build these relationships over a period of time and not lose valuable experience. Succession was also seen as important both in the building of strong, cooperative relationships but also in the passing on of historical knowledge and expertise about local problems.

The confusion amongst the public about who is responsible for different urban drainage assets mirrors contradictory views on appropriate levels of flood risk amongst the stakeholders. For members of the public the issue was the damage caused by flooding and not what asset failed and who was legally responsible for that asset. It is therefore confusing if assets under different ownership regimes have different design and maintenance standards.

Leeds CC has a fairly good GIS record of culverted watercourses in the study area, but the fact that no-one has a *statutory duty* to inspect or keep records of the culverts was a major concern to all parties. Although the riparian owner is responsible for the maintenance, due to the extent and costs involved they are not able or willing to resolve the capacity or maintenance issues.

The public had lobbied various agencies, including the local authority and YWS, to safeguard their property and did not accept any responsibility themselves (even though many householders are riparian owners). There is a need to encourage the public away from a dependency culture and towards greater personal and public responsibility, and a cultural understanding of community and working together.

Stakeholder engagement was a crucial element of this study. Two public meetings were arranged, and an affected resident of the study area was invited to join the steering group. The collaborative approach engendered a high degree of confidence in the public that all the stakeholders were willing to work together in a collaborative manner. This was most noticeable during the public meetings. The result is that people believe that potential responses may be identified as a result of the study and people are motivated to get involved, as is evidenced by the numerous records that have been completed and returned by members of the public.

Following an appeal for flooding information at the initial public meeting, West Garforth experienced the worst flooding in a generation. Much information was provided in detailed discussions at the meeting. Although the flooding in June 2007 delayed progress with the project, it was nevertheless very useful in highlighting deficiencies of the drainage system and has also helped to raise the profile of flooding and engage the community with the project. A further consequence was that many reports of the summer flooding were immediately sent to the study team. These included a wealth of data, in the form of letters, phone calls, digital photos, videos taken by mobile phones, and excellent sketches (**Figure 5**)

Figure 5 – June 2007 flood extent sketch submitted by a member of the public indicating flooding near Barley Hill Road

Instead of arising out of complaints, the majority of the data was provided out of a spirit of cooperation in a joint effort to find the true causes of the flooding and potentially effective improvement measures. Without the collaborative approach, it is unlikely that residents would have helped to produce incident data in such quantities.

The resident representative on the Study Steering Group independently carried out a house-to-house survey in the affected areas and discovered that many more houses had been evacuated, due to internal flooding, than had been realised. This was another clear benefit of the integrated approach and the involvement of local stakeholders in the study and further evidence that current methods for measuring the impact of flooding are not adequate.

4b MAIN IMPLICATIONS FOR THE STUDY AREA

Tangible Benefits

The IUD project part-funded a CCTV survey of the main culverts in West Garforth. This survey revealed eight major obstructions in this small drainage system.

The CCTV inspection presented a number of technical difficulties. Initially there were problems gaining access the culvert, due to lack of manholes. Several new ones had to be constructed to remove constrictions and to allow maintenance access. Prior to the CCTV inspection 'vactoring' was required to remove any silt or debris accumulated in the pipe. There were also difficulties with tree intrusions and man-made obstructions, such as unconsented pipe crossings, footings etc. After desilting and other improvements, the culverts were subjected to a further CCTV inspection. Eight significant obstructions were observed in three general locations. Modelling indicated that removal of obstructions in two of these areas would both increase and decrease flooding at different locations, only the removal of obstructions in the main east-west culvert would cause a reduction in flooding without any adverse impacts elsewhere in the area.

Although Leeds CC has good records of culverts, because no-one is statutorily responsible for holding records of the culverts, statutory undertakers had clearly not always been checking for their existence. Several locations have been found where cables and pipes are seriously obstructing the culverts and causing capacity reduction **(Figure 6)**.

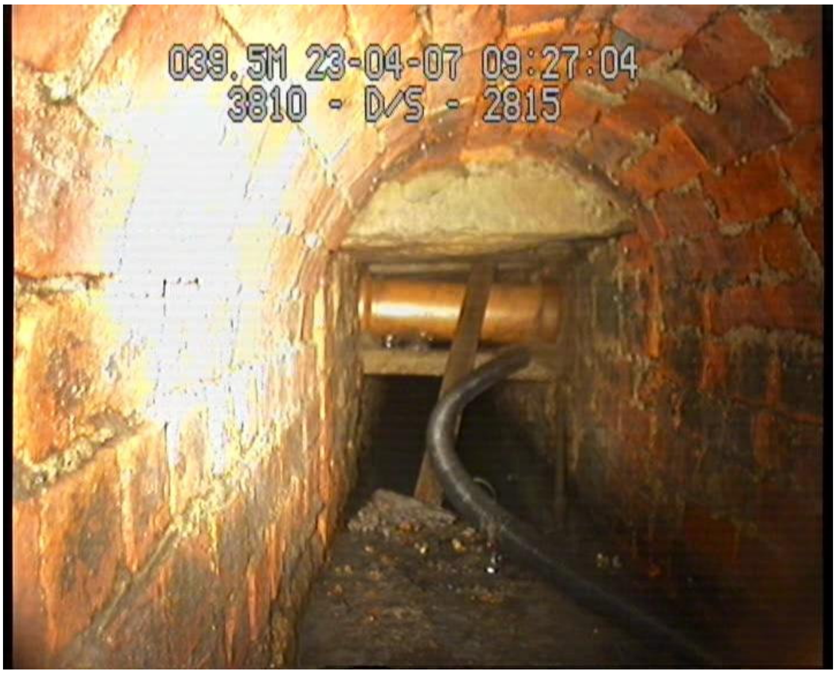


Figure 6 CCTV record of services in culvert at West Garforth (near Lidgett Lane)

It is vital that undertakers check culvert positions before carrying out mainlaying, etc. It is also important that solicitors carrying out searches for homebuyers do similar checks. Often householders did not know of culverts in their own gardens, until told by the study team.

A significant reduction in flood risk has been achieved during the project, because:

- The Council has desilted all the culverted watercourses in order to carry out the CCTV surveys (much more than financed by DEFRA).

- The Council has used its permissive powers to build several new manholes to improve maintenance access to the culverts and has modified some culvert junctions to remove impediments to flow.
- The Council has replaced the length of culvert across Barleyhill Road and constructed new manholes at that location. As well as improving flow characteristics, this has also enabled a partial blockage downstream of the road to be removed, has revealed that two highway gully connections had been severed by services, and has revealed a major land drain connection that can now be considered for attenuation or even removal.
- Yorkshire Water Services has resolved some longstanding, non-hydraulic, public sewer problems (e.g. blockage at Moorland Terrace) that have only been revealed because of the in depth investigations occasioned by the study.

Traditionally, local authorities do not have a significant budget for permissive maintenance and construction works. The fact that Leeds City Council has been able to spend significant sums of money on extending the CCTV survey work for this project and on constructing local access improvements is noteworthy. This has been possible because of the £1.1m p.a. flood action plan implemented from January 2006 (in response to the 2004 and 2005 flooding in Leeds). The removal of some central government support for local authorities' 'Own Flood Defence Expenditure' to the EA, following the flood defence spending review (c.2003) and the transfer of critical ordinary watercourses has not helped in this regard.

This high profile collaborative study has itself enabled some new investment in the West Garforth drainage system. The highway authority has already earmarked funding for a number of significant culvert and highway drain improvements. It is currently designing a scheme to improve the highway drainage system at the flood location in Ninelands Lane.

By drawing together different West Garforth residents affected by flooding, the project has enabled local people to discuss local problems and work together. In this sense, there has been an unplanned benefit from the project in terms of building the local capacity to respond to and address flooding. Through the pilot study, a Flood Warden system for West Garforth has been discussed. The Environment Agency Flood Incident Management team have provided the Steering Group resident representative with information and assistance in setting up a community response. This will be dependent upon involving members of the public to prepare their neighbourhood for a flooding event and for providing a medium for the dissemination of information.

