Much Wenlock Integrated Urban Drainage Management Plan

Final Report

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Produced for

Shropshire Council

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The contribution of the Environment Agency and Severn Trent Water for the provision of data and advice during the verification and working group meetings is acknowledged.

The various departments within Shropshire Council, who helped in providing information, support and GIS data is also acknowledged.

Glossary

Attenuation Pond	A pond designed to detain stormwater runoff. Retention time promotes pollutant removal.
AStSWF	Areas Susceptible to Surface Water Flooding Maps - 1st generation surface flood water maps produced by the EA in response to the Pitt Report
BAP	Biodiversity Action Plan. The UKBAP aims to describe the biological diversity resources of the UK, and set out a detailed plan for their conservation. Each LBAP works on the basis of partnership to identify local priorities and to determine the contribution they can make to the delivery of the national Species and Habitat Action Plan targets. Often, but not always, LBAPs conform to county boundaries
Business Collaborator	Mouchel's collaborative document management system
CCTV	Closed Circuit Television
CFMP	Catchment Flood Management Plan
Defra	Department for Environment, Food and Rural Affairs
DTM	Digital Terrain Model
DSM	Digital Surface Model
EA	Environment Agency
EAD	Estimated Annual Damage
FEH	Flood Estimation Handbook
FMfSW	Flood Maps for Surface Water - 2nd generation surface water flood maps produced by the EA in response to the Pitt Report
GIS	Geographic Information System
GPS	Global Positioning System
Hotspot	Refers to a location where flooding has been identified in the past, often from anecdotal evidence.
Hydroworks	Urban drainage modelling software (predecessor to InfoWorks)
Infoworks	Urban drainage modelling software (updated from HydroWorks using a database format) recent releases incorporating 2D overland flow routing capability.
ISIS	1-dimensional (1D) unsteady hydraulic model software used to assess open watercourses
IH124	Institute of Hydrology 124 method is an alternative method for estimating flows for small, rural catchments
IUDMP	Integrated Urban Drainage Management Plan

LiDAR	Light Detection and Ranging. A device that uses pulses of laser light to measure the distance between an aircraft and the ground, used to produce many reference points over an area of land and allow the mapping of large areas.
MORECS	Met Office Rainfall and Evaporation Calculation System
MWFAG	Much Wenlock Flood Action Group
MWFF	Much Wenlock Flood Forum
MWTC	Much Wenlock Town Council
OS Mapping	Ordnance Survey Mapping
PPS25	Planning Policy Statement 25 sets out the Government's spatial planning policy on development and flood risk and applies to all developments
ReFH	Revitalised Flood Hydrograph Method
Stakeholder	An organisation which has responsibility for assets, buildings or land in Shropshire area which might be at flood risk
SSSI	Site of Special Scientific Interest
STW	Severn Trent Water
SuDS	Sustainable Drainage System
Surface Water Runoff	Runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or watercourse, or it can not enter it because it is full to capacity, thus causing flooding (known as pluvial flooding)
SWMP	Surface Water Management Plan
T_p	Time to peak
Threshold Level	Level at which flood water could enter a property (i.e. bottom of doorway or airbrick)
URBEXT	Urban Extent
WCS	Shropshire Council Outline Water Cycle Study (June 2010)
2D mesh	Surface made up of 2D 'triangles' that allows water escaping from flooding manholes to be routed overland, created from 1m LiDAR.

Executive Summary

Mouchel was commissioned by Shropshire Council in May 2010 to produce an Integrated Urban Drainage Management Plan (IUDMP) for the town of Much Wenlock. It was agreed between Shropshire Council and Mouchel that the IUDMP would follow the Surface Water Management Plan (SWMP) methodology as described in the Defra SWMP Guidance published in March 2010.

Due to the frequency and severity of past flood events in Much Wenlock and the documentation already available that describes potential sources of flooding it was considered necessary by Shropshire Council to proceed directly with the detailed assessment stage. Undertaking a detailed IUDMP has allowed the flooding mechanisms and the characteristics of the catchment to be better understood. The catchment is:

- steep and naturally prone to surface water flooding, and;
- fast-acting (short time-to-peak) particularly when soil saturation is high.

Changes to land use are also a contributing factor to the flooding issues in the town such as natural wetlands drained, changes to farming practices, urbanisation, quarrying and the historic industrial past of the area (railway).

An InfoWorks model for the urban reach of Much Wenlock was built with 2D modelling capability to route any predicting flooding from the sewer / town culvert manholes over the ground to simulate the overland flow paths. One-dimensional (1D) unsteady hydraulic model was used to assess the flood risk along the rural reaches of Sytche Brook, Shylte Brook and Farley Brook. The models were used to assess the existing open watercourses and sewer network, to model any proposed flood mitigation options and to ensure that options proposed do not increase flooding elsewhere.

Conclusions from the three main mitigation options modelled were:

- Option 1 (attenuation ponds and improved land practices) provided the greatest benefit to the town in terms of reducing flood damage to properties by 41%. However the option was also the most expensive. The cost-benefit ratio was economically viable at 16.5.

- Option 2 (improved maintenance and increased number of gullies) was the cheapest but increased peak water levels downstream so should only be implemented in conjunction with an attenuation option to ensure Farley Brook is not adversely affected. The increased jetting of gullies could lead to an increase in contamination of the watercourse downstream. The option reduced flood damages to properties by approximately 24%.

- Option 3 (changes to the drainage network in the area of the Hunter's Gate development and attenuation ponds to avoid adverse affects downstream) benefits the least number of properties by reducing damages costs by only 2% and is relatively expensive.

A combination of the modelled options is recommended as one solution does not improve all flooding issues. If only one mitigation option is to be implemented then Option 1 provides the greatest benefit to residential properties, including those downstream of the Much Wenlock town along Farley Brook.

The stakeholders were closely involved in this study. An Action Plan was compiled (see Section 6 of this report) and the objectives are supported by the stakeholders. The stakeholders have agreed to work with Shropshire Council to achieve the objectives and deliver the Action Plan to the full extent of their flood risk management responsibilities.

1 Introduction

1.1 Background

Mouchel was commissioned by Shropshire Council in May 2010 to produce an Integrated Urban Drainage Management Plan (IUDMP) for the town of Much Wenlock. It was agreed between Shropshire Council and Mouchel at the start up meeting on 12th May 2010 that the IUDMP would follow the Surface Water Management Plan (SWMP) methodology as described in the Defra SWMP guidance published in March 2010[1]. The key steps of the methodology are illustrated in Figure 1.

Figure 1 – Diagram of SWMP cycle (Mouchel interpretation)

The severe flooding in the town of Much Wenlock in summer 2007 has been documented in a report by Telford & Wrekin Council in September 2009[2] and in the Shropshire Outline Water Cycle Study in June 2010[3]. Due to the frequency and severity of the flood events in Much Wenlock and the documentation already available that describes potential sources of flooding it was considered necessary by Shropshire Council to proceed directly with the detailed assessment stage, as recommended in the Water Cycle Study which states that: "*Much Wenlock has experienced significant flooding from both fluvial and pluvial sources. Recently, a*

[1] Surface Water Management Plan Technical Guidance, Department for Environment, Food and Rural Affairs (March 2010)
[2] Much Wenlock Flooding Investigation – An Overview, Telford & Wrekin Council (September, 2009)
[3] Shropshire Outline Water Cycle Study – Final Report, Halcrow (June 2010)

number of locations within the settlement and the adjacent area of Farley were affected during both summer 2007 and November 2008. Shropshire Council has undertaken a detailed review into the sources and mechanisms of flooding within and adjacent to the settlement (Much Wenlock Flood Investigation, September 2009). Anecdotal evidence from the Environment Agency has indicated that there is a significant risk of surface water flooding in Much Wenlock, with approximately 64 properties reported as being affected within Much Wenlock and Farley in June 2007 (Bridgnorth Journal). In particular, flash flooding resulting in runoff from the surrounding area and an inadequate draining system that cannot cope with the volume of water is a particular issue, causing disruption to many parts of the town. There are also issues of capacity with the drainage infrastructure. It is strongly recommended that a detailed assessment of flood risk within Much Wenlock and Farley is undertaken through a SWMP, to ensure the interactions between the different sources of flooding are fully understood and that flood risk is appropriately managed in the future."

1.2 Aim and Objectives of the IUDMP

The aim of the Much Wenlock IUDMP is to understand the causes and effects of flooding and agree the most cost effective way of managing flood risk for the long term.

The objectives for the study have been broken down in to the four main categories and are agreed with Shropshire Council during the study.

Partnership

- Establish a successful working relationship between all partners during and most importantly after the IUDMP Study with clear roles of responsibility and lines of communication.

- Enable decisions to be evidence-based, risk-based, future-proofed and inclusive of stakeholder views.

Flooding Issues

- Increase understanding of the causes, probability and consequences of flooding.

- Understand where flooding will occur, the mechanism of flooding, water levels and the inter-connection between rural and urban drainage systems.

- Quantify annualised average damages for current and future flood risk in Much Wenlock.

Opportunities

- Identify and review various mitigation options (taking account of climate change) and prioritise the options through cost benefit analysis.

- Identify where sustainable drainage systems (SuDS) can have a more significant role in managing flood risk.

- Consider the dual use of public recreation and potential temporary surface water storage areas alongside other surface water drainage options.

- Coordinate and prioritise asset management strategies.

<u>Outputs</u>

- Provide 'on the ground' improvements to reduce surface water flood risk as soon as possible and to produce a coordinated IUDMP action plan to reduce flood risk in Much Wenlock and detail how this will be taken forward. This should be agreed by all partners and supported by an understanding of the costs and benefits.

- Use information gained on likelihood and location of potential future flooding to inform spatial and emergency planning functions within the Council. Consultation should be made with the three main risk management stakeholders (Shropshire Council, Environment Agency and Severn Trent Water) to agree how outputs from this study can be used appropriately to ensure fully informed decisions are made regarding spatial and emergency planning.

- Improve public awareness of the risks and ensure engagement of the public on the actions to take.

1.3 Guidance

Under the Flood Risk Regulation (2009)[4] and the Flood and Water Management Act (2010)[5], county councils and unitary authorities have new responsibilities for a leadership role in local food risk management, of which the production of a SWMP forms a key part in many locations.

The Defra SWMP Technical Guidance[1] provides a clear and logical framework to undertake a SWMP study and produce an action plan. It is structured into four key phases; preparation, risk assessment, options and implementation and review, as shown in the SWMP wheel in Figure 2.

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[4] More information on the Flood Risk Regulations (2009) is available at: http://www.legislation.gov.uk/uksi/2009/3042/contents/made

[5] More information on the Floods and Water Management Act 2010 is available at: http://www.legislation.gov.uk/ukpga/2010/29/contents

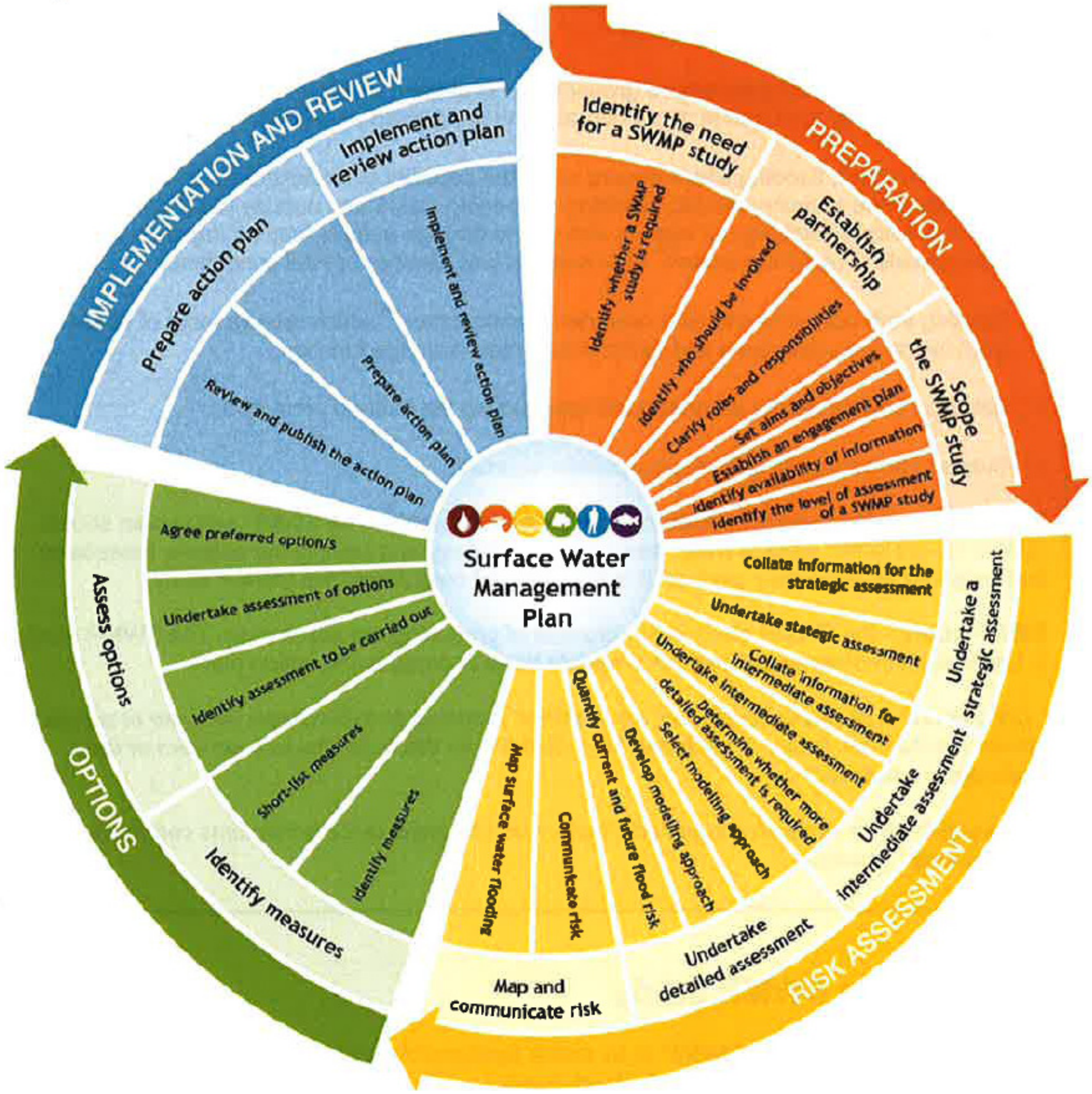


Figure 2 – SWMP Wheel (taken from Defra SWMP Guidance[1])

1.4 Study Area & Catchment Overview

Much Wenlock, earlier known simply as "Wenlock" ("White Place") in Celtic ("Gwyn-loc"), is a medieval market town in South Shropshire surrounded by a rural catchment. Both Much Wenlock and the village of Farley, to the north, are located at the bottom of a steep sided valley drained by the Farley Brook. The Farley Brook is fed by two tributaries upstream of Much Wenlock, the Shylte and Sytche Brooks. To the north west of Much Wenlock is Wenlock Edge, a very steep-sided ridge, and to the south east the Corve Vale hills.

The main runoff paths for the catchment are indicated by the blue arrows in Figure 3 together with the main tributaries that form Farley Brook, Sytche Brook and Shylte Brook.

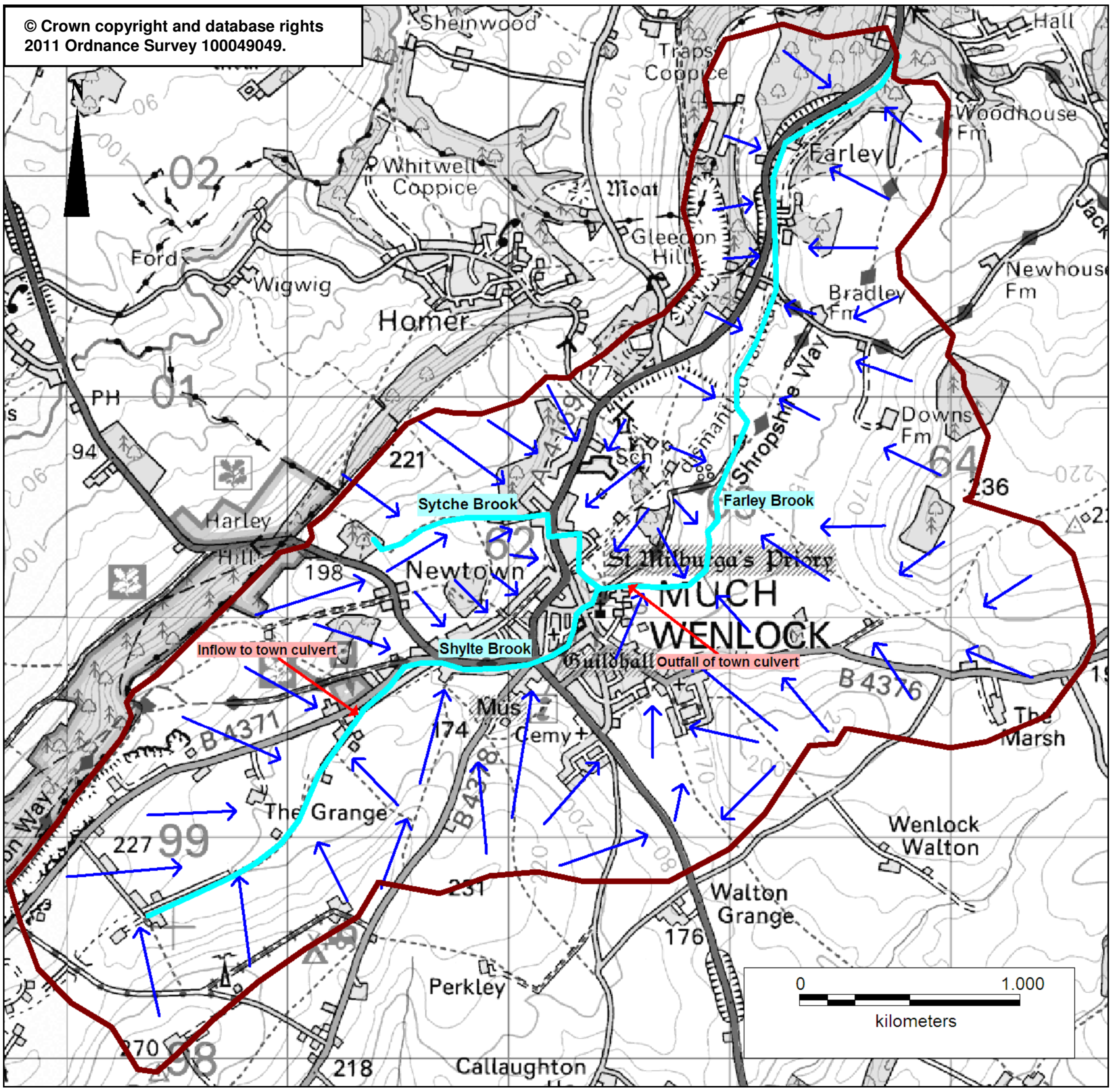


Figure 3 – Main runoff paths (blue arrows), watercourses and whole catchment of the Much Wenlock and Farley

The catchment area is 5.5km^2 down to the outfall of the town culvert to Farley Brook (grid reference: 362550, 300150 and indicated in red in **Figure 3**). The total catchment area down to the village of Farley is approximately 10km^2 (grid reference: 363700, 302650 shown as brown outline in **Figure 3**). The average annual rainfall over the whole catchment is 732mm (FEH CD-ROM 2). Farley Brook has a channel width approximately 4-5m wide (estimated during the site visit in August 2010) and a steep average bed slope of 1 in 30 (0.033 m/m) based on a contour spacing from OS maps. This is a fast flowing watercourse, with a short time-to-peak and high velocities due to the steep catchment, which has the effect of increasing erosion.

The rural sub-catchment upstream of Much Wenlock, shown in **Figure 3** to the south-west of town and draining to the Shylte Brook, is approximately 2.5km^2 and is steep arable farm land with some areas that were quarried in the past. The urban sub-catchment through Much Wenlock is approximately 0.6km^2 and is heavily urbanised until the main culverted watercourse outfalls to the Farley Brook downstream of St Milburga's Priory. The Farley Brook passes an old quarry and eventually discharges to the River Severn 5km downstream. This reach is rural and the land is a mixture of cultivated, grazing pastures and woodland.

1.5 Flooding Issues

Flooding issues and hot spots in Much Wenlock were previously documented in the report produced by Telford & Wrekin Council in September 2009[2] following the summer 2007 floods. These reports provide strong evidence of the numerous flooding issues in Much Wenlock, as well as anecdotal evidence gained from Much Wenlock Town Council, Much Wenlock Flood Action Group and the site visit in August 2010. The flooding issues that arose during the summer 2007 floods are detailed in Section 2.4.4.