During the course of the pilot study Leeds City Council received a planning application for a site on Main Street, Garforth. This raised the question of whether or not new development should be allowed in the area which is known to have a problem with surface water drainage. The issues were discussed and the project team were of the view that the development should be allowed to proceed and a S106 contribution (Town and Country Planning Act) should be taken and used to offset the impacts of the development, through downstream improvements.

Barriers to Public Engagement

Householders who suffer flooding sometimes experience an internal conflict: on the one hand addressing and minimising the extent of flooding problems, and on the other hand, denying their existence and maintaining their house value. This conflict influences people's choices about recording flooding incidents, their willingness to sign up for flood warnings and their preparedness to take preventative measures to minimise the damage caused during a flood. This is an issue when identifying the mechanisms of flooding and justifying flood risk schemes. It may also be the reason why there are currently no properties on the DG5 register of flooding due to hydraulically inadequate public surface water sewers, as this system depends on people reporting sewer flooding to Yorkshire Water Services.

Barriers to Implementation

Ongoing public engagement is needed in the project area with respect to those suggested improvement measures that impact on the streetscape or on local people's lives. Two of the West Garforth's proposed improvement measures fall into this category: the suggestion that the football pitch be used for flood storage, and the idea of placing swales in some suburban streets. In both cases, research processes are planned to check how the proposed measures would impact on other local people. In this sense the involvement of the flood-concerned residents achieved within the pilot is a first step – necessary but not sufficient – in ensuring that flood alleviation measures fit in with local needs and interests.

The most challenging part of the study was to identify possible funding mechanisms. Specific issues come to the fore over the impact of funding between the various public sector bodies and the water utilities.

The Council can only engage in spending public money on objectives that it has a duty to support or where it has permissive powers. Expenditure on other objectives could be considered 'ultra vires' and would leave councillors open to surcharge and other penalties.

Yorkshire Water Services' main role is to improve the environment, improve customer service and minimise costs. There is an agreed process with OFWAT to procure investment to address flooding from public sewers as a result of hydraulic incapacity. A programme of capital works is prioritised in accordance with established Company procedures and progressed on a cost/benefit basis to ensure most efficient use of available funding.

Funding through the EA is subject to cost-benefit analysis, and can only address issues of main river flooding. Additional monies through the 'local levy' also require a cost benefit analysis, but could respond to smaller 'community' issues, such as those in West Garforth, where a partnership approach is possible. Unfortunately this system is not main river.

A thorough examination of historical maps (from 1850 to the present day) in West Garforth, together with drainage records from the former Garforth Urban District Council, has been undertaken in the study. **Figure 7** shows the GIS record of the position of the existing open watercourses (in blue) and culverts (in pink) superimposed on a geo-rectified image of the 1850 Ordnance Survey 1/10,560 scale map. It can easily been seen that the culverts, with only minor exceptions, coincide with previous open channel natural watercourses. This enables the option of 'enmainment' to be re-appraised, and thus opens up the possibility of the EA funding some flood alleviation works – possibly with the support of the 'local levy' funds of the Yorkshire Regional Flood Defence Committee.

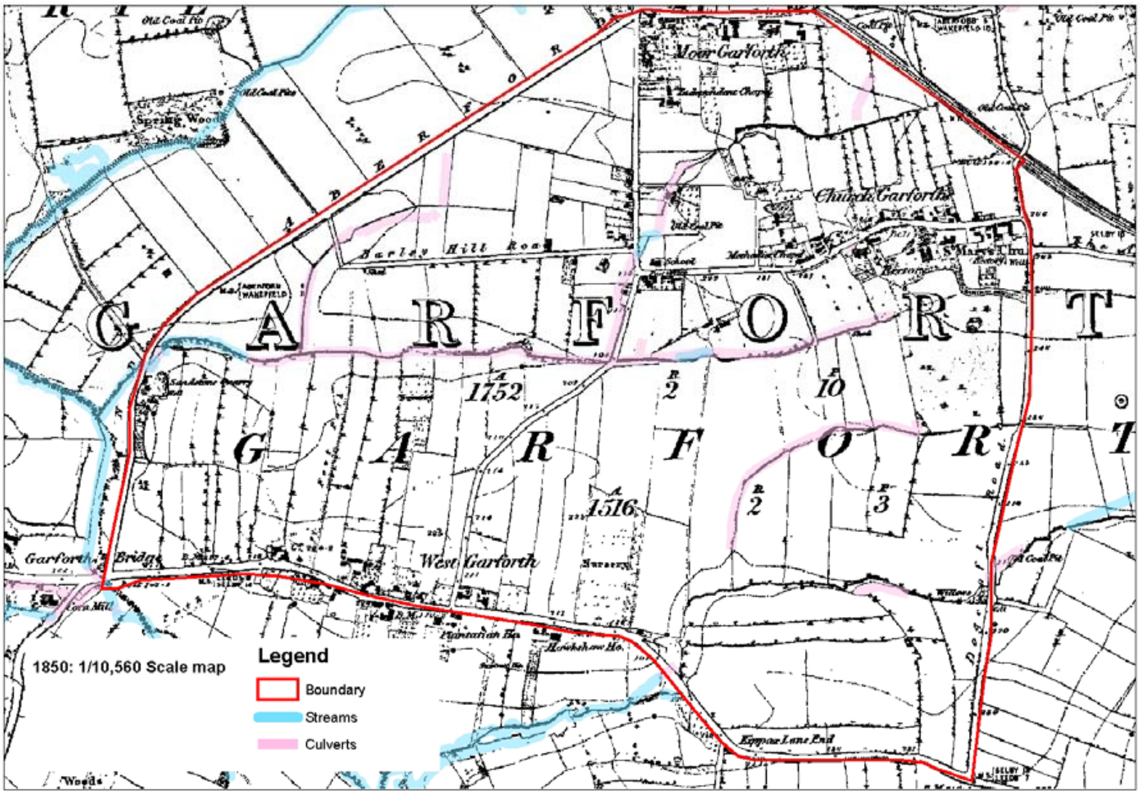


Figure 7 Coincidence of current culverts with the open watercourses of 1850

It is possible that some solutions might address issues that several stakeholders are responsible for (and might address the issues holistically in a more cost-effective way than individual solutions). The stakeholder organisations, have limited resources and flood alleviation works in West Garforth would have to compete with other priorities. It is important that funding is kept to a modest scale and is seen to be shared. In such cases, it may be possible to persuade the Council to promote measures or to fund proposals on a pro-rata basis. However as stated above in the current framework Yorkshire Water Services and the Environment Agency are unable to commit and this is a major barrier to progress.

It is a likely consequence of engaging with the residents and their representatives is that expectations are raised (even though caveats that this was 'simply a study' have been made at every stage).

4c MAIN IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE OF URBAN DRAINAGE SYSTEMS

General

The aspiration (embodied in Work Package 5) of developing potential 'modularised' options "in a mix which will be capable of adoption by the relevant parties" not been successful in identifying works that all the partners could share. Even after splitting the optional improvements down into discrete modules, Yorkshire Water Services and the Environment Agency are still not able, within existing regulations, to adopt any of those modules. The only organisation with permissive power to carry out flood alleviation work of this kind is the Council. The Council has permissive powers under the Land Drainage Drainage Act, 1991, but has no duty and no express budget.

UK drainage responsibilities are not only split between many different bodies: The responsibilities are not even joined up. The study identified key sources of flooding in West Garforth – namely, from open land (e.g. Fairfield Court, Glebelands, etc) – where no agency has any responsibility for dealing with such sources. **REC 1:** *That a national, clear and holistic definition of flooding responsibilities be developed, preferably enshrined in statute.*

This project has shown that joint investigation of flooding does work. It avoids 'buck passing' and gets better results by sharing information. **REC 2:** *That collaborative technical investigation of flooding incidents - involving the local authority, the sewerage undertaker and the Environment Agency* **-** *should be encouraged, especially where prima-facie evidence suggests multiple sources, crossing responsibility boundaries* .

It is clear that riparian owners of culverts, in West Garforth as elsewhere, are responsible for keeping those culverts free of impediments to flow and that a notice can be served under the Land Drainage Act, 1991, s.25, requiring them to carry out remedial works. It is equally clear, however, that these owners are in no position financially or practically to undertake such work. In many cases, they do not even have manhole access in their garden. This is typical of many culverted, urban watercourses. **REC 3:** *That statutory revision and clarification of riparian owners' duties be introduced to resolve this issue, or that maintenance responsibility be transferred with appropriate funding to a capable organisation/agency.*

Planning issues

Most of West Garforth is already fully developed, but the study has shown that Climate Change will cause an increase in run-off and flood volumes. **REC 4:** *That local planning authorities should use the opportunity of redevelopment to secure reductions in existing run-off. PPS25 is very weak on requirements for reducing run-off from 'brown-field' sites. It also has a tendency to concentrate unduly on flood risk in zones 2 and 3. These shortcomings should be rectified*

Significant increases in run-off in the study area have been caused by householders creating patios, drives and parking areas in former gardens. The additional run-off created has often been directed to the public highway, from where it sometimes adds to flooding of lower-lying properties. **REC 5:** *That new drives, etc, are removed from the category 'permitted development'. Owners should be encouraged to use permeable surfacing materials.*

Efforts to identify viable pathways for exceedance flows in critical areas (e.g. Barley Hill Road to Alandale Drive) have been largely unsuccessful, because development is so dense and has obscured the natural valleys and depressions in the area. Similarly, existing culvert routes now have mature trees and garages built over or close to them – making upsizing or 'daylighting' expensive or impossible. **REC 6:** *That green pathways for exceedance flows be designed into future development and re-development proposals, in accordance with the 'Making Space for Water' approach. Greater vigilance needs to be exercised, using powers in Land Drainage Byelaws, to prevent encroachments over culverted watercourse routes.*

Surface Water Management Plans (SWMPs) require open sharing of incident and asset records. The project highlighted certain obstacles to this sharing. An agreement was made to use the project as a pilot for GIS record sharing by the sewerage undertaker and the local authority. This collaborative approach enabled better sharing of information between the partners, without which it would not have been possible to undertake the modelling work, which uses a combination of culvert, highway drain and gully records (Leeds City Council) and the public sewer network records (Yorkshire Water Services), together with rainfall data provided by the Environment Agency. **REC 7:** *That data sharing protocols be formulated at national or local level, which address legitimate water and sewerage company concerns about sharing GIS sewer record and flooding register data.*

SWMPs require *future* flood risk (as identified in this report) to be the basis for strategic planning. **REC 8:** *That OFWAT, Defra, and Water and Sewerage Companies enter into dialogue to agree a funding mechanism for schemes arising from SWMPs that may not meet existing funding criteria.*

There is a need for improved mechanisms to enforce the drainage conditions of planning applications. **REC 9:** *Consideration should be given to introducing incentives such as the use of a bond, for example, as practiced in Canada.*

Inspection, maintenance and recording issues

Widespread silting and blockage problems were encountered during the survey of the West Garforth culverts. There is no doubt that this will have significantly increased the flood risk. **REC 10:** *That a risk-based, properly financed, inspection regime be established for all essential drainage assets (including sewers, culverts, highway gullies and drains).*

CCTV inspection of the culverted watercourses was instrumental in revealing partial blockages that not only were partially causing the flooding, but also could be and were addressed relatively cheaply. **REC 11:** *That inspection regimes by the responsible agencies be accompanied by adequate funding for risk-based maintenance measures.*

Because many culverts are classed as 'ordinary watercourses', the local authority in this area has the powers under the Land Drainage Act, 1991, to require riparian owners to remove impediments to flow (or to carry out remedial works itself). These powers are only meaningful for addressing flood *risk* (as opposed to *actual* flooding) if the authority has a suitably funded programme for desilting and CCTV surveying the culverts. Funding allocation could be based on total length of culvert, with differential rates for different size bands. **REC 12:** *That local authorities are funded to implement recommendations 10 and 11 on the basis of total length of culvert, with suitable differential rates for different size bands.*

Apart from the statutory duty of the sewerage undertaker to maintain a map of the public sewers, there is no legal requirement for any other organisation to keep records of other drainage assets (either as owner, or otherwise). The consequent incompleteness of the available records initially hindered the study. **REC 13:** *That appropriate agencies be given a statutory duty to keep records of watercourses (open channel and culverted). Anyone with a statutory duty to keep such records should also have a duty to share them (in GIS format) with partner agencies. To avoid many of the blockages found in West Garforth, statutory undertakers must check culvert records before planning main laying work.*

Insurance and self-help issues

Few householders in the area, even though they had been previously flooded, had any form of flood protection (air-brick covers, flood-boards, etc). Some flooded properties were restored to their former condition without any greater flood resilience (indeed some insurers would not pay for this). Post-flood house refurbishment should incorporate flood resilient measures, though cost is a potential barrier. **REC 14:** *That all stakeholders (including insurance companies) make greater efforts to inform property-owners of flood protection devices that are available and how to make buildings 'flood resilient' (avoiding soft furnishings, siting electrical sockets above flood level, etc).*

After the flood event of June 2007, it was noted that different insurance companies had quite different standards of flood recovery assistance and properties were repaired at markedly different rates. **REC 15:** *That insurers standardise flooding cover and assessment procedures as far as possible.*

Even though the June 2007 flooding occurred during the study and many residents submitted data, still a significant number of flooded properties (where evacuation had been necessary) only came to our attention weeks later (e.g. at Kingsway and Queensway) through on foot surveys. There is nothing that requires flood victims to notify the Council, or anyone else, that they have been flooded. Within days of the flooding, however, central government was demanding statistics about internal flooding. These demands distracted efforts to investigate causes. **REC 16:** *That a national definition be drafted of what statistics are legitimately required by government and the means of collecting it. Insurers are well placed to help, but a common definition of internal flooding is needed (to avoid the statistics being degraded by including claims for flood damage arising from leaking roofs, etc).*

The assessment of integrated solutions to urban flooding is dependent on the choice of appropriate storm design frequencies. What *is* appropriate was the subject of some confusion. Different standards are current for sewer design and river flood alleviation works. Yet, to the public, 'flooding is flooding' **REC 17:** *That national flood defence guidelines be issued harmonising drainage hydraulic design standards in a rational way.*

Data sharing issues

The quality of flood record is of critical importance in developing integrated solutions. At present, multiple overlapping maps of flood incidents are kept by local authorities, sewerage undertakers and the Environment Agency. The distinction between the different registers relates to what is perceived as the 'cause' of flooding: while the local authority records all flooding incidents, the sewerage undertakers DG5 register only records flooding from public sewers, and the Environment Agency only river flooding and the flood risk map. **REC 18:** *That a single telephone reporting line for flood incidents be established as the starting point for developing a shared register of flooding and an improved flood risk map. At a meeting in Leeds in July 2007, the Chief Executive of the Environment Agency seemed supportive of the idea of piloting a 'one stop' Floodline in Leeds.*

Continuity issues

The success of this project depended on the time to be able to build good relationships both at a personal level and in the more formal forum of joint meetings, which has enabled the opportunity to extend networks for common benefit. In the past these relationships have broken down due to the legal complexities of the situation. **REC 19:** *That the importance of continuing to build these relationships over a period of time (not losing valuable experience) is recognised. Succession is important both in the building of strong, cooperative relationships and also in the passing on of local knowledge and expertise.*

Public Engagement issues

Both public meetings during the project at West Garforth took significant resources to organise. Similarly, the collation and analysis of information and views from the meetings took significant time. **REC 20:** *Flood alleviation projects should incorporate sufficient resources to include effective public engagement*.