One of the aims of the IUDMP is to understand the causes and effects of flooding. This is undertaken by gaining an understanding of the natural shape and steepness of the catchment and the location of urbanised areas, and by investigating all types of flooding that potentially contribute to the problems including surface water flooding, fluvial flooding and groundwater flooding. It is useful to understand the changes in land use such as farming practices, urbanisation and economic activities (such as quarrying) that may exacerbate the flooding issues in order to manage the flood risk in the long term. In addition possible inadequacies in the existing drainage system, relating to both hydraulic capacity and the lack of maintenance, need also to be understood as factors the may contribute to the flooding.

Photographs from the report in to the floods at Much Wenlock and Farley on 25th June 2007 by John Yeats[6] are provided in Figure 4 to Figure 7.

Backing up along a short open channel section of the town culvert caused the collapse of a wall and the spilling of flood water from Shylte Brook on to Victoria Road in Much Wenlock in June 2007, this is illustrated in Figure 4. Figure 5 shows ponding of surface water at a major road junction called Gaskell Corner in the town centre.

Figure 4 – Collapsed wall at The Pound

Figure 5 – Flooding at Gaskell Corner

Surface water flowing through a house at Hunter's Gate during the June 2007 flood

6 A Report of the Floods in Much Wenlock and Farley 25 June 2007, John Yeats (2007)

event is shown in Figure 6. Fluvial flooding from Farley Brook (downstream of Much Wenlock town) is shown in Figure 7.

Figure 6 – Flooded House at Hunters Gate

Figure 7 – Flooding of Farley Brook at Rowan Studios

2 Preparation

2.1 Establish Partnership

2.1.1 Stakeholders

In response to the Flood and Water Management Act 2010[5], Shropshire Council has established a number of Flood Forums with a view to bringing together different organisations and openly discussing local problems and identifying possible local solutions. Much Wenlock falls within the Lower Severn Corridor Flood Forum. Members of the Flood Forum include:

- Shropshire Council
- Severn Trent Water (STW)
- The Environment Agency (EA)
- Much Wenlock Town Council (MWTC)
- Much Wenlock Flood Action Group (MWFAG)
- Landowners

The members have contributed to the IUDMP study by providing information on past flooding and feedback on model results. Their future role includes reviewing the IUDMP report and action plan, and then implementing the IUDMP action plan within the agreed timescales.

2.1.2 Working Group

A Working Group was setup comprising Shropshire Council, Mouchel, the Environment Agency and Severn Trent Water and this provided the technical steer for the duration of the project.

There were four key milestones during the project at which the project Working Group met to review the work undertaken and methodology for going forward. These occurred:

- at project start up to understand who should be involved, the key issues and available information. This was held on 12th May 2010;
- after the information collation task when information had been reviewed and the methodology for assessing flood risk had been proposed in the Inception

Report[7]. This was held on 22nd September 2010;

- after the detailed assessment of flood risk and to set the direction for engineering options to reduce it. This was held on 11th January 2011, and;

- at the end to present the preferred options for flood mitigation.

2.2 Data Collection

During the data collation and review phase (September to November 2010), access to Mouchel's collaborative document management system, Business Collaborator, was given to Shropshire Council and members of the Working Group to upload documents for use by Mouchel's Project Team. The main data providers were Shropshire Council, Environment Agency, and Severn Trent Water.

2.2.1 Previous Reports, Hydraulic Models and Mapping

The following list outlines the key data that Mouchel requested and received from various sources for the Much Wenlock IUDMP. This data was checked and reviewed prior to use on the study:

- Two reports in to the floods at Much Wenlock and Farley on 25th June 2007 by John Yeats[6] and by Telford & Wrekin Council[2]

- Shropshire Outline Water Cycle Study – Final Report[3] (WCS) by Halcrow Group (June 2010)

- River Severn Catchment Flood Management Plan[8] (CFMP) by EA

- OS 1:50,000 Scale Colour Raster maps (Shropshire Council's OS licence number: 100049049)

- LiDAR data for the whole catchment at 1m resolution provided by Shropshire Council from EA

- Information and results printouts of Babtie Hydroworks model of town culvert (1999) provided by Shropshire Council

- As-built drawings of town culvert replacement / rehabilitation by Scott Wilson (2003) provided by Shropshire Council

- Bridgnorth West Drainage Area Plan[9] by Severn Trent Water

[7] Much Wenlock Integrated Urban Drainage Management Plan – Inception Report Revision 2, Mouchel (September 2010)

[8] Severn Catchment Flood Management Plan – Final Report, Environment Agency (December 2009)

[9] Bridgenorth West Drainage Area Plan, Severn Trent Water (May 2005)

- InfoWorks models of the public combined and surface water sewers from Severn Trent Water received in July 2010
- CCTV surveys for the town culvert system and reports of structural condition and blockages, undertaken in 2008 and 2010 by the EA
- Maps showing anecdotal evidence of flooding and flow paths from summer 2007 compiled by members of the Much Wenlock Flood Action Group by hand on maps of Much Wenlock.
- EA Flood Maps Zones 2 and 3, Areas Susceptible to Surface Water Flooding maps (April 2009) and Flood Maps for Surface Water (November 2010).
- EA flow gauge and rainfall gauge at Downsmill along Farley Brook (NGR: SJ62950058), data available from 2008 and 2009. (15 minutely)
- Nearby rainfall data for June 2007 from Willey tipping bucket rain gauge (15 minutely, NGR: SO68169994) and Harnage Grange rain gauge (daily rainfall, NGR: SJ56930215).
- MORECS data provided by Shropshire Council for soil moisture content of historical flood events.
- Much Wenlock Development Planning Document[10] and GIS layers showing all properties and developments.
- Bridgnorth Strategic Flood Risk Assessment by Halcrow 2007
- GIS layer of locations and numbers of gullies was provided by Shropshire Council.

Previous or ongoing Mouchel studies have provided the following:

- Existing drainage drawings at Hunters Gate
- Flooding Appraisal Report for Rowan Studios[11] including a Hec-Ras model of a short reach of Farley Brook.

Also, catchment descriptors and catchment boundaries for the area were obtained by Mouchel from the Flood Estimation Handbook (FEH) CD-ROM 2.0.

2.2.2 *Site Visit*

A site visit was undertaken in August 2010 during which members of Much Wenlock Town Council, the Much Wenlock Flood Action Group and Shropshire Council

[10] Much Wenlock Development Planning Document, Shropshire Council (December 2009)

[11] Rowan Studios, Much Wenlock – Flooding Appraisal Report for Weightmans LLP, Mouchel (August 2007)

provided local knowledge of the catchment and flooding hotspots. Topographic survey information and connectivity checks were undertaken by Shropshire Council surveyors, detailed further in Section 2.2.5.

2.2.3 Hydrogeological Data

Hydrogeological information was obtained from the following sources:

- Ordnance Survey Map 1:50,000;
- British Geological Survey (BGS) Solid Geology & Drift Sheet 152, 1974;
- ESI confidential Report produced for Severn Trent Water Ltd, 2008;
- Borehole logs provided by the British Geological Survey of the area surrounding Much Wenlock.

A site walkover was also undertaken on the 18th October 2010 by Mouchel's Hydrogeologist to supplement the hydrogeological data collection.

2.2.4 Ecology / Environment Data

A desk-top study of ecological records was carried out which initially covered the whole of the Much Wenlock catchment, but then focused on the locations of potential options, refer to Section 4.7. Existing environmental information and plans are provided in Appendix G.

2.2.5 Topographic Survey Data

Topographic survey was required to build the open channel hydraulic models of the Shylte Brook, Sytche Brook and Farley Brook watercourses. No topographical data was available so river cross-sections and details of hydraulic structures were surveyed by Shropshire Council in November 2010. Trimble S6 survey equipment was used to carry out the survey. Processing was carried out using Geosite software with OS values provided by The Severn Partnership, who fixed the control to the Ordnance Survey using their GPS equipment.

The topographic requirements were:

- River cross-sections at approximately 200m spacing along Farley Brook. The length of the reach surveyed was 3.0km. Cross-sections were between approximately 30m and 60m wide including river bed, river banks and part of the floodplain. Additional cross-sections and details at the hydraulic structures (such as culverts, bridges and weirs) were also surveyed.
- River cross-sections at approximately 100m spacing along Sytche Brook and Shylte Brook. The reaches surveyed were 1.2km and 1.5km respectively including hydraulic structures. Cross-sections were between 20m and 50m wide including river bed, river banks and part of the floodplain.

- Flood threshold levels (i.e bottom of doorways or airbricks through which the water could enter the property) of approximately 15 properties were surveyed at houses that may be at risk from flooding. The properties were along Stretton Road (adjacent to the Shylte Brook), Sytche Lane, Sheinton Street and Station Road (adjacent to the Sytche Brook) and houses and works off Much Wenlock Road (adjacent to the Farley Brook).

Some sewer connectivity surveys were undertaken by Shropshire Council surveyors in November 2010 to confirm assumptions made in the InfoWorks model to fully integrate the surface water sewers and the town culvert. The surveyors lifted manholes and undertook dye tracing to check three connections that were assumed for the model build.

2.3 Data Check and Review

The data received was checked and reviewed by Mouchel's Project Team to:

- acquire better understanding of the catchment and the issues;
- check the quality of the data and make best use of existing data for the study;
- assess which data could be used for the validation / calibration of the hydraulic models;
- identify any significant gaps in data;
- refine as appropriate the methodology approach, and;
- provide background information to the key deliverables of this study.

Detailed check and review:

The two reports produced after the summer 2007 floods by John Yeats[6] and Telford & Wrekin Council[2] were reviewed to identify flooding hotspots and anecdotal evidence of possible inadequacies in the system. The maps in the appendices of the Telford and Wrekin report[2] highlighted the flood hot spots and information was transferred into a GIS layer using MapInfo software which provided clear, geo-referenced visualisation of the problem areas and could be overlaid with other evidence of flooding and flood extents. The reports also provided some information on culvert locations and sizes, runoff paths and approximate catchment boundaries which were also transferred to a GIS layer for use on this study. Photographs of recent flooding events provided a useful insight in to understanding the flooding issues and have been used where possible to visually check the hydraulic model outputs.

The relevant sections of the River Severn CFMP were reviewed. The CFMP included references about the summer 2007 floods in Much Wenlock but no specific actions were identified for the area in the CFMP action plan.

The Shropshire Outline WCS highlighted the flooding issues in Much Wenlock and the inadequate drainage in place. It recommended that a detailed assessment of flood risk within Much Wenlock and Farley is undertaken through a SWMP, to ensure the interactions between the different sources of flooding are fully understood and that flood risk is appropriately managed in the future.

Both filtered (DSM) and unfiltered (DTM) LiDAR data was provided by the EA (year when the flight took place is not currently known but it is believed to be recent). The data is at 1m resolution and covered a 15km x 3km area along the main watercourses centred over Much Wenlock. The LiDAR data is presented later in this Section in Figure 8.

Information on the town culvert was reviewed including printouts of the Hydroworks model set-up and results. This was the only information provided for this model but it was possible to extract ground levels, invert levels, sizes and lengths of the culvert sections. The as-built drawings were however used as the main source of data to build the culvert hydraulic model. CCTV records were also checked for correlation with the town culvert as-built drawings and information on Hydroworks model. These showed some differences with culvert section sizes and were used to update the culvert model; the CCTV was used as the definitive information source regarding culvert section sizes as this was the latest information available (as agreed in the Inception Report). A review of the existing town culvert information is provided in Appendix A.

A review of the public foul, combined and surface water sewers was undertaken and is also summarised in Appendix A. The STW sewer model contained the foul, combined and surface water sewers only. There was no representation of the town culvert in this model. However, it was used to extract the surface water sewer information and to determine where the surface water sewers discharge to the culvert.

GIS data for the Hunter's Gate development provided was checked and ultimately used to create the surface water drainage model. This connects into the existing surface water system and was added to the model to assess the performance of the 'as constructed' system, which was one of the areas affected by flooding.

GIS layers of the EA flood maps, AStSWF maps and maps of anecdotal evidence of flooding from the Flood Forum have all been overlaid and compared in MapInfo software.

When developing solution options such as storage areas, the Much Wenlock Development Planning Document[10] has assisted identifying areas identified for possible development which may need to be avoided.

Information regarding land use has been taken mainly from the OS 1:50,000 scale colour raster maps and observations from the site visit.

2.4 Catchment Understanding

The Much Wenlock and Farley catchments are made up of mainly steep sided, rural areas draining to three watercourses: the Shylte Brook, the Sytche Brook and the Farley Brook. The main runoff paths were shown previously in Figure 3. Much Wenlock town is heavily urbanised, surrounded by the rural areas, and has a surface water sewer and a town culvert running through it. The catchment's susceptibility to fluvial, surface water and groundwater flooding are described in this Section.

2.4.1 Fluvial

Both Much Wenlock and the village of Farley downstream are located at the bottom of a steep sided valley. The topography of the catchment is illustrated using the LiDAR data in Figure 8. The Farley Brook and its main tributaries, the Sytche Brook and the Shylte Brook, are also shown in Figure 8.

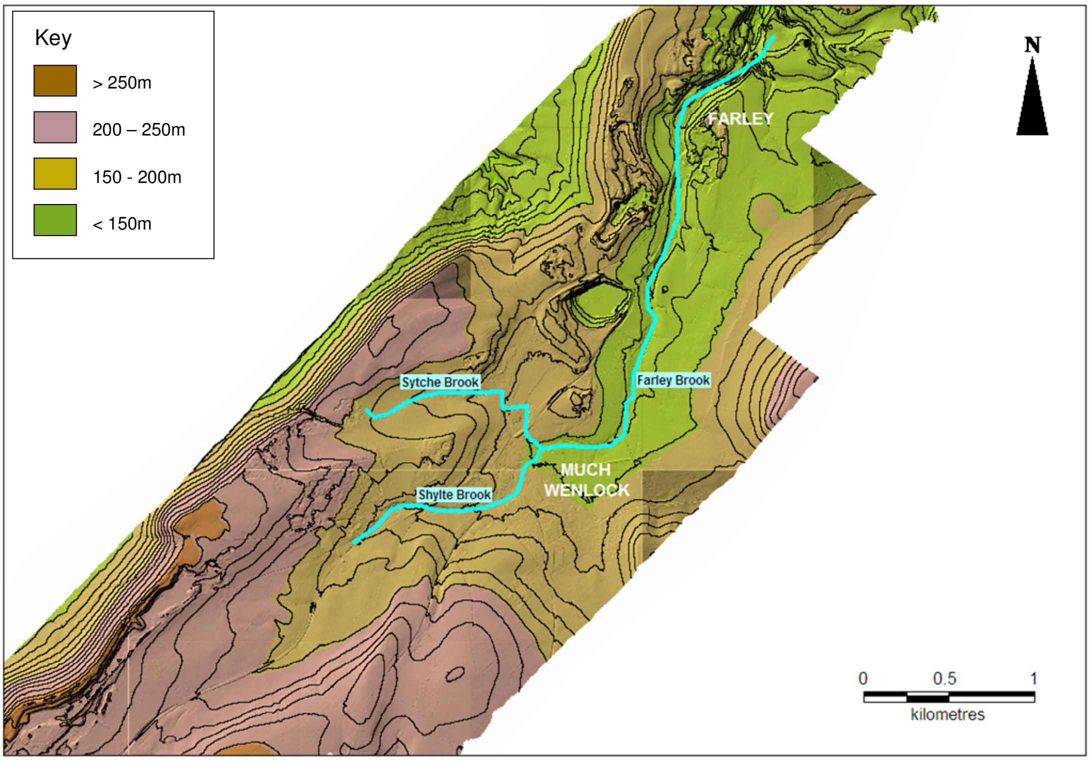


Figure 8 – Topography of the Much Wenlock area and main watercourses (based on LiDAR data)

The Sytche Brook runs in a easterly direction and drains the western catchment. Its source is along the Wenlock Edge at approximately 250m aOD and it discharges to the culverted Shylte Brook that runs through the centre of Much Wenlock. The Sytche Brook is partly culverted and is maintained by riparian owners. The upper catchment of Sytche Brook is steep agricultural land, mainly cultivated, with a few small woodland areas. There is a caravan park at the top of Sytche Lane which has some steep paved areas. The lower catchment is more urbanised, and the brook is culverted along Sheinton Street and Station Road. There are some open sections that border playing fields and small areas of grazing land.

The Shylte Brook runs in a north-easterly direction and is the main watercourse through Much Wenlock town centre. It drains the catchment to the south-west of Much Wenlock and its source is on Wenlock Edge at an elevation of approximately 260m aOD. The upper catchment of Shylte Brook is mainly cultivated land but there are large areas where limestone was quarried in the past. The watercourse runs alongside the route of an old railway line that serviced these quarries and once ran through a large reservoir that is now filled in. Maintenance of the watercourse along the upstream section of Shylte Brook is the responsibility of the landowner. The Brook is culverted beneath Stretton Road Industrial Estate before a small open section. It then flows through the "town culvert" in the heavily urbanised town centre. The ground elevation at the outfall of the town culvert is approximately 150m aOD. In the 19th century the Town Council took ownership of the town culvert but it is not conclusive what responsibilities were transferred to the Council at the time or what remained with the riparian owners[4]. The majority of the length of the town culvert is now designated Main River, apart from approximately 100m at the upstream end.

The town culvert outfalls to an open channel, **the Farley Brook,** immediately downstream of St Milburga's Priory. The Farley Brook flows for 2.5km in a northerly direction to the village of Farley and eventually discharges to the River Severn at Buildwas Abbey a further 2.5km downstream. Although there is an EA flow gauge (NGR: SJ62950058) on the Farley Brook it was noted, during the site visit, that the flow gauge was being bypassed due to undercutting. The Brook meanders through the rural Corve Dale hills. The catchment is mainly agricultural land with some woodland near the village of Farley. Farley Brook flows past an old quarry site, Shadwell Quarry. The Farley sewage treatment works owned by STW discharges to Farley Brook downstream of Much Wenlock.

2.4.2 Surface Water

In April 2009, the EA issued the Areas Susceptible to Surface Water Flooding map (AStSWF map) to local authorities, shown in Figure 9. It is a national map of susceptibility to surface water flooding using the direct rainfall method for rainfall event of 0.5% (1 in 200 chance of occurring in any given year). The national map was distributed to all local Resilience Forums and local planning authorities and indicates flow pathways and locations where ponding could occur. The map appears representative of the flood risk to Much Wenlock as it correlates well with the anecdotal evidence of flooding from summer 2007 which is summarised in Section 2.4.4. A second generation of surface water flooding maps called 'Flood Map for Surface Water' (FMfSW) was issued in November 2010 by the EA. The FMfSW shows very similar flood extents and depths for Much Wenlock as the AStSWF maps.

Both the AStSWF and FMfSW maps show that the catchment is naturally prone to flooding. The maps are based on the direct rainfall method and LiDAR data. In addition, urbanisation, draining of natural wetlands, quarrying and possible inadequacies in the drainage system may exacerbate the natural flooding issues in this area.

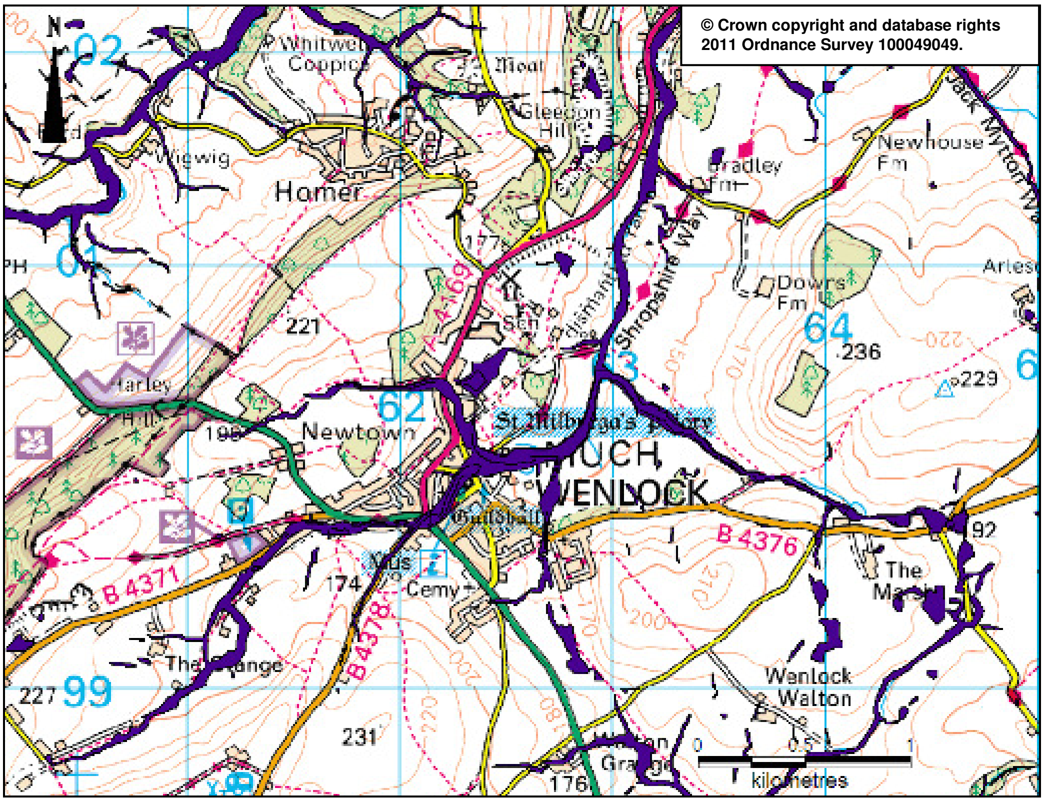


Figure 9 – Map the areas susceptible to surface water flooding (source: EA – April 09)

2.4.3 *Geology and Hydrogeology*

Based on information from the BGS Solid Geology & Drift Sheet 152, 1974, the majority of the catchment is underlain by the Wenlock Limestone at a thickness of up to 90m, whilst the eastern side of the catchment is underlain by the lower Ludlow Shales at up to 120m thickness overlying the Wenlock Limestone. There is a thin cover of drift over part of the catchment predominantly in the valleys and Much Wenlock town.