It is essential to take residents into the confidence of the project team, in order to avoid raising false expectations or over-optimism about the outcome of any project. **REC 21**: *That great care should be taken to ensure that the public is fully aware from the outset of any limitations to the scope of the projects and the barriers to (or criteria for) procuring funding that might be encountered following identification of options for construction works.*

5 ACTION PLAN FOR FUTURE IMPLEMENTATION

The pilot project has been a ‘study’ rather than a ‘scheme design’. Nevertheless, the project has identified a significant number of feasible outline options for flood risk management in West Garforth. All the partners would like to see a major reduction in flood risk in the study area and to this end the following action plan is suggested:

ENVIRONMENT AGENCY

- Re-consider the enmainment of high flood-risk culverted watercourses in West Garforth.
- After any enmainments, consider promoting some of the identified measures in Appendix F, possibly seeking funding from the local levy, other partners and local sources.
- Review policy on instituting flood warden scheme in the area.
- Convene a learning alliance of all actors as part of a strategic approach with EA in the lead role.

LEEDS CITY COUNCIL

- Seek opportunities for promoting some of the identified measures in Appendix F and explore the possible mechanisms for co-funding from other partners and local sources.
- Press forward with improvement of the highway drainage system in Ninelands Lane.
- Ensure that PPS25 is vigorously implemented in relation to new developments and that developers make contributions to drainage improvements where appropriate.
- Continue to implement the new policy of risk-based CCTV inspection of culverted ordinary watercourses, with a view to ensuring that action is taken to remove any fresh impediments to flow.
- Continue to engage meaningfully with the community at regular intervals to develop community capacity to cope with future flood risks and changes.

YORKSHIRE WATER SERVICES

- Raise awareness of the importance of residents reporting sewer flooding so that incidents are properly recorded.
- Support the principle of IUD management and collaborative working and review the findings of the IUD studies and recommendations from DEFRA.
- Consider improvements if defects are identified on YWS assets.

RESIDENTS

- As riparian owners, ensure that open channel watercourses within their property are kept free of impediments to flow.
- As occupants of property at risk of flooding, consider introducing flood protection measures – including air-brick covers and flood-boards. In some instances, minor landscaping measures may provide suitable barriers to flood flows entering property
- As occupants of property that has been flooded or is at risk of flooding, try to build flood resilience into homes (esp. as part of flood damage repair work). This can be done by omitting soft furnishings and floor carpets, where possible, and by siting electrical connections above likely flood levels, etc.
- Consider acquiring a water-butt for rain-water storage. The more roof-water is kept out of the sewers and culverts, the lower the flood risk.
- As community conscious citizens, be vigilant against flytipping in watercourses. Do not throw garden cuttings into watercourses.
- As ‘home improvers’, do not create new patios, drives and parking areas using impermeable materials. Use surfacing materials that allow water to infiltrate into the soil below. Do not let water run off your property onto the public highway.

- As a community members concerned about flooding, support and develop local capacity to minimise the extent of flooding, and the damage and distress it causes.

LCC/ EA/ YWS

- Step up collaboration where feasible on the investigation of flooding problems. A standing technical forum has already been established to provide a vehicle for this collaboration. This has representatives from Leeds CC Land Drainage, Yorkshire Water Services, the Environment Agency and the Highways Authority.
- Continue to share incident and asset data beyond the life of this project, with a view to laying the basis for the production of Surface Water Management Plans in the future.
- Participate in a learning alliance (see EA actions) to continue to review the problems as knowledge advances and progress to solutions.
- Look at how help can be given to promote non-structural measures.
- Promote and sustain the application of adaptation responses that are evolutionary and incremental where possible. Consider what organisational changes are necessary to do this.

THE PILOT PROJECT PARTNERS

- Arrange a Steering Group meeting to consider the lessons from the other IUD pilot projects, after publication of the reports.
- Organise a newsletter and a public meeting in West Garforth to engage residents in a dialogue about the outcome of the project and to promote discussion of the way forward.

6 REFERENCES

The Benefits of Flood And Coastal Risk Management: A Manual of Assessment Techniques (2005) Penning-Rowsell E., Johnson C., Tunstall S., Tapsell S., Morris J., Chatterton J., and Green C., London, Middlesex University Press.

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Appendix A – Specific Objectives and Related Tasks

The specific objectives are as follow:-

Objective 1 – Asset and data inventory and review

- Carry out a CCTV survey to ascertain the condition of the culvert system
- Gather terrain data
- Collect relevant incident and social data for the area
- Confirm the drainage assets, connectivity, etc

Objective 2 – Historical review

- Review the history and consequent status of the key drainage assets

Objective 3 – Risk assessment

- Review the status and relevance of the previous modelling exercise done in the early 1990s
- Carry out additional surveys to facilitate model building
- Build a revised/enhanced model
- Carry out a flow survey
- Verify the model against observed flow and rainfall data
- Input and test future scenarios
- FEH analysis to ascertain land drainage component
- Flow routing

Objective 4 – Attribution of risks and responsibilities, & formulation of a performance matrix

- Produce a benchmark matrix to use in the assessment of options
- Achieve a consensus as to where risks and responsibilities lie

Objective 5 – Develop options

- Develop a series of modular options (including non-structural methods)

Objective 6 – Explore funding of options

- Propose a range of suitable funding options based on the modularised scheme

Objective 7 – Option selection

- Select the options required to give an optimal, viable solution

Objective 8 –Stakeholder engagement

- Seek views of stakeholders by means of leaflets, forums, etc.

Objective 9 – Methodology report

- Produce a report explaining how the original simple, single-sponsor scheme was disaggregated into a number of viable modular options

Objective 10 – Project coordination and liaison

- Coordinate the project activities by means of a Project Director and a Steering Group
- Participate in sharing experiences with DEFRA and other pilot project participants

Appendix B – OFWAT Response

"We have been unable to conclude that Yorkshire Water has any formal responsibility to deal with flooding which results from the culverted watercourses nor to maintain them.

"We have considered the complaint against the background of Yorkshire Water's duty in Section 94 of the Water Industry Act 1991 … to effectually drain its area and to maintain the public sewerage system…..

"We have sought a view from an engineering consultant who advises us from time to time on sewerage matters but we cannot say with any certainty to what extent the contents of the culvert consist of surface water from the public sewers, land or highway drainage. We cannot conclude therefore, that Yorkshire Water has any responsibility for the culverted watercourse or flooding which results from it. (OFWAT to Leeds CC, 10 September 2004).

Appendix C - Table of flooding incidents referred to by residents of West Garforth in response to public meeting on 22/05/07