Groundwater flow is predominantly in the fractured Wenlock Limestone and is partially confined by the overlying Lower Ludlow Shales and glacial till. The Wenlock Limestone is classified as a Secondary (A) aquifer by the EA. A Secondary (A) aquifer includes permeable layers capable of supporting water supplies at a local rather than strategic scale. The main area of groundwater recharge to the Wenlock Limestone aquifer is in the area north west of Much Wenlock where the limestone outcrops along the Wenlock Edge but it is also expected that there will be some recharge from the west and south-west. Groundwater recharge from infiltrating rainfall is expected to be low to very low in areas with glacial till cover or where the shales overlay the limestone aquifer.

Groundwater flow direction is generally east to south-east from the Wenlock ridge toward Much Wenlock, indicated in Figure 10.

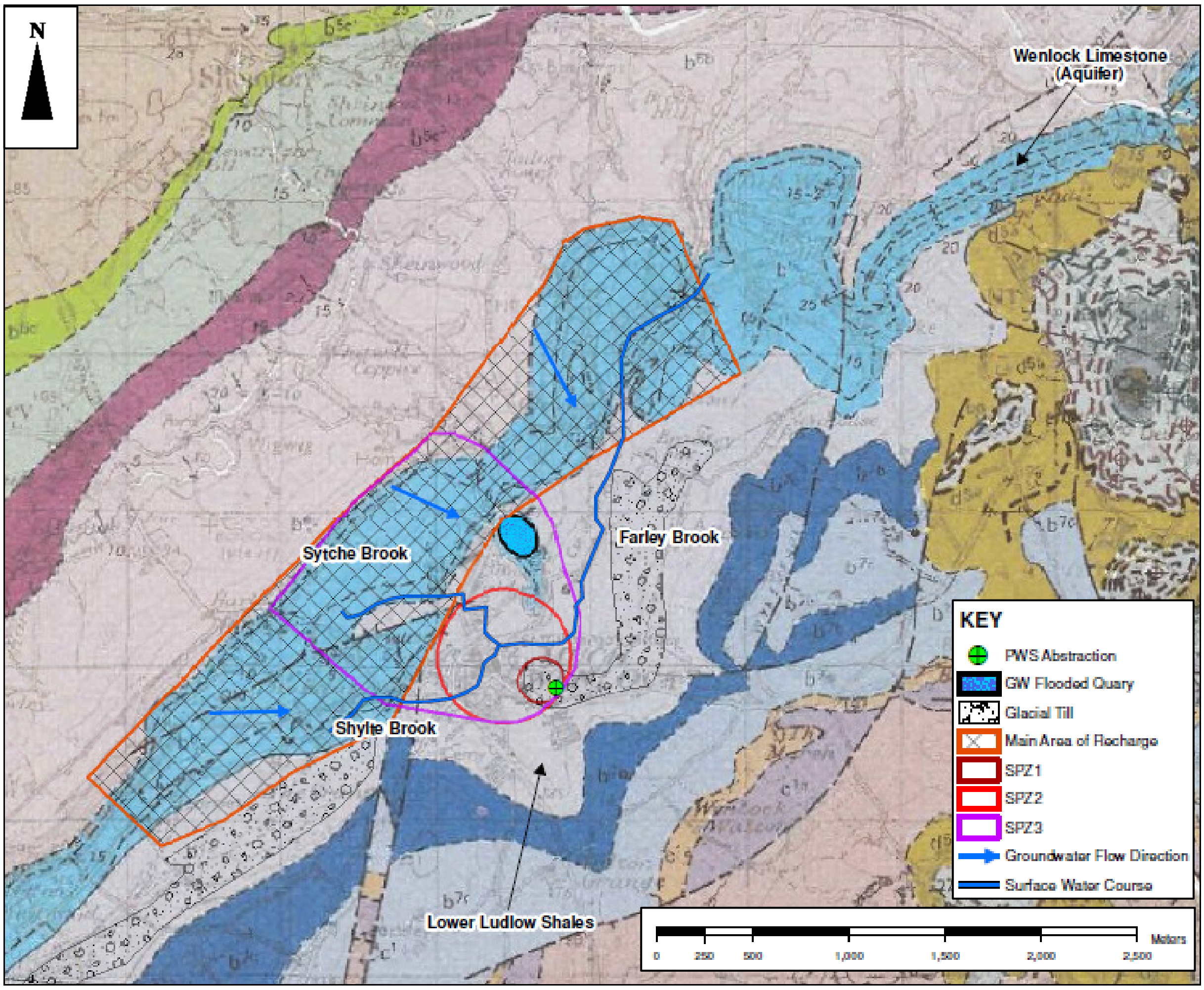


Figure 10 – Hydrogeology summary plan (source: BGS Solid Geology & Drift Sheet 152- 1974)

<u>Groundwater Abstractions</u>

There is only one registered abstraction operated by STW in the vicinity of Much Wenlock located on the northern side of the B4376 road from Much Wenlock, approximately 600 m east of the town centre. It lies in a field on the south eastern side of the Farley Brook valley.

It operates as a public supply well abstracting water from the Wenlock Limestone and supplies the town of Much Wenlock. Information obtained from the ESI report about this well indicates that groundwater level is near to ground level and during periods of no pumping the well may be artesian and discharge into the Farley Brook.

<u>Groundwater Levels</u>

Little information is available regarding groundwater levels in the Much Wenlock area with the exception of a partially flooded quarry called Shadwell Quarry, located at NGR 362,600E, 300,922N to the north of Much Wenlock. The quarry is currently active and information gathered suggests that the water in this flooded quarry could be groundwater. Information also suggests that during the summer months this is dry but overhead mapping available online suggests that there is a considerable volume of water in the quarry. Dewatering is currently taking place during extraction. A summary of the groundwater information is presented in Figure 10 together with the locations of the relevant features.

Conclusions

Due to the partially confined nature of the fractured limestone aquifer in the area of Much Wenlock, groundwater levels in the quarry and the abstraction well are most likely directly affected by rainfall and increased groundwater recharge in the catchment area.

In the case of a high intensity rainfall event, recharge to the limestone is likely to create a rapid response of rising groundwater levels in the quarry and could therefore cause more water to be discharged to the Farley Brook.

Groundwater pressures in the aquifer beneath Much Wenlock would rise and possibly become artesian (groundwater would discharge at the ground surface where pathways through the low-permeability shales), particularly in valley locations. Based on the information reviewed, this is unlikely to be a significant issue at Much Wenlock due to the thickness of the shales, but groundwater discharges could potentially contribute to flooding to the north of Much Wenlock. This in turn could result in the Farley Brook reaching capacity sooner than would normally be expected. However, further assessment and site investigation beyond the scope of this report would be required to estimate the duration of the response or possible discharge to the Farley Brook.

2.4.4 Flooding Hotspots from Summer 2007

The following flooding issues and hotspots during the summer 2007 floods were documented in detail in the report produced by Telford & Wrekin Council, in September 2009[2], and have been summarised in this report. This information is very useful and has been used in the modelling.

Each item is described in short in Table 1 and is located in Figure 11:

- Direct surface water flooding issues in the south-west catchment were noted along the Shylte Brook from highway and field runoff at Havelock Crescent, Bourton Road, Farley Road and Stretton Road. The Shylte Brook becomes culverted and there were reports by residents of backing up and inadequate road drainage during summer 2007 floods, (items 1, 2 and 4).

- At The Pound along Victoria Road there is a short open reach of the otherwise culverted Shylte Brook watercourse (item 3). The Telford and Wrekin Council report[2] states that: "*During normal winter flow conditions it is running at around 80% of its capacity. This open channel section is a known 'pinchpoint' on the system and is the first place on the town culvert to experience flooding during high rainfall events.*" A photograph showed surface water ponding at Gaskell Corner and residents noted the surface water spilled overland from The Pound and Bourton Road, (item 5).

- Flooding of a housing development at Hunters Place and Hunters Gate (development constructed in phases between 2002 and 2005) was noted during summer 2007 floods (item 7). The Telford & Wrekin Council report[2] states that "*attenuation pipes and hydro-brake system are in place in accordance with planning permission. However the system then connects to the existing 300mm diameter surface water sewer which ultimately connects to the town culvert. The surface water system has been designed to take the surface runoff from the development site. It does not have the capacity to receive the runoff from the adjacent catchment area which drains to it.*" "*This controlled discharge was supposed to be piped through the park adjacent to the development and discharged to the ponds at Monks Walk.*" "*There does not appear to have been consideration given to routing these flows through the site and as a result properties at Hunters Gate flood*". The routing of the flows relates to item 8.

- During summer 2007 there was flooding from the culverted Shylte Brook in several locations in Much Wenlock town centre. The Telford & Wrekin Council report[2] shows a photograph of deep surface water ponding at the Bull Ring, (item 9).

- Regarding the Sytche Brook, the Telford and Wrekin report[2] states:

  - "*When flood conditions occur within the town culvert, or if it flows at full capacity, the Sytche Brook can not freely discharge and flooding from the Sytche Brook occurs at the entrance to the town culvert.*" The surface water flooding during the 2007 floods relates to item 10.

  - "*The brook is partly culverted until entering a Victorian brick culvert underneath the former railway embankment. This culvert does not have available capacity in it to enable the 2007 flood event to pass through unhindered, resulting in flooding*" (item 11).

  - "*The overland flow from the Sytche Lane caravan park combined with field runoff causes flooding to Sheinton Street*" (Item 14).

- There was flooding from the Farley Brook downstream of Much Wenlock towards the village of Farley during summer 2007, particularly at Downsmill Cottages, (item 15) and Rowan Cottage (item 17). The Telford and Wrekin report[2] states: "*Downsmill Cottages were severely affected during the 2007 flood event. This was exacerbated by a large blockage downstream of the property, causing upstream water levels to be elevated*" and "*During the 2007 flood event, the flows in the brook were in excess of the capacity of the highways culvert outside Rowan Cottage and as a result the inlet was surcharged.*"

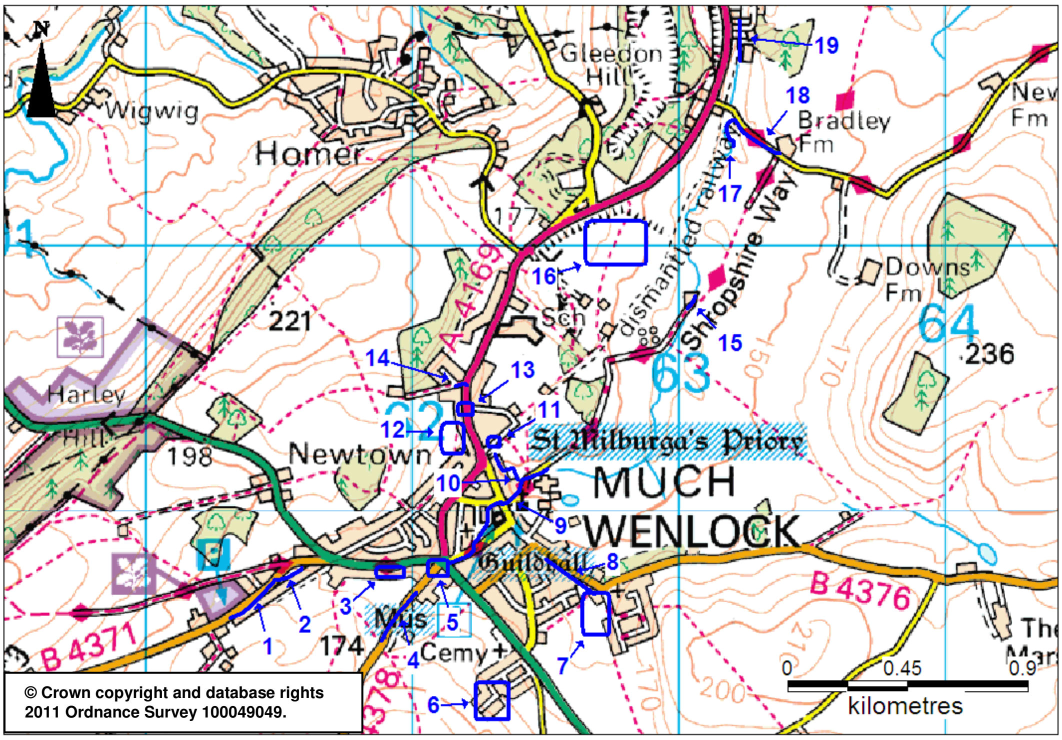


Figure 11 – Flooding hotspots of summer 2007 floods

Item	Location and Issue
1	Stretton Road. Surface water flooding issues from highway & field runoff.
2	Surface water from quarry flows down Stretton Road eventually accumulating outside Havelock Terrace.
3	The Pound. Wall collapsed during 2007 flood due to backing up.
4	Bourton Road (location of an old stream). Road drainage inadequate & poorly maintained. Debris carried & blocks drain.
5	Low Point at Gaskell Corner. Flooding from Bourton Road joins flooding from The Pound and Stretton Road.
6	Oakfield Park. Runoff from fields flooded 3 houses.
7	Hunters Gate. Surface water flooding of new housing development.
8	Drainage of Hunters Gate area may be connected to town culvert via Barrow Street instead of flowing northwards across field to Farley Brook.
9	Surface water flooding during 2007 through Much Wenlock town and past Priory.
10	Upstream of inlet to town culvert, Sytche Brook flooded in 2007.
11	Culvert through old railway embankment failed to cope with flow causing damage and flooding upstream
12	Field runoff
13	Run off split between Station Road (eastwards) and Sheinton Street (southwards)
14	Sytche Stream becomes culverted - under capacity during 2007 flood. Flooding of electricity substation resulted
15	Downsmill Cottages reprofiled land and installed new flood wall to protect properties after 2007
16	Possible ground water flood risk from old Shadwell Quarry
17	Rowan Studios flooded 9 times since 1996. Highway culvert under capacity to take Farley Brook discharge.
18	Surface water discharged on to road from Bradley Farm surrounding fields
19	Culverts under mill damaged by 2007 flood

Table 1 - Flooding issues from summer 2007 floods

2.5 Summary of Sources of Flooding

Evidence from the report by Telford & Wrekin Council[2] following the summer 2007 floods, as well as anecdotal evidence from the Flood Forum and the site visit in August 2010, was used to understand the flooding factors and flooding issues in Much Wenlock and Farley.

Individual or combined factors that can contribute to the increase in flooding issues in Much Wenlock include:

- the natural, steep topography of the catchment. It is prone to fast runoff and the urbanised area is susceptible to ponding of surface water. Rainfall gauge data suggests that Much Wenlock has higher rainfall than the surrounding area due to the local topography;

- changes to **land use.** Many natural wetlands around the surrounding hills have been drained and are now farmed. Changes to land use have also come about due to historic industrial development in the catchment, for example the reservoir next to an old railway line serving the quarry was filled in;

- changes to **farming practices.** The type of crops cultivated and ploughing techniques can affect the volume and velocity of surface runoff;

- **urbanisation**. This has lead to an increase in impermeable surfaces;

- **quarrying**. Extraction of limestone in the surrounding hills has increased in the past 50 years which has lead to exposed areas and possibly affects the water table, and;

- **sporadic maintenance**. Gullies, sewers, culverts, open watercourses, land drains and highway drains, may then become more susceptible to flooding.

It was suggested in the report of the summer 2007 floods by John Yeats[6] that “water appears to reach the river more quickly now” due to the factors mentioned above, an indication that the response time (time to peak) of the catchment has reduced, this is discussed further in Section 3.3 – calibration and verification of hydraulic models.

3 Risk Assessment

The flooding issues to be addressed in Much Wenlock are located in both urban and rural parts of the catchment. It was proposed and agreed with the Technical Working Group to use an InfoWorks model for the urban reach and an ISIS model for the rural reaches. The two-dimensional (2D) modelling capability in InfoWorks to route any predicting flooding from the sewer / culvert manholes over the ground has been used to simulate the overland flow paths.

The ISIS and InfoWorks models have been used to:

- assess the existing open watercourses and sewer networks (where a number of surface water flooding issues and out of bank flooding occurred in summer 2007);
- model engineering options such as possible upstream flood storage areas, and;
- ensure that any options proposed do not increase flooding elsewhere.

3.1 Modelling Approach

This section describes the ISIS and Infoworks models as well as presenting the hydrological modelling approach. The baseline hydraulic models were calibrated using rainfall and soil moisture data for the summer 2007 flood event and flood extent maps verified during the internal and external verification meetings described in Section 3.3. The verified hydraulic models were then run for design return periods: 5, 30, 75 and 100 year + climate change. The flood maps and assessment of flood risk to properties was then used to develop engineering solutions, described later in Section 4.

3.1.1 InfoWorks Model

The InfoWorks model of the town culvert was built in version 10.5, based on ‘as-built’ drawings provided by Shropshire Council, with the Babtie HydroWorks model used to supplement this data, where necessary. For any discrepancies between the two data sets, the ‘as-built’ drawings were used, as discussed and agreed with Shropshire Council at the beginning of the model build activities.

In addition, the public surface water sewers within the STW sewerage model were extracted and added to the InfoWorks town culvert model to develop an integrated model. These surface water sewers were modelled draining to ‘free’ outfalls in the STW model, which have been removed and the sewers connected to the relevant section of the town culvert.

The CCTV survey data for the town culvert (commissioned by the EA and undertaken in 2008 and some additional locations in 2010) was used to model any structural / service conditions found that would be likely to affect the capacity of the culvert.

A screen shot of the InfoWorks model is reproduced in Figure 12, showing the model extents. The red line represents the modelled culvert and the blue lines the surface water sewers.

The InfoWorks 2D module generated flow paths from flooded manholes downstream and the 2D output formed the flood extents.

The foul and combined sewers were not included in the model build and so the risk of flooding from these was not assessed. To add the foul and combined sewers to the hydraulic model is recommended as a possible future update.

Figure 12 – InfoWorks integrated model extents developed by Mouchel: town culvert (red) and surface water sewers (blue). Google Pro licence 156330.

3.1.2 *ISIS Model*

The Farley Brook catchment downstream of Much Wenlock, and the Shylte Brook and Sytche Brook catchments upstream of Much Wenlock, are predominantly rural with open watercourses. Therefore, a one-dimensional (1D) unsteady ISIS[12] hydraulic model was deemed the most appropriate commonly used software to assess the flood risk along these rural reaches.

The LiDAR data and surveyed river cross-section data were used to build the ISIS models. The Sytche Brook and Shylte Brook reaches modelled upstream of Much Wenlock town were 1.2km and 1.5km respectively and the Farley Brook reach

[12] ISIS is a UK-industry standard software for assessing open channel flow.

modelled was 3.0km. The ISIS (light blue) and Infoworks (dark blue) model extents and boundaries are shown in Figure 13.

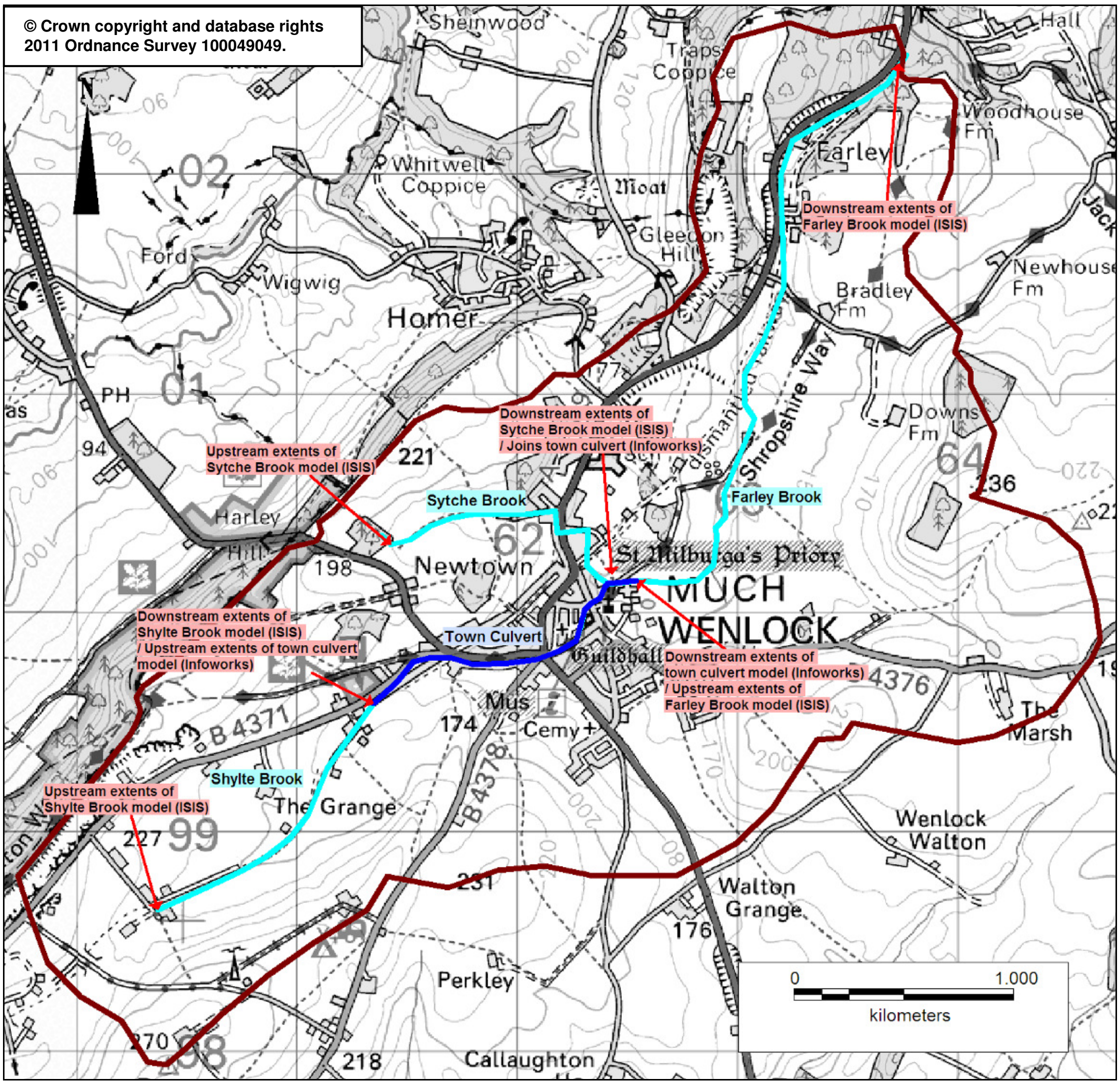


Figure 13 – Extents of Shylte, Sytche and Farley Brook models (ISIS in light blue) and extents of town culvert model (Infoworks in dark blue)

3.2 Hydrological Modelling Approach

3.2.1 Sub Catchment Delineation

To undertake the hydrological modelling, the catchment was delineated in to sub-catchments for hydrological input to the InfoWorks and ISIS models. Sub-catchment boundaries are based on the FEH CD-ROM 2 and were checked and adjusted where appropriate by inspection of Ordnance Survey maps, LiDAR data and sewer network maps. The sub-catchment delineation was presented and agreed during the external verification meeting. The hydrological sub-catchments are shown in Figure 14 and details of location and catchment areas are provided in Table 2. Appendix B provides the details of the FEH catchment descriptors used in this assessment for all sub-catchments.

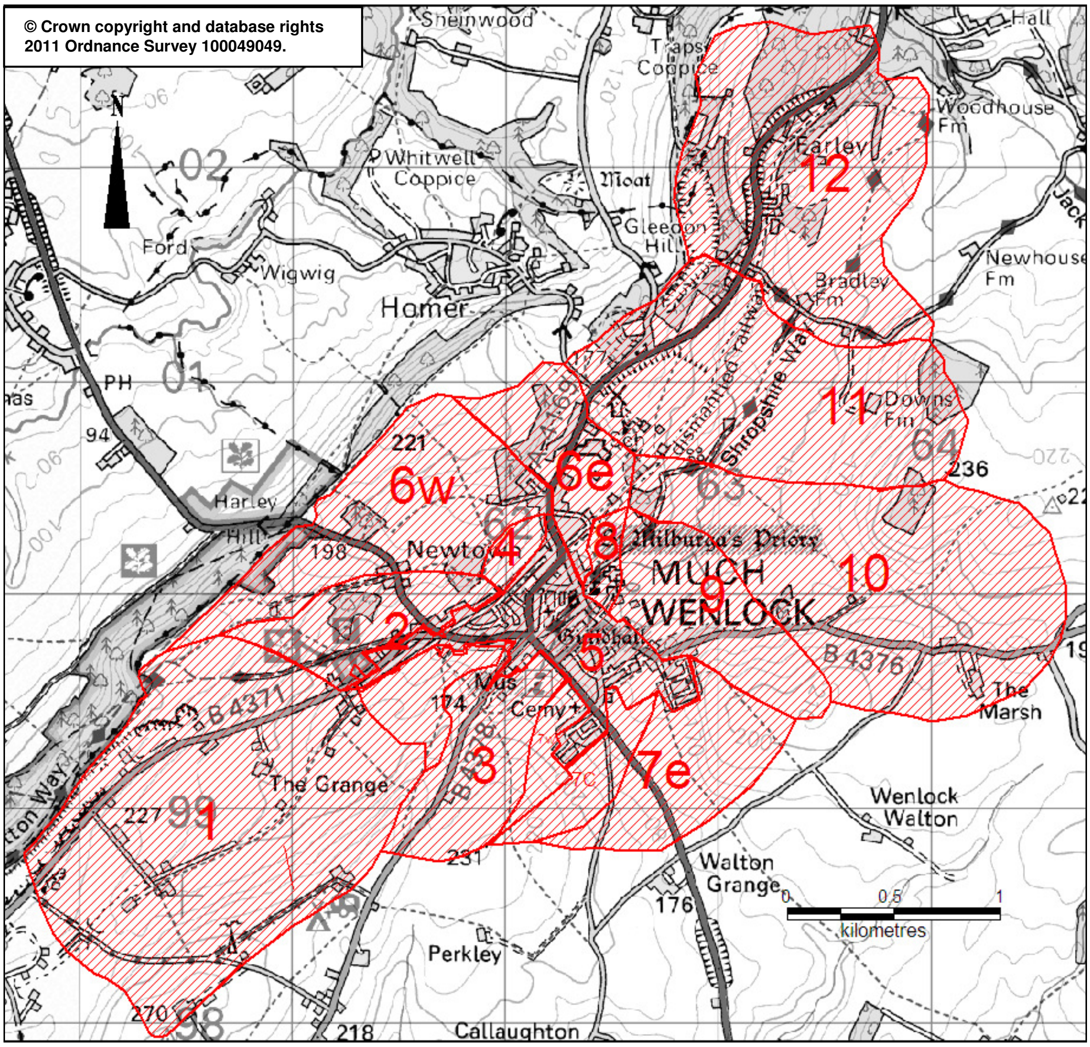


Figure 14 – Hydrological sub-catchments

Sub-catchment code	Watercourse	Site	Grid reference of downstream point		Catchment area based on FEH CD-ROM (km^2)	Adjusted catchment area (km^2)
1	Shylte Brook	Stretton Road	361300	299550	1.9	2.05
2	Shylte Brook	Victoria Road	362000	299780	0.63	0.49
3	Bourton Road Runoff	Bourton Road	362110	299800	0.37	0.42
4	Drainage from Town North	Town N rural	362450	300100	0.14	0.06
5	Drainage from Town South	Town urban	362450	300100	0.14	0.51
6e	Sytche Brook	Sytche Brook	362350	300250	1.08	0.35
6w	Sytche Brook	Sytche Brook	362250	300350		0.73
7e	Hunters Gate Runoff	Hunters Gate	362700	299650	0.72	0.45

Sub-catchment code	Watercourse	Site	Grid reference of downstream point		Catchment area based on FEH CD-ROM (km^2)	Adjusted catchment area (km^2)
7c	Hunters Gate Runoff	Hunters Gate	327700	299650		0.17
7w	Hunters Gate Runoff	Hunters Gate	327700	299650		0.09
8	Priory Runoff	Outfall Town Culvert	362550	300150	0.03	0.06
1-8	InfoWorks Whole Catchment	Outfall Town Culvert	362550	300150	5.45	5.38
9	Farley Brook	Ponds	362900	300300	0.16	0.49
10	Farley Brook	Walton Hills	362950	300600	1.55	1.52
11	Farley Brook	Quarry	363200	301450	1.43	1.26
12	Farley Brook	Farley	363700	302650	1.19	1.36

Table 2 – Sub-catchment areas

3.2.2 *Urban Extent*

For the design runs, the URBEXT 2000 values were updated to year 2010 for each sub-catchment and lateral inflow using UEF FEH formula (based on FEH CD-ROM 2). The sub-catchments are detailed in Table 3 showing any adjustments made.

Sub-catchment code	Site	Value of URBEXT2010	Category of urbanisation	Reason for URBEXT adjustment
1	Stretton Road	0.01	Essentially rural	Rural with a few roads so increased slightly URBEXT from FEH CD ROM
2	Victoria Road	0.01	Essentially rural	Removed urban areas (now included in sub-catchment 5) so URBEXT reduced from FEH CD ROM
3	Bourton Road	0.01	Essentially rural	Removed urban areas (now included in sub-catchment 5) so URBEXT reduced from FEH CD ROM
4	Drainage from Town North	0.01	Essentially rural	Removed urban areas (now included in sub-catchment 5) so URBEXT reduced from FEH CD ROM
5	Drainage from Town South	0.7	Very heavily urbanised	Majority of urban area
6e	Sytche Brook	0.14	Heavily urbanised	URBEXT2000 adjusted value to 2010
6w	Sytche Brook	0.014	Essentially rural	URBEXT2000 adjusted value to 2010

Sub-catchment code	Site	Value of URBEXT2010	Category of urbanisation	Reason for URBEXT adjustment
7e	Hunters Gate	0.01	Essentially rural	Removed urban areas (now included in sub-catchment 5) so URBEXT reduced from FEH CD ROM. Also split into east, central and west to coincide with model extents.
7c	Hunters Gate	0.01	Essentially rural	
7w	Hunters Gate	0.01	Essentially rural	
8	Outfall Town Culvert	0.05	Moderately urbanised	URBEXT2000 adjusted value to 2010
9	Ponds	0.04	Slightly urbanised	URBEXT2000 adjusted value to 2010
10	Walton Hills	0.01	Essentially rural	URBEXT2000 adjusted value to 2010
11	Quarry	0.013	Essentially rural	URBEXT2000 adjusted value to 2010
12	Farley	0.005	Essentially rural	URBEXT2000 adjusted value to 2010

Table 3 – Hydrological sub-catchments: URBEXT values

3.2.3 Hydrological Assessment

For the FEH rainfall runoff, ReFH, rational and IH124 methods, peak discharges were calculated for each sub-catchment for the following range of design return periods: 5, 30, 75, 100 and 100 plus climate change.

For the FEH statistical method, peak discharges were calculated for the same design return periods for two points of interest: the catchment containing the more urbanised sub-catchments 1 to 8 shown in Figure 14 (referred to as the “urban catchment”), and the whole catchment area containing all sub-catchments 1 – 12 in Figure 14 (referred to as the “whole catchment”).

For each sub-catchment, results for each method were compared and the most appropriate method for each particular sub-catchment was selected. The peak flows for all return periods of interest for the selected preferred methods are provided in Table 4. The peak flows using the FEH rainfall runoff method for June 2007 verification event are also presented in Table 4.

Sub-catchment code	Site name	Method used	T_p	Reason for selected method	Peak flow for the return periods (m^3/s)					Jun07 peak flow (m^3/s)
					5	30	75	100	100cc	
1	Shylte Brook	ReFH	1.03	Most realistic representation of catchment	1.97	2.66	3.09	3.26	3.91	1.86
2	Shylte Brook	ReFH	1.02	Most realistic representation of catchment	0.56	0.75	0.85	0.89	1.07	0.50

Sub-catchment code	Site name	Method used	T_p	Reason for selected method	Peak flow for the return periods (m^3/s)					Jun07 peak flow (m^3/s)
					5	30	75	100	100cc	
3	Bourton Road	IH124	1.29	Small rural catchment (<0.5km²)	0.34	0.49	0.60	0.68	0.70	0.33
4	Drainage Town North	IH124	0.98	Small rural catchment (<0.5km²)	0.055	0.082	0.10	0.11	0.14	0.05
5	Drainage Town South	Heavily urbanised – a rainfall intensity was applied over sub-catchment 5 in the Infoworks model. Checks on flows generated showed them to be similar to Rational Method estimates.								
6e	Sytche Brook	ReFH	0.89	Most realistic representation of catchment	0.44	0.62	0.72	0.76	0.91	0.37
6w	Sytche Brook	ReFH	0.65	Most realistic representation of catchment	0.56	0.77	0.91	0.96	1.16	0.67
7e	Hunters Gate	ReFH	0.76	Most realistic representation of catchment	0.39	0.56	0.69	0.78	0.94	0.32
7c	Hunters Gate	IH124	0.76	Small rural catchment (<0.5km²)	0.15	0.22	0.26	0.30	0.36	0.12
7w	Hunters Gate	IH124	0.76	Small rural catchment (<0.5km²)	0.076	0.11	0.14	0.16	0.19	0.07
8	Priory Runoff	IH124	0.84	Small rural catchment (<0.5km²)	0.055	0.08	0.09	0.10	0.12	0.05
9	Farley Brook	IH124	1.34	Small rural catchment (<0.5km²)	0.39	0.57	0.70	0.78	0.94	0.42
10	Farley Brook	ReFH	1.48	Most realistic representation of catchment	1.19	1.65	1.93	2.04	2.45	1.06
11	Farley Brook	ReFH	1.45	Most realistic representation of catchment	1.02	1.40	1.64	1.73	2.08	0.97
12	Farley Brook	ReFH	1.64	Most realistic representation of catchment	0.84	1.16	1.36	1.44	1.73	1.02

Table 4 – Hydrological sub-catchments: peak flow estimates for design return periods of interest and for June 2007 event

3.2.4 *Infoworks Sub-catchments*

The heavily urbanised sub-catchment 5, shown in Figure 14, drains to urban drainage so has been subdivided within the Infoworks model. The Infoworks sub-catchments have been defined to the surface water sewers and some direct to the town culvert where there were no surface water sewers.

The flows from the rural peripheral areas were generated separately (as described above in Section 3.2.3) and hydrographs were applied as inflow files to the relevant sections of the town culvert model. To get a true representation of the shape of the hydrograph entering the InfoWorks model, the hydrographs for sub-catchment 1 were first routed through the Shylte Brook ISIS model and the hydrographs for sub-catchments 6E and 6W were first routed through the Sytche Brook ISIS model.

The InfoWorks model of the town culvert and connecting surface water sewers was updated to include a 2D mesh. This was created from 1m LiDAR data (refer to Section 2.3 and Figure 8), and allows water escaping from flooding manholes to be routed overland.

A range of design storms (5, 30, 75, and 100 plus climate change) were run to determine performance of the system under varying rainfall conditions and assess the impact and effectiveness of engineering options.

The InfoWorks integrated model of the town culvert and associated surface water sewers provided an output flow to feed into the Farley brook ISIS model downstream to assess the interconnections of the two systems as required in the SWMP Technical Guidance, Defra, March 2010.

3.3 Verification and Calibration

The model was verified by obtaining historical rainfall data and soil moisture deficit data from summer 2007, when major flooding occurred in Much Wenlock, in order to replicate this reported flooding in the model. The summer 2007 rainfall data obtained was from the closest EA 15 minutely tipping bucket rain gauge at Willey at NGR: SO68169994, see Section 2.2.1. The soil moisture deficit recorded for the 2 weeks prior to the event from MORECS data was run through the ISIS models and InfoWorks model with the 2D mesh applied to determine predicted flooding locations and overland flow paths.

The results were compared to the historic flooding locations reported in the Telford and Wrekin report[2] and John Yeats' report[6], as well as the surface water flood outlines from the EA National Datasets (AStSWF, FMfSW and EA flood zone 3 maps). The model results showed a good correlation with historical and predicted flood locations and extents. This provided a high level of confidence in the model results. A comparison of the past flooding locations (items of Table 1) and the summer 2007 model results is shown in Figure 15.

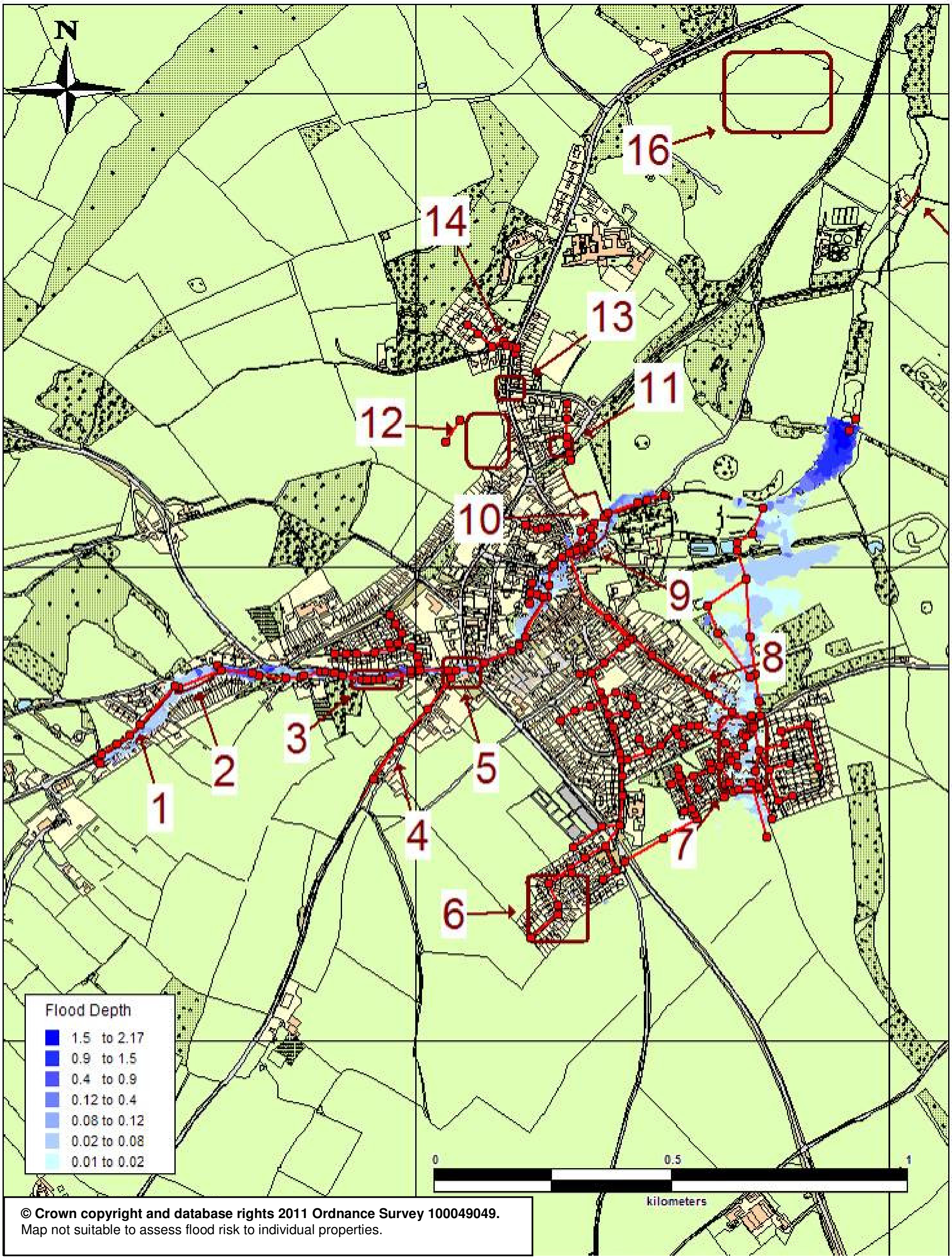


Figure 15 – Past Flooding Locations (numbered) compared against model results of June 2007 event

Two meetings were held to assist with the model verification process. The first was an internal meeting with Shropshire Council and the EA held on 11th January 2011 to present the initial modelling outputs and compare this to knowledge of past flooding events within Shropshire Council and the EA. The second meeting was an external meeting held on 26th January 2011 with Much Wenlock Town Council and Much Wenlock Flood Action Group, as well as Shropshire Council, utilising their detailed 'local' knowledge of the summer 2007 flooding event to further verify the model.