Location	Circumstances	Time	Information and comments provided by members of West Garforth community
Lidgett Lane	Only in the winter. NO problems during summer storms	In last 34 years, experienced flooding on I occasion during each of last 2 winters	Resident describes floodwater seeping in through cellar wall & draining away afterwards. When this occurs Resident also describes that gully in front of house fountains approximately 450 mm high. Resident also describes torrents of water running down Lidgett Lane & the parallel back lane. Resident suspects that the highway drainage is inadequate & is concerned that new development in Lowther road will loose green space for filtration and by putting more water into the system potentially increase flood problem.
Lidgett Lane	Worst during summer storms, both during & afterwards	Worsened over last 5 years	Residents describe water running down lane & seeping through the cellar walls, & spurting through cellar under pressure then draining away over 1-4 hours Residents believe the culvert in this area has a blocked in manhole. Residents recently installed a grill at upstream end of culvert and one resident regularly clears it. Residents remove manhole cover to effectively drain area, which takes up to 1 hour to drain.
Junction of Lowther Road & Lidgett Lane	Summer storms	Extreme event 31st August 1997	Residents describe area flooding to a depth of 300mm at manhole & at its worst the flood was knee deep. Residents report that the only time sewage debris was present in floodwater was during extreme event on 31/08/97 Residents report that this watercourse has a history of blockages & consider a contributory factor might be the frequency with which highway gullies are cleaned observing that, in their opinion the road sweeper appears ineffective at clearing the road gutter.
Moorland Terrace	Worst during summer storms but sometimes also after the storm has passed	In first 8 years of past 16 years only 2 events but in last 8 years flooding has occurred 8+ times	Resident describes water flooding into cellar, garden & garage via the garden of a property in Lidgett lane to a depth of 12”. Resident reports having to replace the fridge & has installed a sump pump in the cellar & a soak away in the garden because although the cellar is lined water seeps through the cellar walls. Resident suspects water comes from the property’s manhole, the road, & neighbours property. Resident also considers the culvert cannot cope with the flow from the ditch.
Lidgett Lane			Resident reports flooding in cellar. Resident considers source of water is from Moorland Terrace and standing water in Lidgett lane, which is swept towards property by the passage of vehicles. Also considers there are insufficient gullies in Mooreland Terrace, which has recently been resurfaced. Resident has contacted LCC highways with this information.
Lidgett Lane			Resident reports flooding in cellar. Resident considers water comes over surface directly from Lowther Lane. Resident would like advice on raising the drive level to prevent water from Lowther Lane
Lidgett Lane	During rain	2/3 times in last 10 years	Flooding occurred inside and below house to a depth of 7”. Resident describes the flooding as coming up through the floor. Questions resident has are 1) Where do the main gullies go to? Where do the culverts run? 3) How do you find culverts to gain access? Along with answers to these questions, resident would like personalised advise about how to improve their specific situation.

Oak Road			Although Residents have not experienced internal flooding, floodwater gets close to breaching an air grate on their property. Residents describe Floodwater backing up via road gullies in Fiddlers close and Oak Road. Residents suspect backing up is caused by open gully under Medical centre (Church Lane) cannot take flow. Residents believe grassy area east of BT exchange could be made into dry pond in order to provide storm water surface management solution.

Location	Circumstances	Time	Information and comments provided by members of West Garforth community
Kingsway	During rain		Resident describes that at a low level, below road there is significant internal flooding. YW contacted and responded by creating new link from storm sewer to culvert.
Kingsway	During rain	Every year for the last 3 years in August	Resident reports flooding in cellar, garden, garage and street up to 60cm. Resident reports floodwater containing foul sewage Resident suspects floodwater drains from neighbouring property
Barley Hill Road	Always after heavy rainfall		Resident reports flooding inside property. Resident considers floodwater is escaping from manhole in Queensway & then through back gardens. Resident reports the manhole in Allandale road often lifting at the same time as the one in Queensway. Residents have observed that a new pipe was laid when the old orchard was filled in & a new house was built.
Barley Hill Road	Heavy storms & heavy rain	Excessively every five years, 8 times in last 42 years. To a certain extent it floods every year.	Resident reports flooding inside & below house, & in the garage, garden, highway & local open land in. Resident reports water coming from their house drains and neighbouring property & containing foul sewage. Resident considers the cause of the flood to be the drains to the rear & side of their house not coping. Resident installed retaining wall, which stops most water, entering garden from Queensway housing estate. However, they describe extensive floodwater rising through garden under dividing wall with neighbour.
Junction of Barley Hill Road & Strawberry Avenue	After road resurfacing	18 months ago i.e. beginning of 2006	Residents report highway is regularly flooded. Residents suspect cause of flooding is the gullies not being covered after resurfacing and so are at risk of becoming blocked.
Grange Avenue & Windemere Drive	Only in last 5 of previous 25 years on the flowing dates during July & August. 07/08/02 12/08/04 28/07/05 23/08/06		Resident reports severe flooding. Resident believes reason for flooding is due to the trend to hard landscaping, building extensions to properties and paving driveways over gardens thereby reducing green areas & the opportunity for rain to soak away. Also resident considers there are too many houses for the existing drains and sewers. Resident considers that another reason for increasing flood problem is climate change but only to a limited extent.
Rydal Avenue	During Rain	More than 3 time per year	Resident reports flooding up to 1' in cellar, & flooding in garden, & garage. Resident describes floodwater coming down Grange Avenue into Lindsay Road, into Rydal Avenue & into their drive.
Lindsay Road	Severe rainfall	Last incident 23 August 2006	Resident describes water gushing out of the highway gullies & forms lakes in the low parts of highway.
Lindsay Road	During rain	13 times in last 20 years between years 01 – 06.	Resident describes road flooding between garden walls & flooding the garden & highway. Resident describes floodwater as backing up from gullies & occasionally containing foul sewage. Resident considers floodwater comes from own & road drains. In response, Resident has blocked off lower holes in air bricks.

Ninelands Lane	During rain	In 26 years 3 times in last 10 years during August. [97, 02 & 06]	Resident describes severe flooding occurring inside, below & around the bungalow in garden to a depth of 15 – 40 cm. In response Resident has to lift all possessions possible to safety. Resident describes feeling anxious at not knowing when flooding may occur again.
Fairfield Court	After recreation ground was redeveloped	2-3 years ago	Resident describes water running from recreation ground into gardens & then into the back gardens of Queensway

Location	**Circumstances**	**Time**	**Information and comments provided by members of West Garforth community**
Fairfield Court	During rain	3 times in last 8 years, every 2 years	Resident describes flooding occurring inside & below the house to a depth of approximately 12cm. at the same time the highway floods. Resident also describes floodwater containing foul sewage. Resident considers the floodwater comes from manholes in road/garden & from a land drain.
Fairburn Avenue			Resident describes being flooded from the highway to the front of their property. Resident has invested approximately £4000 in fitting flood guards around the property generating interest in neighbours.
Fairburn Drive	During rain	Over last 40 years twice inside house & [Inside = 31/08/97 & 02/06/82] numerously outside 1-7 x per year	Inside the house flooding to depth of 2', outside house flooding to a depth of 3'. Resident describes floodwater running along road surface, accumulating & running down drive. It then came out of uncovered drains. Because of constant anxiety Resident has invested thousands in demountable flood protection barriers which because of no reliable warning system is deployed every night. Resident considers the flooding is due to insufficient capacity in the public water surface sewer.
Queensway	Flooding appears to coincide with flooding at Old George Hotel.		Residents report that manhole lifts up at the bottom of garden. Kerb has been raised to retain water, however Residents consider that this is of limited effect because it is a bus route.
Culvert under Wakefield road & Old George Hotel			Residents describe flooding occurring higher up in catchments from culvert. Residents suspect that culvert has insufficient capacity & also that the screen on the culvert may be blocked.
Ninelands Lane, & Medway Avenue,	During rain		Residents report gardens flooding
Gleglands close, & Derwent avenue	During rain		Residents report gardens flooding from the adjacent playing fields of Ninelands school
(off) Barley Hill Road			Residents report flooding around bowling area
HIGHWAYS	During heavy rainfall		Residents report flooding at Poplar Avenue, The bottom of Grange Avenue & Lindsay Road, Ringway at the bottom of Goosefield Rise and at the top of Goosefield Rise where the street dips towards Selby Road. Also flooding occurs at various points along Fairburn Avenue towards the junction with Hazelwood Avenue and Ninelands Lane.