As a result, a number of 'tweaks' were made to the model and hydrological assessment to provide a better representation of the reported flooding, as detailed below:

- Rainfall from a 15-minute tipping bucket rain gauge, 6km east from Much Wenlock called Willey at NGR SO68169994, was used for the calibration event. Long periods of observations have been used to compare the rainfall amounts at various gauges by John Yeats[13] . Mouchel confirms that 20% increase is a reasonable factor to be applied to account for local effect over the Much Wenlock catchment.
- The rural sub-catchments are very steep with little top soil (or even bare rock in places) and information gathered from the Much Wenlock Flood Action Group indicates very fast runoff. Therefore, the time to peak, T_p, was reduced to be more realistic of the fast acting rural sub-catchments. T_p was reduced by 30% for rural sub-catchments (1-3, 6E, 6W, 7E, 7C & 9-12) and the very small sub-catchments 4 & 8 seemed unrealistically high so T_p has been reduced by 50%. This contributes also to applying a conservative approach
- It was emphasised by the Much Wenlock Flood Action Group that the catchment is particularly sensitive to flooding if there have been prolonged periods of rain previously that cause the catchment to be saturated. Therefore, the design events use typical winter soil moisture deficit (based on FEH catchment descriptors) with a summer rainfall profile (which characteristically is of shorter duration but with higher rainfall peaks) to represent the worst hydrological conditions for the design events.
- Inlet restrictions were applied via limiting discharge orifices for sub-catchments 1 and 2 to represent gully capacity issues at the upstream end of the town culvert. These were based on an estimation of the existing number of gullies, their state of maintenance and then backed up by anecdotal evidence during the summer 2007 event.
- A length of field drain at an assumed diameter and level from Bridgnorth Road, connecting into the Hunters Gate surface water system was added to the model. This receives the inflow from sub-catchment 7C;
- A length of field drain of assumed diameter and level from cemetery at the back of Oakfield Park, connecting into the Racecourse Road surface water sewer was added to the model. This receives the inflow from sub-catchment 7W;
- A length of field drain of assumed diameter and level from Merrywell Road, connecting into the Hunters Gate surface water system. This receives inflow from sub-catchment 7E.

[13] Annual Rainfall Patterns in the Much Wenlock Catchment (1987 – 2010) – analysis provided by John Yeats in Sept 10.

- The addition of the surface water sewer in Sytche Close / Sheinton Street. This has an inflow from sub-catchment 6W and models the out-of-bank flow spilling from the Sytche Brook culvert onto the 2D mesh (based on the limiting capacity of the culvert under Sheinton Street and Station Road).
- A length of the Sytche Brook culvert under the abandoned railway embankment at Station Road represents the out-of bank flow spilling from Sytche Brook in this location.
- A limiting discharge added to the hydrobrake chamber in Hunters Gate to represent the silt observed during the site survey.
- A more accurate representation of the field drainage and ponds located in Monks Walk, following a detailed survey.

There are still some minor issues with the modelled representation of the 2007 flooding event such as the lack of predicted flooding along the High Street, where the culvert turns into Back Lane. This is due to slight errors in the underlying LiDAR data, used to create the 2D mesh. There is also an issue with the volume of flooding predicted at Hunters Gate, where this is potentially slightly under predicted by the model, therefore further investigation of the whole drainage system is recommended.

Overall it was agreed that the model was generally accurate representing the summer 2007 flooding event and hence suitable as a tool to develop flood mitigation options.

Possible future updates to the hydraulic model may include:

- investigate further, by detailed site survey and flow verification, the capacity of and predicted flow within the highway drains and field drains which discharge to the surface water sewer system at Hunters Gate;
- investigate further the whole drainage system (including hydrobrake and connections) to improve confidence in model and results in the Hunters Gate area.
- to better calibrate the hydraulic model by installing in the future an EA rainfall station in the catchment and undertaking some monitoring of water levels / flows. The EA river water level stations should be improved / repaired / installed at critical locations in the en-mained reaches.
- update model with any larger new developments;
- incorporation of the combined and foul systems at a later date.

3.4 Assessment of Groundwater

Desk study information obtained indicates that the primary cause of flooding in Much Wenlock is not attributed to groundwater flooding as the presence of low-permeability shales and glacial till confines the Wenlock Limestone aquifer in this area.

The only known pathway for the temporarily artesian groundwater to find its way to the ground surface at Much Wenlock is the STW public water supply well which is reported to overflow temporarily under non-pumped conditions.

Water in the Shadwell Quarry might originate from groundwater discharges. Groundwater levels may rise rapidly during a heavy rainfall event which would be immediately observed in Shadwell Quarry. As a consequence of groundwater rising in Shadwell Quarry there is an increased discharge to Farley Brook.

Generally, groundwater discharges from the limestone aquifer could contribute to flooding to the north of Much Wenlock. This in turn could result in the river system reaching capacity sooner than would normally be expected. However, as groundwater flooding is unlikely to be a key issue at Much Wenlock there are no recommendations for future investigations or assessments in this area.

3.5 Flood Hazard/Risk Mapping

Flood hazards maps have been produced for the design flood events of 5, 30, 75 and 100 year (including climate change) years return period. These show the extent of flooding and the areas affected. The flood maps are presented in Appendix C.

Flooding mechanisms and locations affected are described below for the 30 year flood event. It can be noted that flooding for the higher return periods is generally similar in terms of flood extent and locations but to greater depths.

The flood extents for the summer 2007 calibration event compared well with the flooding hotspots shown previously in Table 1. The calibration event was routed through the model based on the following information:

- The rainfall from a 15-minute tipping bucket rain gauge, 6km east from Much Wenlock called Willey at NGR SO68169994, was used for the calibration event and a 20% increase was applied to account for local effect over the Much Wenlock catchment (reasoning discussed previously in Section 3.3).

- The initial soil moisture content was calculated using the rainfall and MORECs data for the 2 weeks prior to and during the summer 2007 event so was realistic of the soil conditions (essentially the catchment was already saturated causing nearly 100% runoff).

When comparison was made to other design runs with similar hydrological antecedent conditions, the return period of the flood event was found to be less than 10 years. This result was confirmed during the external verification meeting.

The model results show flooding at the upstream end of the town culvert along Stretton Road and Victoria Road. The cause of the flooding at this location appears to be field and highway runoff that is not able to enter the town culvert due to a lack of highway gullies in the vicinity (and potentially a lack of maintenance of the gullies that are present).

There is a 'pinch point' in the town culvert immediately downstream of the short open channel reach at The Pound. This causes backing up and out of bank flooding at The Pound. This is a known 'release point' based on evidence from the summer 2007 flood where a side wall directing the flow collapsed due to backing up at this location and caused flooding of the road.

Ponding occurs at Gaskell Corner due to the surface water flowing from The Pound and the road and field runoff flowing down Bourton Road (similarly due to a lack of highway gullies and potential maintenance issues that do not allow the runoff from this catchment to enter the sewer system). The flooding at Gaskell Corner blocks the main traffic route through the town.

There was flooding from surcharged manholes in the model along the High Street, Back Lane, the bottom end of Queen Street and the Bull Ring. The model results were in line with evidence of blown off manhole covers along this section of town culvert during the summer 2007 event, which was confirmed during the external verification meeting. An electrical sub-station adjacent to the Bull Ring was flooded in summer 2007, and is shown to be flooded under all return periods modelled.

Flooding occurs from the open section of the Sytche Brook at the junction of Sytche Lane and Sheinton Street due to backing up of the long culvert under Sheinton Street and Station Road. Additional flooding occurs on the Sytche Brook at a former bus depot, upstream of the old railway embankment at Station Road.

Runoff from steep fields causes surface water flooding at a number of locations in the south-west part of town which is newly developed: at the south-east corner of Much Wenlock cemetery, at the bottom of Oakfield Park and at Hunter's Gate. Additional flooding from surcharged manholes occurs at Hunter's Gate.

3.6 Quantifying flood damages for receptors

For this cost – benefit analysis, the receptors considered are the residential properties. Residential Properties represent the vast majority of the receptors and damages to commercial properties, agricultural or environment have not been estimated as they would likely represent only a small proportion of the total damages.

A range of return period design flood events were modelled to determine the flood extents and depths of flooding in a 5, 30, 75 and 100 year (plus climate change) flood events.

The outputs from the InfoWorks 2D modelling were imported into MapInfo. This was in the format of 2D 'triangles' representing the overland flow path with a peak predicted depth associated with each. A MapInfo query was used to identify the maximum depth of all the triangles surrounding each individual building within the catchment. This depth was applied to the building as a 'worst case' flood depth for each flood event.

The results were exported into Excel and, using the Multi-Coloured Manual[14] figures for residential (domestic) property flooding (Figure 16), a damage cost was allocated to each building based on the predicted flood depth and area of the building.

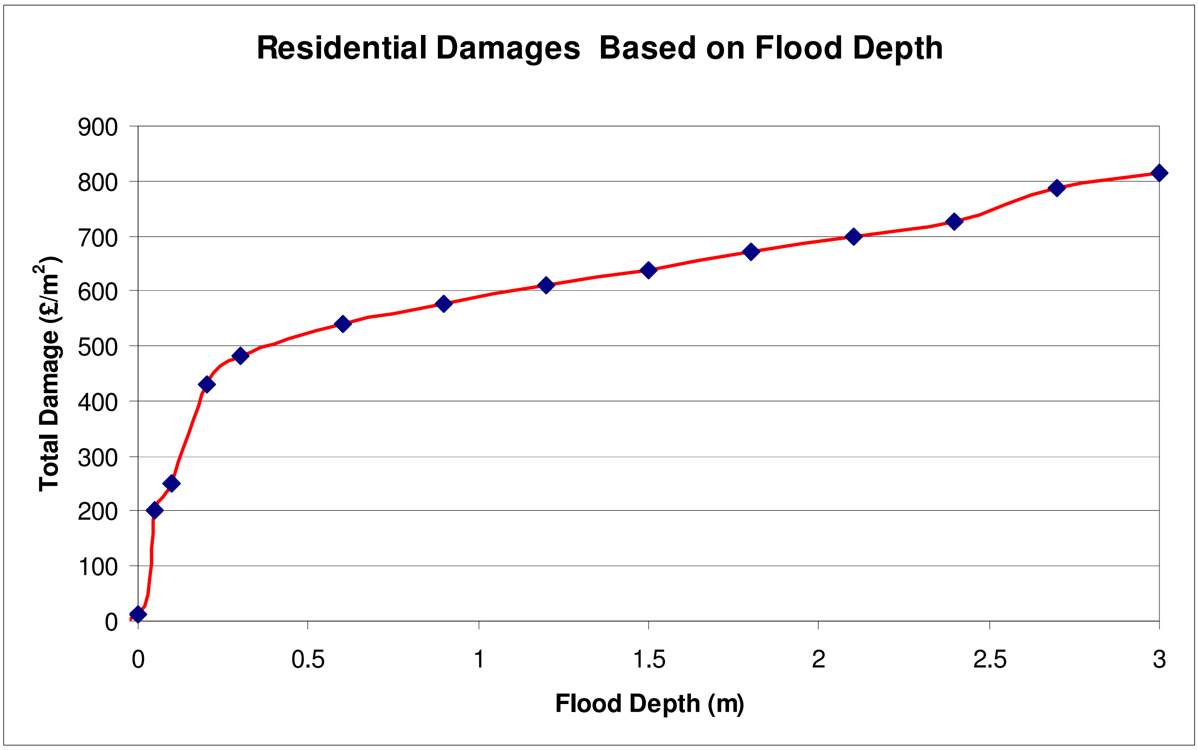


Figure 16 – Residential Damage Costs (Multi-Coloured Manual)

The results for the existing system give a base damage cost for each return period on which to compare any flood mitigation options.

To calculate an Estimated Annual Damage (EAD) the total damage for each return period run has been multiplied by the probability of the flood occurrence (i.e. the probability of a 1 in 5 year return period flood is 1/5 = 0.2). The sum of the damages multiplied by probability gives the EAD for the existing scenario (i.e. using the baseline model flood depth results). Further information is provided in the Cost-Benefit Analysis of the proposed mitigation options in Section 4.6.

3.7 Communicate Risk

Draft versions of the 25 year (later changed to the 30 year in line with the Sewers for Adoption scheme that requires all new public surface water sewers to accommodate flows for up to 1 in 30 year return period design storm, however the capacity of the existing system will vary depending on date of construction) and 100 year plus climate change flood risk maps and the summer 2007 verification event flood risk maps were presented to Shropshire Council and the EA. This was done at the internal verification meeting held on 11 January 2011. The flooding locations were discussed and small changes to the model were agreed and subsequently

[14] The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques'(The "Multi-Coloured Manual") by Flood Hazard Research Centre at Middlesex University Press 2005

incorporated into the model. During the meeting, various flood mitigation options were also presented and discussed and a short-list of options to be modelled was agreed.

Updated versions of baseline flood maps were presented at the external verification meeting alongside some initial results for the short-listed proposed mitigation options. This was done on 26 January 2011. Further feedback from Much Wenlock Town Council and the Much Wenlock Flood Action Group about flooding locations and mechanisms was provided and used to update the baseline model where appropriate.

In this report, flood risk has been communicated using the number of residential properties at risk as the indicator. Analysis of the mitigation options based on number of residential properties at risk is provided in Section 4.6.

4 Flood Mitigation Options

4.1 Identification of measures

A variety of flood mitigation measures were initially identified to address some of the known flooding problems. These were not constrained by funding or their delivery and multi-benefits were flagged where possible. Initial ideas were generated on the site visit by discussion with Much Wenlock Town Council and Much Wenlock Flood Action Group.

Flood mitigation options can be implemented either at the **source**, to interrupt / divert the **pathway** or to protect the **receptor**. Examples are provided in Sections 4.1.1 – 4.1.3. A map showing the locations of initial ideas relating to flood mitigation for the catchment are shown in Appendix D. The main measures are discussed in detail in Section 4.2, including reasoning for counting, or discounting, them as a viable option to be modelled.

4.1.1 Source

Protection can be provided near the sources of flooding. For example, this can be done through the construction of attenuation ponds or basins to reduce or slow down the flow reaching the receptors. Examples taken from the Scotland SuDS manual for roads[15] are provided below. Attenuation ponds are being considered in Option 1 and Option 3.

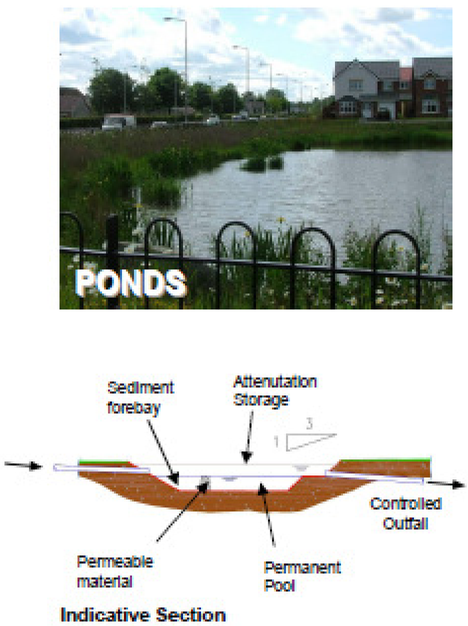


Figure 17 – Example of an attenuation pond (has a permanent pool)

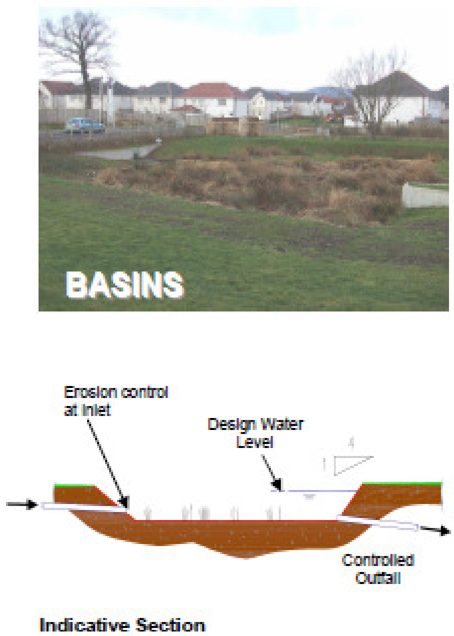


Figure 18 – Example of an attenuation basin (dry most of the year)

[15] 'SuDS for Roads' commissioned and guided by SCOTS and SuDS Working Party and authored by WSP (2010)

4.1.2 *Pathway*

The pathway of the surface water travelling over impermeable areas can be intercepted by way of a sustainable drainage system (SuDS). Examples of pathway SuDS are provided below in Figures 19, 20 and 21. These SuDS options are not being specifically tested by modelling in this study but could be implemented in the future for new developments or when upgrading roads.

Other options that affect flow pathways are being modelled, however. Options such as improved maintenance to gullies and changes to farming practices to reduce field runoff rates and reduce the amount of sediment transported downstream are being considered.

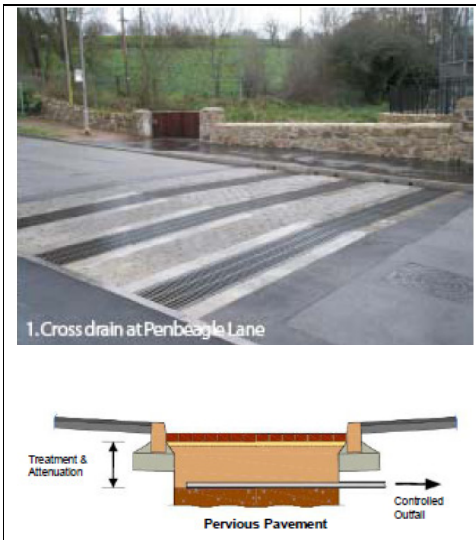


Figure 19 – Photograph of a cross drain and a diagram of pervious pavement

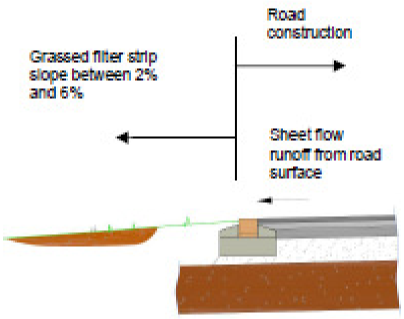


Figure 20 – Diagram of filter strip (SuDS for roads Scotland p35)

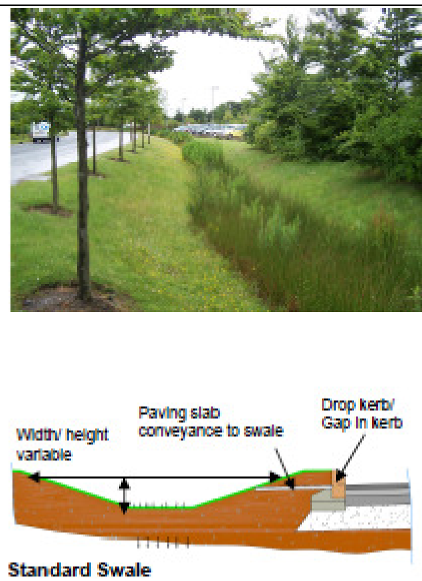


Figure 21 – Example of swale (SuDS for roads Scotland p38)

4.1.3 *Receptor*

Examples of protection to receptors include temporary and permanent flood defences, local earth bunds or retaining walls, raising vulnerable equipment (i.e. electrical sockets) and sealing of vulnerable buildings (e.g. cable ducts and below ground pipework). These local measures to protect specific buildings and assets have not been considered in the options for this study, the options modelled aim to reduce the flooding (in order to reduce the damages) rather than reduce the damages only. Such receptor measures should be considered by individual property or asset owners if they have not already been implemented. Care must be taken, however, to ensure that any measures implemented do not increase flood risk elsewhere and in some cases a Flood Risk Assessment may be required to ensure this is the case.

4.2 Short listing of Measures

Table 5 summarises the measures initially identified. Details of whether they have been modelled as an option are also provided.

Problem and Measure	Details and Rationale
Groundwater infiltration holes near old quarry to allow water to permeate into ground.	Not modelled. Too close to SSSI to be implemented.
Attenuation pond(s) upstream of town culvert (Shylte Brook) to reduce peak flows.	**Modelled.** Pond may not be able to be placed at old reservoir site due to contamination issues (would require further investigation).
Change unconventional **headwall** at upstream face of town culvert and make whole of town culvert an EA designated main river.	Not modelled but **recommended** for clearer responsibilities and to improve maintenance.
Improve **land and farming practices** to address fast field runoff contributing to flooding and sediment deposits in culverts downstream.	**Modelled**. Improve land practices to slow down runoff and to reduce sediment being carried downstream by flood waters. Examples: 1) plantation of hedgerows at field edge 2) ploughing direction 3) crop types.
Maintenance of gullies	**Modelled**. Improve regular maintenance of gullies to improve conveyance of surface water runoff to the sewer system and town culvert.
Increased number of gullies	**Modelled.** To allow additional surface water runoff to enter either the sewer system or directly to the town culvert. If connecting to the surface water sewers then checks and an application would need to be submitted to STW Asset Protection Team.
Maintenance of culverts	**Modelled.** Improve regular maintenance to culverts to avoid blockages.
Maintenance of Private Drain Systems	Advised to raise awareness and offer guidance to riparian owners about their duties and responsibilities to maintain watercourses and private drain systems. Develop a program for one-to-one meetings with riparian owners.

Increase capacity of **town culvert**	Not to be modelled. Increased hydraulic capacity may to lead to increased peak water levels downstream.
Investigate the surface water drainage system as a whole (i.e. land drains, highway drains, private storm cells, sewer system and hydrobrake) and to make changes where appropriate to reduce surface water flooding of properties.	**Modelled**. Increased pipe sizes to take 30 year return period event and ensured flooding is not made worse downstream on Farley Brook by use of attenuation ponds. One option for mitigating the flooding in this area (Option 3) was modelled however other options should be investigated that may be simpler to fund and implement.
Attenuation pond(s) on Sytche Brook to reduce peak flows downstream.	**Modelled.** Will aim to reduce flooding at junction of Sytche Lane and Sheinton Street.
Remove blockages and **repair** collapsed culverts	Not modelled but **advised** along Sytche Brook to avoid backing up and maintain capacity of channel along whole reach.
Increase culvert capacities along urban sections of Sytche Brook.	Not modelled fully but **indicative sizes** provided to avoid backing up in the 30 year return period event.
Use old pumping station tank or playing field as flood **storage**	Not modelled. Not sufficient detail of old pumping station tank underground and playing fields are already flooded in the existing base-case (and shown by past flood events).
Other **SuDS** such as permeable pavements and swales.	Not modelled but **advised** for future developments and when upgrading roads to reduce the amount of surface water runoff, increase infiltration into the ground and increase the time it takes rainfall to reach the town culvert.
Designing for Exceedence (involves safely accommodating floods which exceed the design capacity of the sewers by exploring the potential to route flood water along roads or through open spaces, avoiding properties)	Not modelled and too late to fully integrate principles to existing sites, but is **recommended** for future developments. refer to CIRIA Document C635 'Designing for exceedence in urban drainage – good practice'.
Measures downstream of Much Wenlock town along **Farley Brook**	No specific options modelled downstream. Isolated flooding issues may be tackled locally as described in Section 4.1.3.

Table 5 – Short-listing of Measures

4.3 Identification of Options

The measures identified for modelling were grouped into three options. These options are shown in Figure 22:

1. Change farming land practises and install attenuation ponds upstream of the town.

2. Increase the number of gullies in various parts of the catchment, and improve the maintenance regime of the entire highway drainage system.

3. Improve the flow of water through the existing Hunters Gate system, and create an attenuation area downstream around Monks Walk

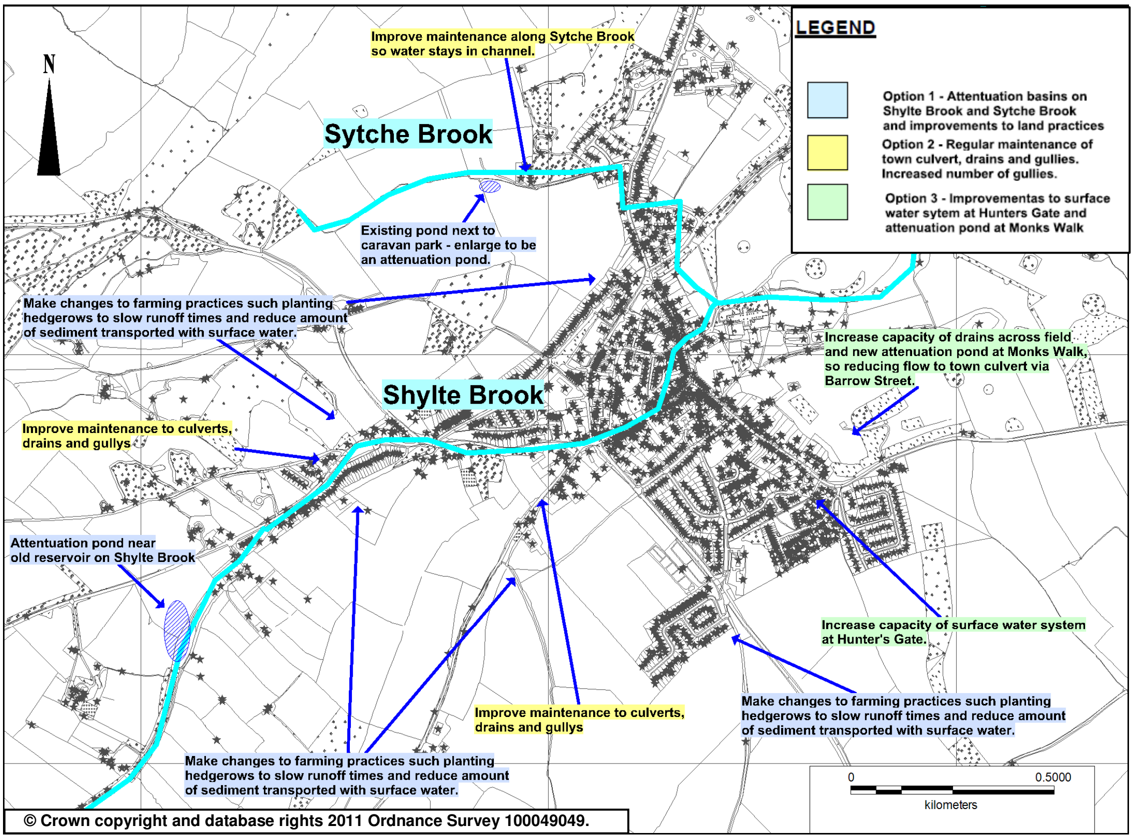


Figure 22 – Map showing the three flood mitigation options modelled

4.3.1 Option 1

This option involves constructing attenuation ponds upstream of the town on both the Shylte Brook (south-west) and Sytche Brook (north-west). The attenuation ponds would retain water upstream and release it in a controlled manner in order to reduce the peak flows downstream. The 30 year return period design event was used to size the ponds in the 1D hydraulic models of the open watercourses (using ISIS software). The verification event of summer 2007 and the 100 year plus climate change event were also run to check the impact of the ponds for larger and multi-peak events.

Option 1 also involves improvements to land practices by increasing the time to peak for the rural sub-catchments. This was implemented in the model by altering the sub-catchment inflow hydrographs as inflows to the model. The increase in time to peak would be achieved by changes in farm practices such as planting of hedgerows, changing the type of crop farmed and changing the direction of ploughing.

The attenuation ponds (by use of a settlement forebay) and improvements to land management practices would also bring the benefit of reducing the amount of sediments being washed down from the fields with the surface runoff. This would potentially also reduce the amount of silt blocking gullies or reaching the town culvert (thus reducing the maintenance requirements and the flood risk) and improve water quality levels.

4.3.2 *Option 2*

This option involves improved maintenance of existing gullies and provision of further gullies in the upstream reaches of the town culvert to enable flows generated in a 30 year storm to be able to enter the culvert more efficiently.

To model this option the two inlet restrictions from sub-catchments 1 and 2, (refer to Section 3.3), were removed. To quantify the additional number of gullies required the difference between the peak flow entering the upstream section of the town culvert with and without the restrictions in place was assessed. Half of this flow was assumed to be due to improved maintenance and the rest additional gully capacity required.

The baseline model included downstream restrictions (in the form of a silt depth) which replicated obstructions observed from the CCTV of the town culvert. Option 2 also includes the removal of these downstream restrictions to represent improved culvert maintenance.

4.3.3 *Option 3*

This option involves the mitigation of flooding in the Hunters Gate area. Option 3 described here is just one agreed option that has been tested for mitigating flooding in this area but other options should be investigated in the future depending on the funding channels available. All drainage systems should be considered including highways drains, land drains, surface water sewers, private drainage systems etc.)

This particular option includes some upsizing of the existing surface water system, land drainage pipes and highways drains as well as two small attenuation ponds and a large pond in Monks Walk.

Some assumptions have been made in this option as it required upsizing of the notional land and highways drainage pipes added to the model (refer to Section 3.3). This was to keep flows within the piped systems and prevent overland flows affecting Hunter's Gate. As these are only notional pipes in the baseline model, their upsizing has not formed part of the options costs. The main purpose of this option was to reduce flooding to properties on Hunter's Gate and tihis was achieved by transferring flows through the surface water sewers; however other options should be investigated in the future. There remains uncertainty in the size of pipes and the connections of the whole drainage system in this area and further verification is recommended before progressing an option.

The option also includes enhancement of the drainage system through Monks Walk to deal with the additional flows arriving downstream of Hunter's Gate. Two small attenuation ponds (1 and 2) were tested, one by the cemetery to the west of Bridgnorth Road and the other just to the east of Bridgnorth Road to attenuate flows getting into the Racecourse Road surface water sewer. Flooding from the upstream end of this system is predicted by the model to finds its way to Hunter's Gate, hence the requirement for the ponds.

A more substantial retention pond (3) was tested in Monks Walk, modelled at the location of the top pond just to the north of Barrow Street.

The extent of this option is shown in Figure 23, with the pipes that require upsizing highlighted in pink.

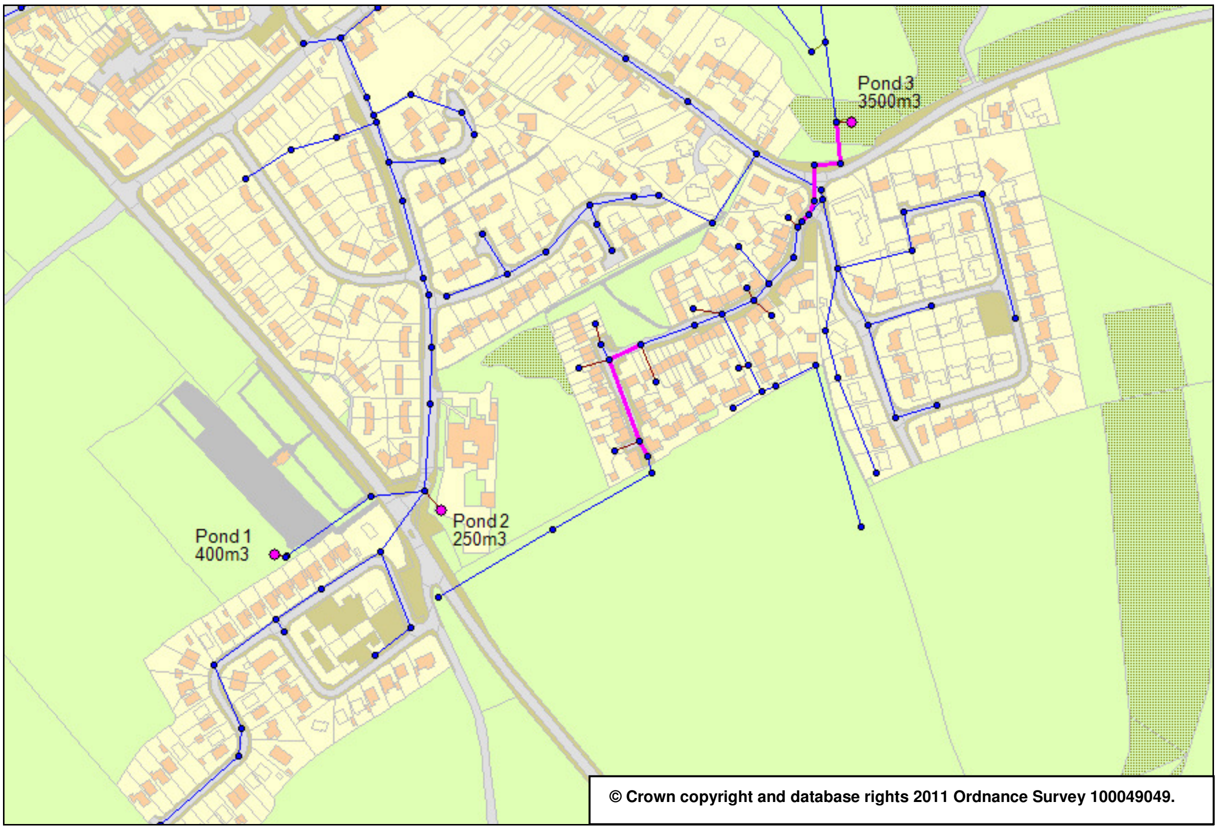


Figure 23 – Option 3: changes at Hunter's Gate and Monk's Walk

4.4 Stakeholder Engagement & Public Consultation of Options

The map of the measures identified initially was provided to Shropshire Council during the baseline model build for their information and consideration. The measures were then discussed between Shropshire Council, the EA and Mouchel during the internal verification meeting. The measures were combined in to the three options shown in Figure 22.

Initial results of the baseline and options modelled were presented to Much Wenlock Town Council and the Much Wenlock Flood Action Group at the external verification meeting. Each option was discussed regarding its effectiveness to reduce flooding in various parts of the town. It was acknowledged from the results that one option in isolation could not solve all flooding issues in the town. The feedback from Much Wenlock Town Council and the Much Wenlock Flood Action Group was positive and it was understood that a combination of options would be required to reduce the town's susceptibility to flooding. The cost-benefit analysis would also assist in the identification of the most likely options to be recommended for implementation.

4.5 Assessment of Options

For the cost-benefit analysis the options were added to the model and re-run for the same design events as the existing system model (refer to Section 4.6). Flood maps were produced for the design events of 30 and 100 year (including climate change) return periods which illustrate how the flood risk changes after implementation of the option. The flood maps are presented in Appendix E.

4.5.1 Assessment of Option 1

The volume of the attenuation pond required to reduce flooding along Sytche Brook for the 30 year return period is 6,000m^3. The pond is assumed to be 2m deep and therefore have a surface area of 3,000m^2. The outflow from the pond has been limited to a constant rate of 0.04m^3/s (modelled as orifice flow through a pipe of 0.1m diameter) and the pond would drain within 48 hours. This volume of pond and outflow arrangement ensures that peak flow downstream in Sytche Brook does not exceed 0.25m^3/s for the 30 year return period event. This is the maximum capacity of the existing culvert under Sheinton Street (based on size and slope) therefore prevents 'out of bank' flooding of Sytche Brook at the junction of Sytche Lane and Sheinton Street.

The volume of the attenuation pond required to reduce flooding along Shylte Brook for the 30 year return period is 8,000m^3. The pond is assumed to be 2m deep and therefore have a surface area of 4,000m^2. The outflow from the pond is limited to a constant rate of 0.11m^3/s (modelled as orifice flow through a pipe of 0.2m diameter) and the pond would drain within 24 hours. This volume of pond and outflow arrangement ensures that peak flow entering the upstream end of the town culvert does not exceed 1.2m^3/s for the 30 year return period event. This reduction in peak flow reduces the amount of surface water trying to enter the town culvert and greatly reduces the flooding downstream through both the High Street and Bull Ring.

The 'changes to land practices' modelled as part of Option 1 may not, in isolation, constitute a significant reduction in peak flow through the town culvert. These changes would, however, improve the effectiveness of the highway gullies in both intercepting surface water runoff and reducing the amount of sediment entering the drainage system. This option aims to reverse or at least reduce the effects of historic agricultural trends that have tended to increase rates of field runoff.

The cost-benefit analysis of Option 1 (as well as 2 and 3) is described in Section 4.6. Assessment of the water levels downstream of Much Wenlock town along Farley Brook showed that Option 1 reduces the peak water level therefore does not cause adverse effects elsewhere. The reduction varies between 30mm and 600mm depending on location along Farley Brook for the 30 year return period event.

The sizing of attenuation ponds has been based on a 30 year return period event. However, the ponds were also tested for the event of June 2007 and the 100 year plus climate change (100yr+cc) return period event.

For the June 2007 event both the 6,000m^3 pond on the Sytche Brook and the 8,000m^3 pond on the Shylte Brook were sufficient to attenuate the flows to the levels described above. Since this was a multi-peak event over a 72 hour period, the outflow arrangement would allow the pond to partially drain between spells of rainfall.

For the 100yr+cc event the capacity of the attenuation ponds outlined above were exceeded but flows downstream within both the Sytche Brook and Shylte Brook were still significantly reduced in comparison to the baseline results, by approximately 50%. In order to attenuate the flows experienced during a 100yr+cc event storage volumes of 10,000m^3 and 18,000m^3 for Sytche Brook and Shylte Brook respectively would be required. It should be noted that for this event the town culvert would most likely be surcharged due to the exceeded capacity of the drainage system from the other urban and rural sub-catchments which ultimately connect to the town culvert.

4.5.2 *Assessment of Option 2*

Option 2 involves an increase in the volume of surface water entering the town culvert by improving maintenance and increasing the number of highway gullies. Modelling of the option led to a reduction in surface water flooding at the upstream end of town (in particular sub-catchments 1, 2 and 3 shown previously in Figure 14). However there was still flooding shown in the model from surcharged manholes at the bottom end of the town culvert (along Queen Street and Bull Ring). As the culvert generally follows the 'low' area of the catchment any surcharge in the culvert will flood from culvert manholes rather than those from the connected surface water sewers.

The peak water levels along the Farley Brook showed an increase by up to 46mm for the 30 year return period event and by up to 86mm for the 100yr+cc return period event in comparison to the baseline model. Therefore **Option 2 should not be implemented on its own.** Joint implementation with Option 1 would result in the proposed benefits of both options without the negative effect of increasing flow rates downstream.

4.5.3 *Assessment of Option 3*

The volume required for the attenuation pond by the cemetery (Pond 1 in Figure 23) is 400m^3. The volume required for the attenuation pond to the east of Bridgnorth Road (Pond 2 in Figure 23) is 250m^3. These ponds would attenuate flows getting into the Racecourse Road surface water sewer for the 30 year flood event.

A more substantial attenuation pond (Pond 3 in Figure 23) is required in Monks Walk, modelled at the location of the top pond just to the north of Barrow Street. The volume required here is 3,500m^3 to retain a 30 year flood event. The pond is assumed to be 2m deep and therefore have a surface area of 1,750m^2. A 100mm diameter outlet pipe has been modelled to ensure no downstream exacerbation of water levels in Farley Brook. The pond takes approximately 48 hours to drain down.

For this option approximately 110m of the existing surface water sewers would need to be upsized within the Hunter's Gate development in order to transfer 30 year flows to the downstream hydrobrake chamber. A weir was modelled in this chamber to provide a high level overflow during storms of higher return period. Around 100m of land and highways drainage pipes were assumed to need to be upsized downstream of this chamber to transfer flows to a new pond in Monks Walk. However there remains uncertainty in the sizes of some of the existing pipes and connections so further investigation is recommended prior to progression of an option in this area.. A schematic layout of the existing surface water sewer, land and highways drainage pipe sizes (assumed) and the sizes of upgraded pipes is provided in Appendix F. It should be noted that the land and highway drainage is only notionally modelled and thus upsizing has not been included in the costings. Further details are provided in Appendix F.

4.6 Cost Benefit Analysis

The required elements making up each of the three options have been costed using 'Typical SuDS Costs' from the CIRIA SuDS manual[16], the Spons Civil Engineering and Highways Price Book 2010 and data from the Standard Bill of Rates used by Shropshire Council for its maintenance contractor.

The estimate annual damages (EAD) for each option has been calculated in the same way as the existing system EAD (refer to Section 3.6). The whole life benefit of the scheme has been calculated by deducting the reduced damage after the scheme and annual maintenance of the scheme from the existing annual damage. The whole life multiplier has been applied to this total, which is calculated based on a 30 year design life and a 3.5% discount rate, based on recommendations from the Defra SWMP Guidance 2010.

The net benefit of each option is then the whole life benefit less the capital cost. The cost benefit ratio is the net benefit divided by the cost. The cost benefit calculations are presented in Table 6, all costs exclude VAT. A breakdown of the capital costs and maintenance costs is provided in Appendix F.

Option	Current EAD (£)	EAD after implem-entation of Option (£)	Capital Cost (£)	Annual Mainte-nance (£)	Whole Life Multiplier	Whole Life Benefit (£)	Net Benefit (£)	Benefit Cost Ratio
Option 1	646,688	382,843	280,000	7,000	19.04	4,889,240	4,609,240	**16.5**
Option 2	646,688	494,446	22,837	1,700	19.04	2,865,675	2,842,838	**124.5**
Option 3	646,688	632,361	117,910	2,400	19.04	227,050	109,140	**0.9**

Table 6 – Cost Benefit Analysis of 3 Options modelled

A cost benefit of less than '0' is considered ideally not viable. A value greater than '0' may be viable, but may not meet the required threshold (for Defra's approval a cost benefit ratio greater than 4 is required).