Moorland Terrace		15 times in last 12 years & recently more than twice a year.	Resident reports creeping water causes flooding approximately 1'. Resident suspects the water comes from neighbours property, nearby stream & blocked road drains – but isn't sure

Location	**Circumstances**	**Time**	**Information and comments provided by members of West Garforth community**
Moorland Terrace	During or after heavy rainfall	Twice a year, especially in August	Cellar floods to 1 foot deep then drains naturally within 2 days Concerned that taking any action will affect neighbour's cellar's
Moorland Terrace	During heavy rainfall	August	Surface water can run down street so fast that children cannot be brought home.
Moorland Terrace	Heavy, persistent rain immediately following a dry spell		Standing water in cellar Resident pumps the water out when it reaches the bottom step and explains that she has learnt to live with it. However, has concerns that the property wont sell
Moorland Terrace			Resident describes floodwater coming from watercourse into garage & garden. In response resident opens their manhole in order to ease the flooding. Resident describes a blocked culvert inlet just down stream
Moorland Terrace	Worse when it is exceptionally wet	Most of time but worst in last five years	Resident describes the depth of floodwater in the cellar as varying & having a bad smell. Resident also describes the garden as flooding. Resident explains that it is sometimes so deep waders are worn to go into cellar.
Moorland Terrace	Not connected to rain	Often August & more than twice per year	Cellar & garden, flooded approximately 3 feet deep Take everything out of cellar and Neighbour's pump clears water
(off) Barley Hill Road			Flooding around bowling area
Moorland Terrace	Even when no rain	Throughout year & worse in last 5 years.	Resident describes flooding in cellar by ground water, Resident considers: *"it [*FLOODWATER] *must be another source of water"* [OTHER THAN RAIN]

Appendix D - Analysis of Questionnaires and Maps from West Garforth IUD pilot study public meeting, 10th December 2007 [CONFIDENTIAL]

Introduction
This report presents the comments of members of the public who attended the IUD pilot study public meeting on the 10th December at Ninelands Primary School.

Method
The aim of the public meeting was to discuss the flooding problems in West Garforth, the improvement measures and to touch on how climate change will affect the flooding. People were invited to attend the public meeting through:

- Letters to those who have suffered from flooding in the West Garforth Area;
- Information supplied and printed in the local press.
- Flyers and posters in shops.

The meeting began with presentations from the IUD partners about the flooding problems in West Garforth and potential improvement measures available. In the second part of the meeting participants were invited to suggest what improvement measures they thought could be located in different parts of the West Garforth area. Coloured dots and tape were used to signify different improvement measures. Participants were encouraged to place the dots or tape on appropriate locations on maps relating to each of the flood prone areas. Questionnaires were then available for participants to provide comments on the improvement measures suggested. A copy of a blank questionnaire is provided in Appendix 1.

Presentation of Results
The following tables show what was recorded on the questionnaires and the maps for each of the map areas, corresponding to the six different flooding problems identified. If the street name is written in italics then this means that the measure being commented on is not marked on the map.

In total 42 questionnaires were filled in at the meeting. The numbers of questionnaires received for each of the areas are shown on the headings for each of the tables. There was also a lot of information which was only demonstrated on the maps using the coloured dots and tape. For this reason not all of the measures have positive and negative impacts filled in. Many people when filling in the questionnaire did not fill in any negative impacts. This may reflect the audience at the public meeting, many whom had been flooded.

Some people also suggested improvement different from those symbolised by the dots and tapes. In these cases, the information on the questionnaires has been transcribed as fully as possible onto the table. It should be noted that all comments on the tables are those received through the questionnaires and do not represent the views of the research team.

Appendix D Tables omitted from published version in order to respect the privacy of people whose names or addresses are mentioned

Appendix E - Work Packages [and coordinator]

WP1 – Asset inventory [LCC] A full list of data available to the project will be compiled. This will include asset data, incident data, map data, terrain data, currently proposed activities affecting the area and socio economic data. The data will be assessed for completeness and enhancements/methodological changes will be identified. A CCTV survey will be carried out to assess the condition of the culvert system and its connectivity.

WP2 — Historical review: [LCC] The history of the culverts in West Garforth will be researched, in order to establish the definitive status of each length in a way acceptable to the partners..

WP3 – Risk assessment: [PWG] The performance of the drainage infrastructure (culverts, sewers, land drains and highway drains) will be modelled. As much valid data as possible will be gathered from previous modelling exercises (early 1990s), but it is envisaged that a significant amount of fresh survey work will be required to enable the production of a terrain model for the flooded areas and their surroundings. The model will be used to determine the inundation profile for a range of probabilities, to test the effects of climate change and to test optional solutions. A modest flow and rainfall survey will be required to verify the drainage network model. The modelling environment will be InfoWorks, supplemented by FEH methodologies to assess the impacts of urbanisation on the original rural watercourse. The risk assessment will be benchmarked using current land use and climate, but will also assess the potential impact of controlled and uncontrolled development and climate change. A study will quantify the historic trends of urban intensification within the catchment and this will be used to help to predict future pressures. Specific tasks are:

- InfoWorks
  - Review current model and asset and identify need for enhancements and terrain modelling
  - Carry out surveys
  - Enhance model
  - Commission flow survey
  - Verify model
  - Benchmark modelling using event matrix and inputs for observed flood events
  - Inputs for future development proposals and intensification
  - Simulations for benchmark event matrix, observed events and future rainfall scenarios.

- FEH
  - Assessment of flows using current (urbanised) catchment criteria and catchment without urban contribution leading to assessment of current urbanisation on stream flows.

- Flow routing
  - Routing of flows using GIS and possible modelling techniques to assess contributions to flooding of sinks

WP4 – Attribution of risks and responsibilities: [PWG] A workshop will be held in order to present the results of the risk assessment to representatives of the stakeholder groups. The aims of the workshop will be

- to facilitate the development of a consensus as to where the different risks and responsibilities lie.
- to agree a benchmark performance matrix which will then be used in the assessment of options

WP5 - Develop options: [PWG] Potential options will be developed in a heavily 'modularised' form, so as to lend different modules to different forms of promotion. Whereas the simple (single promoter) scheme developed by the Sewerage Agency in 1993 was based on a conventional pipe system, the current project will try to make use of sustainable drainage solutions where possible. This might open up a range of lower cost, more acceptable options. For example, encouraging the uptake of non-structural methods might be a component part of a comprehensive strategy.

A number of options will be developed for each module, where practicable, so as to maximise the chances of arriving at a mix which will be capable of adoption by the relevant parties.

A cost-benefit assessment will be made for each of the modular options.

WP6 - Explore funding of options: [EA] A number of different funding options will be suggested for each module, taking into account the following characteristics of the various stakeholders:

(a) duties; (b) powers; (c) rights; (d) interests/benefits; and, (e) capabilities

WP7 - Option selection: [All] A workshop will be held to present and discuss the outputs of work packages 6 and 7 within the context of the consensuses arrived at within work package 4. Following this workshop, a plan for future local actions, beyond the scope of the MSFW study, will be developed.

WP8 – Stakeholder engagement: [PWG] This work package will run throughout the duration of the project and will assess the effectiveness of current best practice thinking which will be introduced to the project.

The package will involve three linked tasks:

- First, a leaflet will be prepared to communicate with residents about the proposed investigation and how it will work. As well as communicating about the investigation, the leaflet will also invite residents to a forum in which they can learn more about the scheme and through which they can contribute ideas and preferences.
- Second, another forum (WP4) will be organised in an appropriate community location. The forum will emphasise the exchange of information, highlighting the extent to which the residents are themselves ‘expert’ about the flood impacts.
- Third, towards the end of the investigation, a final forum (WP7) will be convened to explain what has been done and to highlight any ongoing issues of concern.

The forums will be professionally facilitated, and the findings will be recorded and provided in a paper report.

WP9 - Methodology report: [LCC] A report will be prepared on the methodology used to disaggregate a simple conventional scheme into viable modules. It is intended that this will incorporate techniques and considerations that will be transferable to other areas which face similar problems. Partners will be consulted during the progress of the study, with a view to ensuring that the modular options are ones which provide the best realistic chance of getting funding assent.