The overall number of properties affected by flooding and number of properties protected for the baseline scenario and for each of the options tested are provided in Table 7 for various return periods. This analysis used MasterMap data which included

[16] The SUDS Manual, CIRIA C697 (2007)

the TOID number but did not provide secondary and tertiary descriptions to differentiate between 'building' types. Hence the analysis has assumed all buildings are residential for the property counts and damages calculations (and includes out buildings and sheds which are significant for the Hunters Gate area).

Return Period	Properties Flooding (All)				Properties Protected (All)		
	Existing	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
5 year	467	296	393	380	171	74	87
30 year	500	376	463	403	124	37	97
75 year	556	417	511	449	98	4	66
100 yr +cc	556	544	556	511	12	0	45

Table 7 – Number of properties flooding and protected for each option

The number of properties affected by flood depths in excess of 150mm, (i.e. where internal property flooding is likely to occur), and number of properties protected, for the baseline scenario and for each of the Options tested are provided in Table 8 for various return periods.

Return Period	Properties Flooding (>150mm)				Properties Protected (>150mm)		
	Existing	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
5 year	34	21	28	34	13	6	0
30 year	55	29	52	46	26	3	9
75 year	56	39	56	56	17	0	0
100 yr +cc	69	57	66	69	12	3	0

Table 8 – Number of properties flooding by >150mm, and number protected for each option

4.7 Brief Environmental Assessment of Options

4.7.1 Ecology / Environment

In order to determine the effect of the possible mitigation measures on the surrounding environment, a desk-top study of ecological records was carried out. This initially covered the whole of the Much Wenlock catchment, but then focused on the locations of construction and other work associated with the various options. Existing environmental information and plans are provided in Appendix G.

The catchment of Much Wenlock contains several sites of environmental importance. These include:

- five areas of SSSI, running along Wenlock Edge to the south-west of the town, and around Tick Wood to the north-east of the town;
- the centre of the town, which is classed as a Conservation Area;

- the area around Wenlock Priory, which is classed as a Scheduled Monument;

- Shadwell Quarry, located to the north of Much Wenlock, which is a Regionally Important Geological and Geomorphological site;

- three areas to the north-east of the town which are classed as Sites of Importance for Nature Conservation;

- the Shropshire Way and Jack Mytton Way, both long distance footpaths, crossing the catchment at various locations;

- four known locations of Black Poplar to the south and east of the town, and;

- many Local Biodiversity Action Plan areas located throughout the catchment, generally running in a south-westerly to north-easterly direction along Wenlock Edge and extending beyond the town. Otters have been spotted to the east of the town, and dormice have been spotted at several locations along Wenlock Edge and to the east of Shadwell Quarry. One site of Great Crested Newts has been located, at a quarry along the B4371 road to the south-west of the town. Bat populations have been recorded in the far northern area of the catchment.

While considering the possible options for flood mitigation, the above information helped to inform the decision process. For example, surface water runoff could be disposed of directly to the ground via infiltration boreholes. An ideal location for these is Wenlock Edge. But as the area is a SSSI, borehole drilling would not be suitable, and so the option cannot be pursued.

4.7.2 *Environmental Assessment for Option 1*

Changes to land practices include the provision of new hedgerows to limit the amount of runoff from agricultural land reaching a flow route into the town. Hedgerows provide vital resources for mammals, birds and insects. They also act as wildlife corridors, allowing species to move between isolated habitats. Hedges provide an important habitat for a wide variety of animals by providing food and shelter in all kinds of urban and rural locations.

Hedges have been identified as a Priority Habitat in the UK Biodiversity Action Plan (BAP), with a number of actions being undertaken to increase the quantity and quality of hedges, so that they continue to support a wealth of biodiversity.

About 130 BAP priority species are significantly associated with hedgerows – these include moths, birds, lichen and fungi. While a few of these species are dependent on hedgerows alone, the loss of hedgerows, or a decline in their quality, would be likely to have an adverse effect on their populations.

As well as supporting wildlife, hedges play other important roles in the environment, such as helping to prevent the spread of pollutants and protecting against soil erosion.

The proposed attenuation pond associated with this option could possibly be located at the site of an old reservoir. This site is adjacent to the dismantled railway, to the south-west of Bridge House, off the B4371 to the west of the town. A Local Biodiversity Action Plan (LBAP) site is located just under 250m to the south-west of this location. Further investigation would be required for this option to find out what particular species of plant or animal is protected at this LBAP site. However the risk of a problem in implementing an attenuation pond is low.

As well as the implementation of a new pond, this option will also involve the improvement of an existing pond by the caravan site next to Sytche Brook.

There are 80 or so pond species that are of national priority for conservation action under the UKBAP. Ponds are defined by the UKBAP as small, man-made permanent or seasonal waterbodies up to 2ha (20,000m^2).

Ponds are important for many invertebrates including the broad bodied chaser (Libellula depressa), the red-eyed damselfly (Erythromma najas) and the protected lesser silver water beetle (Hydrochara caraboides).

The vegetation in ponds varies depending on their depth. For example, plants like spiked water milfoil (Myriophyllum spicatum), rigid hornwort (Ceratophyllum demersum) and yellow water lily (Nuphar lutea) are all characteristic of deeper water. Whereas the following; Soft rush (Juncus effusus) creeping bent (Agrostis stolonifera) and yellow flag iris (Pseudacorus) are more characteristic of typical marginal areas.

In Shropshire, ponds are particularly important as homes for the protected great crested newt (Triturus cristatus). Ponds also provide habitats for other amphibians such as common toad (Bufo bufo), smooth newt (Triturus vulgaris), palmate newt (Triturus helveicus) and common frog (Rana temporaria). Water voles (Arvicola terrestris) and white-clawed crayfish (Autropotamobius pallipes) can also be found in ponds.

There are many threats to ponds:

- Loss and fragmentation due to natural succession, urban and industrial development, and in-filling as a result of agricultural intensification and diversification.

- Decline of water quality due to eutrophication.

- Lack of appropriate management, and little or no financial incentive to create new ponds in the wider agricultural landscape.

- Failure to consider surrounding terrestrial habitats and the wider pond landscape.

This option will make some attempt to reverse these threats by the improvement and creation of ponds.

Although the desk study has not revealed any protected species of plant or animal in these areas, a survey of the sites by a qualified ecologist will still be required prior to any construction work commencing. The time required for the surveys, and any consequent mitigation, could take up to one year to complete due to the time taken for licences to be acquired, and breeding seasons for different species. This must be taken into account when programming any work in these areas.

4.7.3 Environmental Assessment for Option 2

The installation of new highway gullies, and improvement of the existing system, should not have a detrimental effect on the local environment. However, improved maintenance will have a positive effect.

Gullies generally contain sumps within which silt is collected. This silt is washed in from the adjacent carriageway during storm events, and so will also pick up pollutants deposited on the carriageway by vehicles.

Silt from the gully sumps is normally removed using a machine and the silt and water is then deposited at a waste site. If any of the polluted silt enters the pipe system, then jetting of the system will wash the pollutants downstream, and they will eventually end up in the receiving watercourse. If jetting of any sewer or drain is planned, then a bung or stopper should be used in the most downstream pipe in the system such that any silt can be removed by tanker to be disposed of at a waste site.

4.7.4 Environmental Assessment for Option 3

The installation of a new attenuation pond, extensions to the existing ponds in this area, and the installation of new pipes will all affect the area adjacent to Monks Walk.

There is a LBAP site within 100m of this area, and a UKBAP site within 250m. Further investigation would be required for this option to find out what particular species of plant or animal is protected at the site. The risk of a problem in implementing an attenuation pond, however, is low.

As the site is adjacent to Wenlock Priory, a Scheduled Monument, an archaeological watching brief would be required during any excavation work in this area.

As with Option 1, an ecology survey will be required and, along with any potential mitigation work, this could add a year to any construction programme. The benefits of pond improvement and creation will also be made evident through such a survey.

5 Conclusions and Recommendations

5.1 Conclusions

5.1.1 Partnerships

- The stakeholders have come together in the Much Wenlock Flood Forum (MWFF), which drives actions to reduce flood risk. Future roles of the Stakeholders include reviewing this draft report and then implementing the IUDMP action plan in the near future. Funding options are also important for the Stakeholders to discuss, agree on strategy and if appropriate 'buy-in' and/or commit to schemes.
- A Working Group comprising Shropshire Council, Mouchel, the EA and STW provided the technical steer for the duration of the project.

5.1.2 Flooding Issues

- Undertaking a detailed IUDMP using the recent surface water management Defra Guidance for Much Wenlock has allowed the flooding mechanisms and the characteristics of the catchment to be far better understood, the rural – urban interaction to be investigated and factors that affect the flooding issues and consequences observed in recent years to be addressed.
- The data collection at the beginning of the study provided a good understanding of how the catchment is naturally prone to surface water flooding due to steep rural catchments and subsequent ponding in urban areas. The catchment is fast-acting (short time-to-peak) and is prone to flooding particularly when soil saturation is high. Changes to land use are a contributing factor to the flooding issues in the town such as the draining of natural wetlands, changes to farming practices, urbanisation, quarrying and the historic industrial past of the area.
- Desk study information collected indicates that the primary cause of flooding in Much Wenlock is not attributed to groundwater flooding as the presence of low-permeability shales and glacial till confines the Wenlock Limestone aquifer in this area. Therefore, there no further recommendation for future groundwater investigations or assessments in this area.
- An InfoWorks model for the urban reach of Much Wenlock was built with 2D modelling capability to route any predicting flooding from the sewer / town culvert manholes over the ground to simulate the overland flow paths. One-dimensional (1D) unsteady hydraulic model was the most appropriate commonly used software to assess the flood risk along the rural reaches of the Sytche Brook, Shylte Brook and Farley Brook. The InfoWorks and ISIS models were used to assess the existing open watercourses and sewer network, to model any new flood storage areas upstream and other proposed flood mitigation options in Much Wenlock and to ensure that options proposed do not increase flooding elsewhere. Best use of existing information provided by Much Wenlock Town Council and the Much Wenlock Flood Action Group

regarding the most recent severe flood event (summer 2007) was made to verify the model in partnership with stakeholders.

5.1.3 Opportunities & Constraints

- A variety of measures were considered initially, not constrained by cost or feasibility. These were discussed between Shropshire Council, Mouchel and the EA and it was decided that three options, containing a variety of measures, would be tested using the hydraulic model. Some of the measures originally identified were not modelled specifically but are still advisable and have been included in the recommendations.

- Three options investigated by modelling were:

    1. Attenuation Ponds upstream of Much Wenlock Town and improvement to farming practices

    2. Improved maintenance and increased number of highway gullies to allow surface water to enter the surface water drainage network more effectively

    3. Changes to the drainage network in the area of the Hunter's Gate development, and attenuation ponds to avoid adverse affects downstream

- Options 1 and 3 will also bring ecological benefits through the enhancement of the environment:

    - Hedges have been identified as a Priority Habitat in the UK Biodiversity Action Plan (BAP), increased quantity and quality of hedges support a wealth of biodiversity.

    - Attenuation ponds have been identified to increase biodiversity including invertebrates, vertebrates and vegetation. They also provide improved recreation and amenity to the area. Health & safety risks must be considered, however (especially if near Caravan Park with children in the vicinity).

- Option 2 has the constraint that jetting of the system may wash pollutants downstream, this may be reduced by removing from the last chamber of the system and disposing of it at a waste site. Option 2 should only be implemented in conjunction with Option 1 to ensure peak water levels in the Farley Brook downstream are not adversely affected.

- A cost-benefit analysis was undertaken for the three options.

    - Option 1 (attenuation ponds and improved land practices) provided the greatest benefit to the town in terms of reducing flood damage to properties by 41%, however the option was also the most expensive. The cost-benefit ratio was economically viable at 16.5.

- Option 2 (improved maintenance and increased number of highway gullies) was the cheapest but increased peak water levels downstream so should only be implemented with an attenuation option too to ensure Farley Brook is not adversely affected. The increased jetting of gullies could lead to an increase in contamination of the watercourse downstream. The option has the potential to reduce flood damage to properties by approximately 24%.

- Option 3 (changes to the drainage network in the area of the Hunter's Gate development, and attenuation ponds) benefits the least number of properties by reducing flood damage costs by only 2% and is relatively expensive.

5.2 Recommendations

- Quick 'on the ground' actions include:

  - Maintenance of existing highway gullies should be improved.

  - Improved land practices such as planting of hedgerows, ploughing directions of fields, promotion of growing crop types that slow the field surface runoff.

- Advisory recommendations that were not specifically modelled include:

  - Replacement of the trash screen at the head of the town culvert in accordance with the EA's Trash Screen Design and Operation Manual.

  - The top, approximately 110m, section of the town culvert, currently ordinary watercourse, should be enmained. This would bring clearer boundaries of responsibility. Remedial works to the reinforced concrete upstream headwall of the culvert may be required in order for this to take place.

  - Remove blockages and repair collapsed culverts along the Shylte Brook and Sytche Brook to avoid surcharging. This would help to maintain the capacity of the channel along its whole reach.

  - The existing culverts that take the Sytche Brook under Sheinton Street and Station Road (200m long) and under the old bus depot (60m) are under capacity for the 30 year flood return period. A full analysis has not been undertaken to assess the effect of upgrading these culverts. However, indicative sizes for each are 0.6m diameter and 1.0m diameter respectively. The open channel reaches upstream of the old bus depot would also need alterations to contain the 30 year return period flow within the channel. The channel banks would need to approximately 155.3m aOD. These have been sized based on 30 year return period peak flows for the baseline model. It should be noted that reducing the flooding along Sytche Brook by keeping flows in channel will have the effect of increasing flows downstream where Sytche Brook discharges into the town culvert. These upgrades should not be implemented without full investigation of the consequences downstream. If Option 1 were implemented then the existing 200m and 60m culverts would not be surcharged for the 30 year return period event, however the open channel reach between these two culverts has very limited capacity and the banks would overtop and cause flooding at the old bus depot. Therefore it is recommended this reach of open watercourse is upgraded (i.e increase channel capacity by increasing bank level) even if Option 1 were implemented to prevent flooding for the 30 year return period.

  - SuDS solutions, such as permeable pavements and swales, are recommended for future developments. Local road upgrades, when undertaken, should look to reduce the amount of surface water runoff, increase infiltration into the ground and increase the time it takes for runoff to reach the town culvert.

  - Any new developments should use attenuation ponds / infiltration strips / increased hedgerows & vegetation upstream to reduce or slow the field runoff from the steep catchments surrounding them. Within developments swales and permeable pavements should be used to avoid fast surface water runoff. Drainage for developments should be adequately designed to take the upstream rural catchment runoff as well the urban catchment runoff.

  - Further investigation should be undertaken for the areas where there is still uncertainty in size and connections of the drainage system, in particular in the Hunters Gate area (including the land drains, highway drains, private drainage systems, hydrobrake and connections to the sewer system).

- A combination of the modelled options is recommended. Each option, individually, does not improve all flooding issues:

  - The attenuation ponds in Option 1 provide the greatest benefit to the whole town (and properties along Farley Brook downstream) in terms of estimated annual damages by reducing the peak flows in the town culvert and reducing the likelihood and frequency of surcharge in the system. The cost-benefit ratio is not high (because the option is expensive) but it is greater than 0 indicating that it may be viable.

  - It is not recommended to solely increase the number of highway gullies in the Victoria Road and Bourton Road area without implementation of attenuation (either Option 1 or additional attenuation upstream of properties along Farley Brook).

    - The changes made to Hunter's Gate tested in Option 3 are the least economically viable (cost-benefit ratio 0.9). However, as 1 property sustained major damage and a further three properties a little less 4 during the summer 2007 floods, the area is recognised to be particularly susceptible to flooding. There is still uncertainty regarding the capacity of highway and land drains, route of flow downstream of the hydrobrake, condition and performance of private drainage systems, which means that flooding mechanisms are still not completely understood, so it is recommended to continue to improve understanding of the issues in Hunters Gate regardless of whether Option 3 itself can be progressed.

- If only one mitigation option is to be implemented then Option 1 provides the greatest benefit to residential properties, including those downstream of the Much Wenlock town along Farley Brook.

6 Implementation and Review

6.1 IUDMP Action Plan

The Much Wenlock IUDMP action plan below was discussed and agreed with the key stakeholders during the May 2011 4th Working Group meeting. The meeting was attended by the Environment Agency, Severn Trent Water and Shropshire Council. The timescales in the action plan use the following targets, either: immediate and ongoing action, or 3, 5 or 10 year targets.

Shropshire Council is responsible for monitoring and reporting the implementation of the IUDMP action plan. It should regularly review progress of the action plan, to check whether the proposed actions are being undertaken by the relevant partners and stakeholders. The progress of actions in the Much Wenlock IUDMP action plan is subject to availability of funding.

The actions for the delivery partners set out in the action plan are in addition to their numerous on-going duties and responsibilities for flood risk management.

The IUDMP action plan should be reviewed and updated once every six years as a minimum (in accordance with Defra SWMP Technical Guidance), but certain circumstances might trigger a review and/or update of the action plan in the interim or in some cases annually. Further information is provided in Section 6.6.

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
1.1	High	To encourage alternative land management activities, farming practices and potentially change land use to reduce runoff from agricultural land and to reduce sediment transport being carried downstream by runoff. Examples include: 1) plantation of hedgerows at field edge 2) ploughing direction and soil management plans 3) crop types and cropping techniques. Information to be presented and explained to landowners on the Action that can be implemented, examples and the benefits so win-win situations are found and put in place This will facilitate they 'buy-in' on the Action. The Action will also be beneficial to water quality of the watercourses and to a lesser extend to the groundwater. Any incentives available to the landowners should be clearly outlined. Environmental Stewardship is an agri-environment scheme that provides funding to farmers and land managers to deliver effective environmental management on the land. Natural England work with land managers through the Entry Level Stewardship and encourage High Level Environmental Stewardship schemes to reduce run off in rural areas within the upper catchment reaches. Higher Level Stewardship (HLS) involves more complex types of management and agreements are tailored to local circumstances. Applications are assessed against specific local targets and agreements offered where they meet these targets and represent good value for money. Stewardship is to be applied for by the individual landowners with support from Shropshire Council.	No. of landowners who take action	Shropshire Council Environment Agency Defra National Farmers Union Natural England Landowners	2011 – 2014 (3 years and ongoing)

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
1.2	High	Maintain the existing Much Wenlock and District Community Flood Information, Prevention and Action Plan (including Activation Process), January 2010 (updated February 2011)[17], authors and copyright by Bert Harper and Much Wenlock Flood Action Group. This plan aims to increase the resilience to flooding within Much Wenlock and District through developing a robust co-ordinated approach that compliments the plans of responding agencies. The Much Wenlock Town Council Flood Management Working Group (FMWG) meet to discuss the community's resilience on a quarterly basis. A full review of the plan is currently undertaken by the FMWG together with a test / exercise on an annual basis. The plan has already been endorsed by Shropshire Council and the Environment Agency and the authors should look for opportunities to improve its effectiveness regularly. Ensure key partners are aware of their roles for flood risk management. Ongoing availability of suitable training on responsibilities during flood events (i.e. exercise Watermark) for those people with roles (such as Flood Watch Co-ordinator, Deputy Flood Watch Co-ordinator and Flood Wardens). Volunteers, local residents and local businesses should also be aware of the 'Much Wenlock and District Community Flood Information, Prevention and Action Plan (including Activation Process)'[17]document. The community should also be asked to inform the Flood Wardens of any blockages or flooding issues they spot in the town as and when they arise.	Continuous review of 'Community Flood Information, Prevention and Action Plan (including Activation Process'[17] document	Bert Harper and Much Wenlock Flood Action Group Shropshire Council Much Wenlock Town Council Environment Agency Severn Trent Water	2011 (ongoing annually)

[17] Much Wenlock and District Community Flood Information, Prevention and Action Plan (including Activation Process), January 2010 (updated February 2011). Author and copyright by Bert Harper and Much Wenlock Flood Action Group

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
1.3	High	Promote Sustainable Drainage Systems (SuDS) for new developments and encourage retro-fitting. Reduce the amount of surface water runoff, increase infiltration into the ground and increase the time it takes rainfall to reach the town culvert. Shropshire Council, Much Wenlock Town Council and the Flood Action Group should promote this. Developing a guide specific to the local conditions / catchment would be beneficial, as well as workshops on the benefits of SuDS. Shropshire Council has already recently developed a 'Surface Water Management Interim Guidance for Developers' which is available on the website. When developing a site care must be taken to ensure that flood risk is not increased at the site or elsewhere. During the spatial planning stage, a Flood Risk Assessment in accordance with Planning Policy Statement 25 (PPS25)[18] may be required to ensure there is no increase in flood risk from any source (fluvial, surface water or groundwater). Stakeholders should liaise closely with developers to maximise any benefits that can be brought about through new developments.	Proportion of developments that incorporate SuDS.	Environment Agency Shropshire Council Much Wenolck Town Council Much Wenlock Flood Action Group Developers Severn Trent Water	2011 (ongoing)