Appendix F – Suggested Responses

Table 1 lists the suggested responses and flooding location along with a short description of the response

Option No.	Option Location	Flooding Location	Description
P1	Lowther Road	Lowther Road	The replacement of pipe sections adjacent to the corner of Lowther Road/Lidgett Lane, to remove adverse gradients in pipes adjacent to Lowther Road. Node positions and subcatchments retain original positions and sizes. Invert levels taken at 8_030 and 8_040 nodes and now linked with 450mm diameter pipe with a uniform gradient.
P2	Lowther Road/Rydale Avenue	Lowther Road	New pipe constructed to start at the junction of Rydal Avenue/Lowther Road to take flows to outlet of southern surface water drainage system located close to Highfield Drive. Pipe diameter 450mm. The invert levels taken at node 8_030 and southern outlet.
P1+P2	See above	See above	See above
P3	Lowther Road	Lowther Road	Remove pipe in Lowther Road, between node 8_033 and 8_030 and combine with option no. 2. This aims to ensure that all flows from upstream of Lowther Road are directed southwards to the system at Highfield Road
P4	Lidgett Lane/Church Lane	Lowther Road/Fidler Lane	Add pipe at node 1_067 to 108_010 combined with option 2, concept is to take excess flows from Lidgett Lane/Lowther Road junction to the south.
P5	Lidgett Lane/Church Lane	Lowther Road/Fidler Lane	Option 4 combined with pipe removal at Lidgett Lane between nodes 8_033 and 8_030
P6	Barley Hill Road	Barley Hill Road/ Queensway/ Allandale Drive	Addition of new pipe at node 16_110 (Barleyhill Road) to remove excess water from highway drains on Wakefield Road and from system upstream (Queensway etc) to stream located to NW at Moor House Farm. 600mm diameter pipe slope selected so that it does not surcharge.
P7	Gardens behind properties on Allandale Road	Allandale Drive	Replacement of culverted with daylighted stream. Use invert level of culvert as base level of stream.
S1 (8)	Storage at Recreation Grounds	Barleyhill Road/Queensway	Surface pond on lower football pitch, connect to node 16_050, surface pond 1300m^2 in area 1.5m deep.
S2 (9)	Storage at Catholic School, in NE of study area	Oak Drive/ Station Road Fidler Lane/Lowther Road	Surface pond in south side of school grounds, connect to node 1_030
S3 (10)	Storage/Swale - Oak Road/Oak Drive	Oak Drive, junction with main north-south line	Swale along Oak Drive/ Oak Road, connect to node 1_060 - modelled as small storage pond 165m^2 by 1m.
D1 (17)	Storage/Swale - Oak Road/Oak	Oak Drive, junction with main	Disconnect system at 1_050 Disconnect system at 1_050 and provide new

	Drive	north-south line	outlet, this simulates disconnection of system above 1_050 to simulate at least the effect of a total roof disconnection
D2 (19)		Derwent Avenue/Glebelands	Disconnect system on branch 130 upstream of branch 170
D3 (20)	Works to East of Ninelands Lane	Ninelands School	Disconnect works located to east of Ninelands Lane

Table 1 – Solution description and flood locations

Appendix G – Description of Response Effectiveness

Table 2 contains a short description of the effectiveness of the reported solutions.

Option No.	Option Location	Flooding Location	Solution Assessment Current Conditions	Solution Assessment with 2055 climate change
P1	Lowther Road	Lowther Road	Reduces Lowther Road flooding at 8_040 by about 25%. No effect at any other node.	Not done as solution does not provide significant benefits under current conditions
P2	Lowther Road/Rydale Avenue	Lowther Road	Removes flooding at 8_030 and reduces at 8_040 by about 20%. No effect at any other node.	Not done as solution does not provide significant benefits under current conditions
P1+P2	See above	See above	Combining the two above removes all flooding at 8_030 and 50% at 8_040 at Lowther road. Also causes slight increase at downstream node 1_091.	Combining the two above removes all flooding at 8_030 and 50% at 8_040 at Lowther road. Also causes slight increase at downstream node 1_091.
P3	Lowther Road	Lowther Road	Not quite as effective as P1+P2, flooding removed at 8_030 and 40% removed at 8_040.removes some of the flooding at Lowther road - slight decrease downstrean at 1_091.	As this solution was less effective than P1+P2 no climate change solution examined.
P4	Lidgett Lane/Church Lane	Lowther Road/Fidler Lane	Additional pipe was 450mm in diameter but invert levels means that the pipe slope is adverse and so this solution can provide no additional benefit in comparison with P2	Not done as solution does not provide significant benefits under current conditions
P5	Lidgett Lane/Church Lane	Lowther Road/Fidler Lane	Not as effective as P1+2 - removes all flooding at 8_030 and 35% at 8_040 but causes some more flooding at 1_091 downstream. Similar in effectiveness to P3.	As this solution was less effective than P1+P2 no climate change solution examined
P6	Barley Hill Road	Barley Hill Road/ Queensway/ Allandale Drive	Removes a small amount of flooding at 16_130 (downstream) and a slight reduction at 16_110 immediately upstream but no impact elsewhere. Reduces water depths in culvert.	Not done as solution does not provide significant benefits under current conditions

P7	Gardens behind properties on Allandale Road	Allandale Drive	Has same impact on flooding as P6, although it does not significantly reduce upstream or downstream flooding of the culvert it does reduce water depths in culvert. At maximum flows pipe 1_180 and 16_120 are totally filled indicating capacity problems both upstream and downstream of culvert	Not done as solution does not provide significant reductions in flooding under current conditions
S1 (8)	Storage at Recreation Grounds	Barleyhill Road/Queensway	Removes flooding in leg 16 downstream of 16_050 – i.e. Barleyhill Road/Queensway and culvert and also in leg 21 entirely. Some flooding in leg 16 upstream of storage pond but significantly reduced. Combining solutions P6 and S1 does not appear to have significant additional benefits	Not so effective – still removing flooding in leg 21, however only reduced flooding in leg 16, at Barley Hill Road and in culvert. This could be improved by the addition of more storage
S2 (9)	Storage at Catholic School, in NE of study area	Oak Drive/ Station Road Fidler Lane/Lowther Road	Reduces flooding upstream, and to a very slight extent downstream. Reduces flooding at 8_040 slightly	Not done as solution does not provide significant benefits under current conditions
S3 (10)	Storage/Swale - Oak Road/Oak Drive	Oak Drive, junction with main north-south line	Removes flooding at 1_060 and reduces it upstream by 75% at 1_050 and downstream at 1_063 and 1_091 again by about 80%.	Not done
D1 (17)	D1 (17)	Storage/Swale - Oak Road/Oak Drive	Removes flooding at 1_060 and 1_063, and 1_091, reduces flooding at 8_040 by 20%	Still removes flooding at 1_060 and 1_063 now limited reductions at 1_091 and 8_040.
D2 (19)		Derwent Avenue/Glebelands	This has no effect on the downstream system, e.g. branch 170 draining Glebelands Court/ Derwent Avenue	Not done as solution does not provide significant benefits under current conditions
D3 (20)	Works to East of Ninelands Lane	Ninelands Schol	This removes significant flooding at nodes next to the School but only has a no reduction further downstream – very local impact.	Not one as solution does not provide significant benefits further downstream in the system

Appendix H – GLOSSARY of terms used in this report

Drain - A pipeline which conveys foul sewage and/or surface water runoff from a single property. It is usually of small internal diameter. (The responsibility for its maintenance will generally lie with the property owner.)

Private Sewer – A pipeline serving two or more properties that conveys foul sewage and/or surface water runoff and has not been vested or adopted as a public sewer (maintenance is the shared responsibility of the property owners)

Public Sewer – A sewer that conveys foul sewage and/or surface water runoff that is vested in a Water and Sewerage Company or predecessor, that drains two or more properties and conveys foul sewage, surface water or combined sewage from one point to another point and discharges via a positive outfall (maintenance is the responsibility of the Water and Sewerage Company).

Watercourse - A stream, river, ditch, cut, dyke, sluice, or passage through which water flows. The statutory and common law definitions are complex and different. They can only be understood in relation to specific circumstances, which cannot be adequately dealt with in a glossary..

Main River - A watercourse marked as such on the main river map. New additions to the map are proposed by the Environment Agency for Ministerial approval. These are the watercourses that represents the greatest risk to people and property.

Ordinary watercourse - A watercourse that is not a 'main river' watercourses.

Culvert - A covered channel or pipeline which is used to continue a watercourse or drainage path below ground level or under an artificial obstruction

Highway Drain – A pipe or conduit constructed for the purpose of carrying away surface water from a road. This will usually connect gullies or other highway drainage features (e.g. 'Beany' Blocks') to a sewer or watercourse.

DG5 Register - OFWAT,s Director General 5th measure of service that relates to sewer flooding.

1. Properties and incidents flooded in any year as a result of "other causes" (i.e. blockage, collapse, equipment failure)
2. Register of properties known to be "at risk" of flooding due to overloaded sewer more frequently than 1:20 years.

Internal Flooding - For the purposes of DG5, internal flooding is defined as flooding which enters a building or passes below a suspended floor. For reporting purposes, buildings are restricted to those normally occupied and used for residential, public, commercial, business or industrial purposes. Garages forming an integral part of the property are classed as part of the building.

OFWAT - The Office of Water Services (OFWAT) is the economic regulator for water and sewerage services in England and Wales. Ofwat monitors the way in which services are provided to customers and to seek value for customers.

FEH – Flood Estimation Handbook

WaPUG – The Waste Water Planning Users Group: a not-for-profit organisation established over twenty years ago to promote best practice in the wastewater industry.

APPENDIX I – PROTOCOL FOR INVESTIGATION OF FLOODING PROBLEMS WITH MULTI-AGENCY INPUT

Introduction

This protocol is to be used when flooding problems appear to fall outside the currently accepted operational responsibilities of any single competent agency. It aims to provide the information needed for the agencies involved to make informed decisions regarding the actions they may wish to take to resolve or ameliorate any identified flooding problem. It aims to allow an objective investigation of the source of any flooding problem followed by an initial examination of potential improvement measures before any allocation of responsibility. This should provide the best possible information base, available at a reasonable cost, to be available to all agencies before they make any decisions. It also aims to engage the public effectively in the investigation of the flooding problem and potential remediation measures.

In particular, the protocol is attentive to the varied needs of the public in this respect. Members of the public whose properties are flooded or who have a strong personal interest in flooding may be able to provide information about local flooding incidents, to contribute ideas about potential responses or improvement measures, and will also be interested in hearing about the progress of the investigation. In contrast, the wider public may have limited interest in the investigation until and unless improvement measures are identified that will impact on their daily life (for example, through a swale in their street or their football pitch being flooded). The views and opinions of this wider set of the general public are crucial towards the end of the investigation when the acceptability and design of location-specific improvements are being considered.

The protocol is in seven stages:

1. Invitation
2. Problem and Resource Definition
3. Information Gathering
4. Information Collation
5. Performance Investigation
6. Response Investigation
7. Consultation and Responsibility
8. Post-implementation performance and adaptation

1. Invitation

In this stage, one of the competent authorities identifies a potential flooding problem that may, in some part fall outside its own area of responsibility. It then defines the problem and a study area and then invites other professional stakeholders to carry out a joint investigation. Other stakeholders then agree to carry out a joint investigation and agree on the scope and a timescale for the study and nominate a person in each organisation to represent that organisation in the joint investigation. Consideration may need to be given to involving key riparian owners.

2. Problem and Resource Definition

In this stage, the original authority provides a written definition of the problem. One authority agrees to co-ordinate the investigation and the other stakeholders list the resources available for the investigation and a project team is formed. They produce a project plan, listing timescale, available resources and criteria against which potential responses will be appraised. All professional stakeholders then agree programme and resource availability.

3. Information Gathering

In this stage all partners list the available information they hold. The project team gathers the data. This may include: asset databases, flooding incident data, rainfall and flow records, survey records, public contacts, topographical data, and any existing studies and system models. Partners should also make the others aware of any other data that they cannot release to the investigation team. The project team will make the public aware of the joint investigation, including information on its scope and timescale, and will gather information from the public, especially on the description of flooding incidents. The public with interest and enthusiasm for involvement at this stage are likely to be those members of the public whose properties are subject to flooding, or have another strong interest in flooding. This information gathering is likely to occur through an appropriate public participation event, such as through a dedicated public meeting, or through the team's involvement in a larger community event. As well as information about flooding incidents, the project team should gather contact details of interested members of the public who could provide some perspective on the viewpoints of the local community.

4. Information Examination

The investigation team will examine the available information, summarise potential information gaps and then outline the methods required to identify, the extent of the flooding, the reason of the flooding, and potential responses.

If information gaps are identified, for example on the condition of the drainage system, then arrangements will be made to collect the required data (e.g. CCTV survey, flow survey data), subject to resource constraints.

5. Investigation of System Performance

All professional stakeholders, taking account of the views of those at risk, will first agree an acceptable level of flood risk.

The data on the flooding incidents from the professional stakeholders and the public will be collated. System data from asset databases, CCTV surveys will also be collated. The key elements of the drainage system will be identified and an appropriate engineering model(s) of the drainage system(s) will be built, if required. The complexity of the model(s) will reflect the complexity and scale of the flooding problem. The model will be used to predict the drainage system performance to examine whether it achieves an acceptable level of performance. A traditional model will not be required in every case. The primary need is for an understanding of the system performance. This can often be achieved using flow pathway mapping, without an expensive model.

If an acceptable level of performance is not achieved, then the reasons why acceptable performance is not achieved will be identified.

The cost of damage caused by flooding at the desired flood risk will be quantified using an expected annual damage cost methodology.

The project team will produce a report on system performance, describing whether an acceptable flood risk is achieved and if not what the reasons are for this situation and an estimate of the cost of flooding. It will also advise stakeholders as to the assumptions used in this study.

A joint meeting with stakeholders will be held to agree the findings of the investigation. These findings will be reported to the public who have an interest in flooding, possibly through a newsletter inviting them to an event to explore potential responses (see below).

6. Response Investigation

The project team will meet with the professional stakeholders and develop a list of potential responses, without regard to responsibility for implementation. The project team will also meet with the public, report the agreed conclusions on system performance and seek views on potential responses and their acceptability. Members of the public choosing to participate in activities identifying potential flooding solutions are likely to be largely those with an existing interest in flooding.

The project team will then examine responses in terms of performance in reduction of flood risk, response cost, public acceptability and adaptability to future climate change. All responses will be considered.

The results of this assessment will be reported to the professional stakeholders and the public. The project teams will rank responses against the criteria defined in Stage 2. Responses must be capable of adapting to and accommodating residual flood risk.

7. Consultation and Responsibility

The professional stakeholders will discuss the potential responses, agree the most effective of these and provisionally allocate responsibility for implementation.

The stakeholders will then individually consider the possibility of implementing responses, in the context of their own statutory and regulatory constraints and powers – taking into account budgetary constraints and priority issues.

If provisional allocation of responsibility and implementation of responses is confirmed, then the project can move to a detailed design and procurement stage. If proposed responses impact on the streetscape or public sphere, further research into their public acceptability may be required in specific locations. For example, neighbours might be consulted about the acceptability, size, location and planting preferences for a proposed street swale. An update on progress will be distributed to the public attending or expressing an interest in previous meetings.

8. Post-implementation performance and adaptation

The effectiveness of any response measures implemented needs to be closely monitored in terms of ability to cope with expected return periods of occurrence (reducing) and impacts on receptors (increasing damage). In addition, advances in knowledge need to be considered in relation to the expected levels of performance being provided. Both the drivers of impacts and the effectiveness of the performance of the responses implemented will change with time (in some instances quite rapidly). Any residual risks not addressed in the initial response implementation will also need to be monitored in terms of their impacts and possible increase over time. Unlike past responses, future climate change will necessitate a recurrent review of system performance. Where these effects are likely to be significant, the establishment of a long-term learning alliance should be considered, incorporating all actors and stakeholders. This will also ensure that any non-structural responses are maintained.