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
1.4	High	Promote the uptake of flood resilience and flood resistance measures to assets, including : • community assets for which Shropshire Council should take the lead (e.g. schools, electrical sub-stations, nursing homes), • Severn Trent Water assets • commercial properties • residential properties A list of assets at risk should be compiled by Shropshire Council (requirement of the Flood and Water Management Act since April '10) Receptor measures include temporary and permanent flood defences, local earth bunds or retaining walls, raising vulnerable equipment (i.e. electrical sockets) and sealing of vulnerable buildings (e.g. cable ducts and below ground pipework). Systems should already be in place, however, to ensure that any measures implemented do not increase flood risk elsewhere and in some cases a Flood Risk Assessment (PPS25)[18] may be required to ensure this is the case and that a holistic view of flood risk management is developed. Further information can be found in Shropshire Council's Surface Water Management Interim Guidance for Developers. Shropshire Council also offers property flood surveys. Sub-actions: • Promote awareness of protecting assets to the community (leaflets, workshops etc). Developing a guide to promote flood resilience and resistance would be beneficial • Investigate streams for funding and make opportunities clear to commercial and home owners. Assist where necessary to prepare technical side of grant applications etc.	No. of grant applications for flood proofing No. of FRA's	Shropshire Council Severn Trent Water Environment Agency Central Networks Much Wenlock Town Council Much Wenlock Flood Action Group Commercial property owners Homeowners	2011 – 2016 (5 years and ongoing)

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
1.5	High	Increase frequency of maintenance operations to gullies, watercourses and culverts. Remove blockages and repair collapsed culverts to avoid surcharging. Raise awareness and offer guidance to riparian owners about their duties and responsibilities to maintain watercourses and private drain systems. Develop a program for one-to-one meetings with riparian owners. Sub-actions (Shropshire Council): • Identify the riparian owners in the Much Wenlock catchment • Arrange one-to-one meetings.	Maintenance records of gullies and ordinary watercourses (SC). Maintenance records of enmained watercourses and culverts (EA),	Shropshire Council (SC) Environment Agency (EA) Riparian owners Much Wenlock Town Council Much Wenlock Flood Action Group	2011 (ongoing regular maintenanc e)

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
1.6	High	Implement Option 1 tested in the Much Wenlock IUDMP study. Construct attenuation ponds upstream of the town on both the Shylte Brook (south-west) and Sytche Brook (north-west). The attenuation ponds would retain water upstream and release it in a controlled manner in order to reduce the peak flows downstream. The ponds should be sized using the 30 year flood return period design event. The use of a settlement forebay would also bring the benefit of reducing the amount of sediments being washed down from the surrounding steep fields with the surface runofff and would reduce the amount of silt in both the sewer system and town culvert (thus reducing the maintenance requirements and the flood risk) and improve water quality levels. Sub-actions: • clarify responsibilities and asset ownership (estimated duration: 1 year) • investigate the possible streams for funding the scheme (estimated duration: 2 years) After the first two sub-actions: • undertake design and Environmental Impact Assessment (estimated duration: 1 year), • procure and build (estimated duration: 3 years) • operate with clear responsibilities for operation and maintenance procedures (ongoing)	Construction and maintenance records	Shropshire Council Much Wenlock Town Council Much Wenock Flood Action Group Landowners Environment Agency	2011 (ongoing)

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
2.1	Medium	Mitigation of flooding in the Hunters Gate area and ensure flooding is not made worse downstream. Maximise the benefits that could arise from any future developments. The IUDMP study tested one option for mitigating the flooding in this area (Option 3) however other options should be investigated that may be simpler to fund and implement. Sub-actions: • clarify responsibilities and asset ownership • investigate the possible streams for funding the scheme	Construction and maintenance records	Shropshire Council Environment Agency Severn Trent Water Landowners & riparian owners Developers	2011 (ongoing)
2.2	Medium	Replacement of the trash screen and wing walls at the head of the town culvert in accordance with the EA's Trash Screen Design and Operation Manual.	Record of upgrade	Environment Agency Shropshire Council	2011 -2014 (3 years)
2.3	Medium	After implementation of Action 2.2, the top, approximately 110m, section of the town culvert, currently ordinary watercourse, should be en-mained by the EA. This will clarify responsibilities for its management.	Record of enmainment of watercourse	Environment Agency Shropshire Council	2011 – 2016 (5 years)

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
2.4	Medium	Ongoing studies regarding sewer and fluvial flooding can use the hydraulic model developed for the Much Wenlock IUDMP. The model should be kept live using new information from appropriate parties. The hydraulic model should be used to support planning applications including Flood Risk Assessments (FRA's) for new developments, where it is considered necessary by the Flood and Water Management Team on a case by case approach, to ensure flooding is not made worse elsewhere. Possible future updates to the hydraulic model: • update model with any larger new developments • to better calibrate the hydraulic model by installing in the future an EA rainfall station in the catchment and undertaking some monitoring of water levels / flows. The EA river water level stations should be improved / repaired / installed at critical locations in the en-mained reaches. • look to include the combined and foul systems at a later date.	Record of updates to hydraulic model Installation and/or maintenance records of EA rainfall / level / flow gauges. FRA studies	Shropshire Council Environment Agency Severn Trent Water	2011 (ongoing)
2.5	Medium	Implement Option 2 tested in the Much Wenlock IUDMP study. Increase volume of surface water entering the town culvert by increasing frequency of maintenance operations **and** increasing the number of gullies. This action should not be implemented on its own. Joint implementation with Action 1.6 would result in the proposed benefits of both Actions without the negative effect of increasing flow rates downstream. Detailed design checks would need to be done using the hydraulic model and if connecting to the surface water sewers then checks and an application would need to be submitted to STW Asset Protection Team. This action's priority should be reviewed once Action 1.6 has been completed.	Records of gully installations	Shropshire Council Highways Agency	2011 – 2021 (10 years)

Action Number	Priority	Action	Indicator	Delivery Partner(s)	Timescale
3.1	Low	Bring ecological benefits through the enhancement of the environment and contribute towards Biodiversity Action Plans (BAPs) including targets for wet grassland, reedbed and wet woodland habitats and local objectives for wetlands. Also bring benefit to local economy through recreation. This Action is linked to Action 1.1 (increased number of hedgerows) and Action 1.6 (attenuation ponds) and will require consultation with: • Natural England • RSPB • Wildlife Trust An Environmental Impact Assessment will be required for the construction of the attenuation ponds and other large capital works undertaken in the catchment.	Habitat Management Plans	Environment Agency Shropshire Council Much Wenlock Town Council Landowners	2011 (ongoing)

6.2 Capital Investments

The main capital works are the flood attenuation ponds along Sytche Brook and Shylte Brook detailed in Option 1. These provide the greatest benefit, with regard to flood alleviation, of the options modelled.

Further capital works are recommended in the Hunter's Gate and Monk's Walk areas, the cost-benefit ratio of these capital works is lower than the attenuation basins along Sytche Brook and Shylte Brook as there are fewer properties affected by flooding in this location.

Capital works for the Environment Agency include investment in the hydrometric stations for the catchment and en-mained watercourses.

6.3 Maintenance Actions

The IUDMP action plan includes increased frequency of maintenance operations for Much Wenlock. This is for highway gullies and watercourses whether open or culverted.

If there is capital investment in to attenuation ponds, then responsibilities and asset ownership will need to be clearly defined and there will be associated annual maintenance costs.

6.4 Local Authority and Spatial Planning

This IUDMP report should be made available to local authority planners by Shropshire Council so they are aware of areas in Much Wenlock that are vulnerable to flooding and at risk of flooding. The Flood Maps for Surface Water, the Areas Susceptible to Surface Water Flooding maps and EA Flood maps should also be available to planners for additional information on the extents of flood hazards and the risk of flooding. Consultation should be made with the three main risk management stakeholders (Shropshire Council, Environment Agency and Severn Trent) to agree how outputs from this study can be used appropriately to ensure fully informed decisions are made regarding spatial planning.

This report provides some examples of SuDS and resilience measures that can be implemented for new developments and existing properties and assets to reduce the increasing risk of flooding.

Planning Policy Statement 25 (PP25)[18] sets out the Government's spatial planning policy on development and flood risk and applies to all developments.

[18] PPS25 (2006) Planning Policy Statement 25: Development and Flood Risk (PPS25), Communities and Local Government, Crown Copyright 2006. Revised March 2010

6.5 Emergency Planning

The IUDMP report should be made available to emergency planners such as the emergency services, Environment Agency who provide flood warnings, Much Wenlock Flood Action Group and those who have roles during flood events as set out in the Much Wenlock and District Community Flood Information, Prevention and Action Plan (including Activation Process)[17]. Consultation should be made with the three main risk management stakeholders (Shropshire Council, Environment Agency and Severn Trent) to agree how outputs from this study can be used appropriately to ensure fully informed decisions are made regarding emergency planning.

The comprehensive Community Flood Information, Prevention and Action Plan (including Activation Process) [17] document in place in Much Wenlock should be regularly reviewed and updated where necessary. Suitable training on responsibilities during flood events should be made available for those people with roles (such as Flood Watch Co-ordinator, Deputy Flood Watch Co-ordinator and Flood Wardens).

Volunteers, local residents and local businesses should also be aware of the Community Flood Information, Prevention and Action Plan (including Activation Process) [17]. It would be beneficial to inform the community first by leaflet / workshops etc. The info should also be available to all through Shropshire Council, Much Wenlock Town Council and/or Much Wenlock Flood Action Group (via a website so the latest version available to all etc). The local media (including radios) should have it as well so they can inform the people during flood events when communications to remote areas can be difficult.

Routes that may be at particular risk of surface water flooding and may become impassable include:

- the 5 way junction at Gaskell Corner (where Victoria Road, Sheinton Street, High Street, Bridgnorth Road and Bourton Road meet);
- the Bull Ring next to the Priory;
- along High Street and Back Lane; and
- Sheinton Street where it meets Station Road.

Critical infrastructure that may be at particular risk of surface water flooding include:

- the school on Farley Road;
- electrical sub-station next to the Bull Ring near the Priory and Sytche Brook;
- electrical sub-station at Hunter's Gate, and;
- electrical sub-station in the main town near Back Lane.

The source of information on critical infrastructure comes from the Shropshire Council Preliminary Flood Risk Assessment[19].

6.6 Review of IUDMP

The IUDMP report and action plan from Section 6.1 have been reviewed by Shropshire Council (including a scrutiny committee) and approved, then were reviewed by the stakeholders prior to approval of the final action plan.

Stakeholders have agreed to support the objectives of the IUDMP and will work with Shropshire Council to achieve these objectives and deliver the action plan to the full extent of their flood risk management responsibilities and within the limits of their business / work plans.

Once the plan has been reviewed and agreed, the IUDMP action plan should be published and made available to all via a website for example.

Shropshire Council is responsible for monitoring and reporting the implementation of the IUDMP action plan. It should regularly review progress of the action plan, to check whether the proposed actions are being undertaken by the relevant partners and stakeholders.

The SWMP Technical Guidance[1] recommends that the stakeholders continue to work together, meet and discuss implementation of the proposed actions, and to discuss progress. The action plan should be reviewed and updated once every six years as a minimum, but the following circumstances might trigger a review and/or update of the action plan in the interim or in some cases annually:

- occurrence of a flooding incident;
- additional data or modelling becoming available, which may alter the understanding of risk within the study area;
- outcome of investment decisions by partners is different to the preferred option, which may require a revision to the IUDMP action plan, and;
- additional development or other changes in the catchment that affect the surface water flood risk.

[19] Shropshire Council Preliminary Flood Risk Assessment, Mouchel Report No. 1034787/DG/001, March 2011

We have used our reasonable endeavours to provide information that is correct and accurate and have discussed above the reasonable conclusions that can be reached on the basis of the information available.

Appendix A – Review of Existing Models

Babtie Hydroworks Model

The existing Babtie HydroWorks model from 1999 was not available during the data collection part of this study (assumed it could not be found). It was agreed that this model should be reconstructed in InfoWorks based on the Hydroworks paper records and the 'as built' culvert drawings.

The only information received was a paper copy of the results file from some model runs. It was not possible to determine the model extents from these files but comparing this information to the 'as built' drawings it was possible to conclude that the hydroworks model covered the extent of the town culvert. From the Hydroworks model it was possible to obtain the main information relating to the model, such as ground levels, pipe sizes and invert levels. However there were no coordinates for the modelled manholes so it was not possible to import this information directly into InfoWorks.

There was no information within the results files on the sub-catchments that may have been defined within the Hydroworks model, however it appears from the results files that the model was only run with inflow files so it is likely no sub-catchments were defined to generate the storm runoff from the surface water sewers. The parameters used to generate the inflow files were provided, based on the Flood Studies Report parameters, but the inflow files themselves were not provided.

Due to the very limited information provided regarding this model, following a review, it was decided the model was not fit for purpose. Therefore, the InfoWorks model needed to be reconstructed and the main source of information was the 'as-built' drawings of the town culvert, which were provided. These were found to provide sufficient information to construct the InfoWorks model of the culvert.

STW InfoWorks Models

The InfoWorks model of the Much Wenlock foul / combined system appeared to be a fairly detailed model although the number of sub-catchments, generating flow into the system, was very low compared to the number of modelled manholes. Although the surface water system was included in the model there were no sub-catchments draining to this system hence flows were modelled in the foul / combined system only. There was impermeable area added to the foul / combined system so the assumption must have been that this was not a completely separately drained system. The model contained one combined sewer overflow, approximately 750m upstream of the waster water treatment works, which was modelled as a 'free' outfall.

The only use that has been made of the model is the extraction of the surface water sewers and the connection of these to the InfoWorks model of the town culvert.

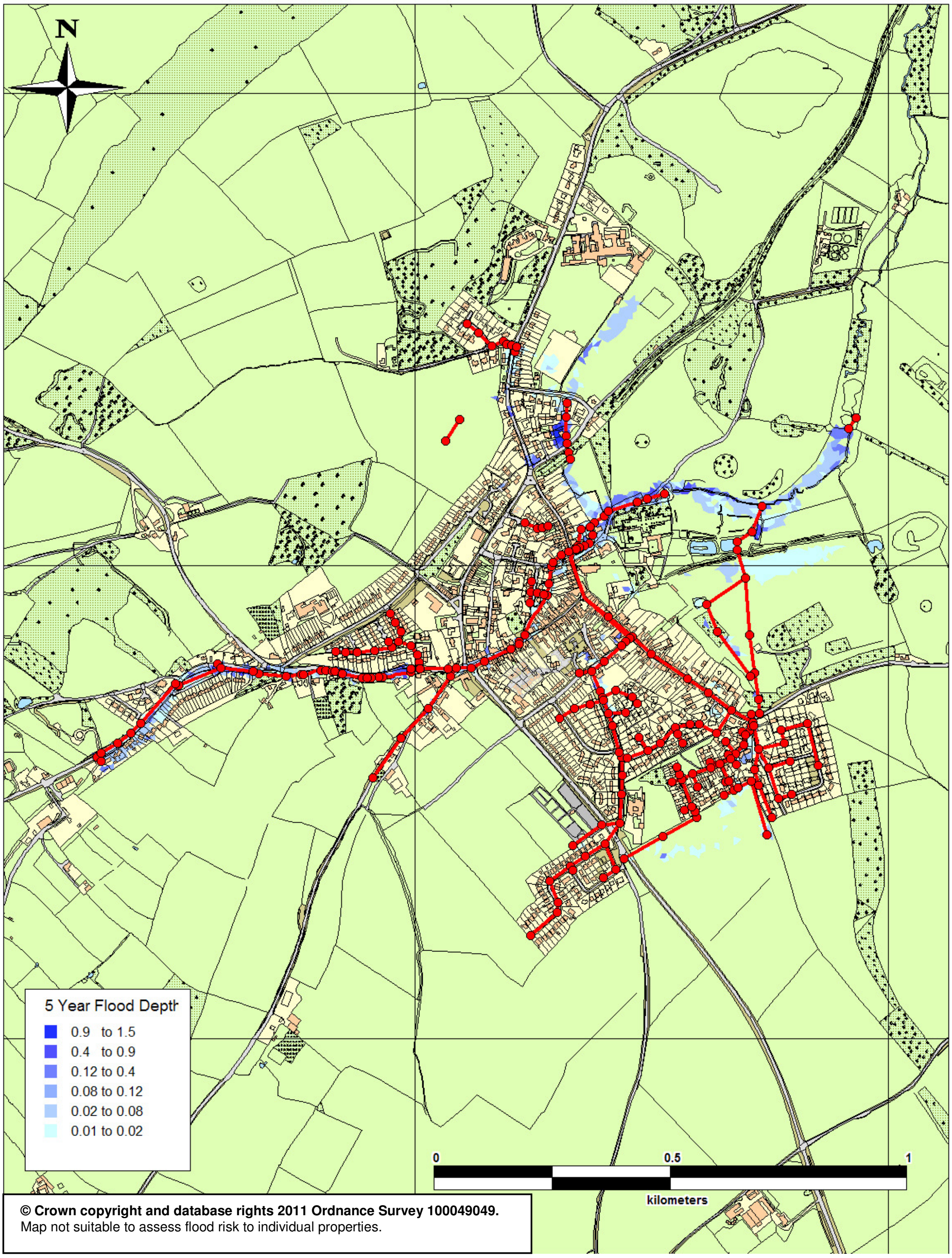
Appendix B – FEH Catchment Descriptors

CD	1 Stretton Road	2 Victoria Road	3 Bourton Road	4 Town N	5 Town	6e Sytche Brook east	6w Sytche Brook west	7e Hunters Gate east	7c Hunters Gate central
Grid Ref	361300, 299550	362000, 299800	362100, 299800	362450, 300100	362450, 300100	362350, 300250	362250, 300350	362700, 299650	327700, 299650
AREA	2.05	0.49	0.42	0.59	0.51	0.35	0.73	0.45	0.17
ALTBAR	222	187	199	195	195	175	89	185	185
ASPBAR	60	108	30	59	59	135	0.54	37	37
ASPVAR	0.41	0.41	0.41	0.569	0.569	0.48	0.641	0.52	0.52
BFIHOST	0.548	0.486	0.520	0.535	0.535	0.474	0.94	0.588	0.588
DPLBAR	1.15	1.15	1.77	1.77	1.77	0.94	77.5	0.68	0.68
DPSBAR	79.6	80.9	89.6	70.635	70.635	73.18	1	77.9	77.9
FARL	1	1	1	1	1	1	0.0034	1	1
LDP	2.21	2.21	3.16	3.33	3.33	1.99	0.017	1.49	1.49
PROPWET	0.36	0.36	0.36	0.36	0.36	0.36	-999999	0.36	0.36
RMED-1H	11.2	11.2	11.2	11.2	11.2	10.9	1.99	11.1	11.1
RMED-1D	33.2	33.2	33.9	33.3	33.3	33	0.36	33.7	33.7
RMED-2D	41.6	41.6	41.6	41.6	41.6	41.1	10.9	41.8	41.8
SAAR	742	728	739	739	739	714	33.3	742	742
SAAR4170	778	773	777	777	777	769	41.4	778	778
SPRHOST	30.22	35.23	28.70	30.34	30.34	36.84	714	20.37	20.37
URBCONC	-999999	-999999	0.269	0.452	0.452	0.583	769	0.75	0.75
$URBEXT_{1990}$	0.001	0.06	0.189	0.108	0.108	0.0182	30.64	0.1258	0.1258
URBLOC	-999999	-999999	0.432	0.383	0.383	0.125	0.583	1.334	1.334
C	-0.025	-0.026	-0.027	-0.026	-0.026	-0.027	0.0154	-0.027	-0.027
D1	0.348	0.35	0.357	0.353	0.353	0.353	-0.026	0.361	0.361
D2	0.354	0.342	0.342	0.344	0.344	0.342	0.352	0.337	0.337
D3	0.317	0.327	0.325	0.328	0.328	0.331	0.3442	0.326	0.326
E	0.288	0.292	0.297	0.295	0.295	0.294	0.329	0.300	0.300
F	2.442	2.444	2.434	2.436	2.436	2.436	0.292	2.428	2.428
C(1km)	-0.025	-0.038	-0.028	-0.028	-0.028	-0.028	2.441	-0.028	-0.028
D1(1km)	0.345	0.389	0.355	0.355	0.355	0.355	-0.028	0.359	0.359
D2(1km)	0.347	0.321	0.341	0.341	0.341	0.341	0.355	0.338	0.338
D3(1km)	0.323	0.375	0.335	0.335	0.335	0.335	0.341	0.333	0.333
E(1km)	0.285	0.346	0.299	0.299	0.299	0.299	0.335	0.3	0.3
F(1km)	2.456	2.360	2.434	2.434	2.434	2.434	0.299	2.43	2.43
Notes on changes made:			ASPBAR: -6.5° to 30° (from map)						

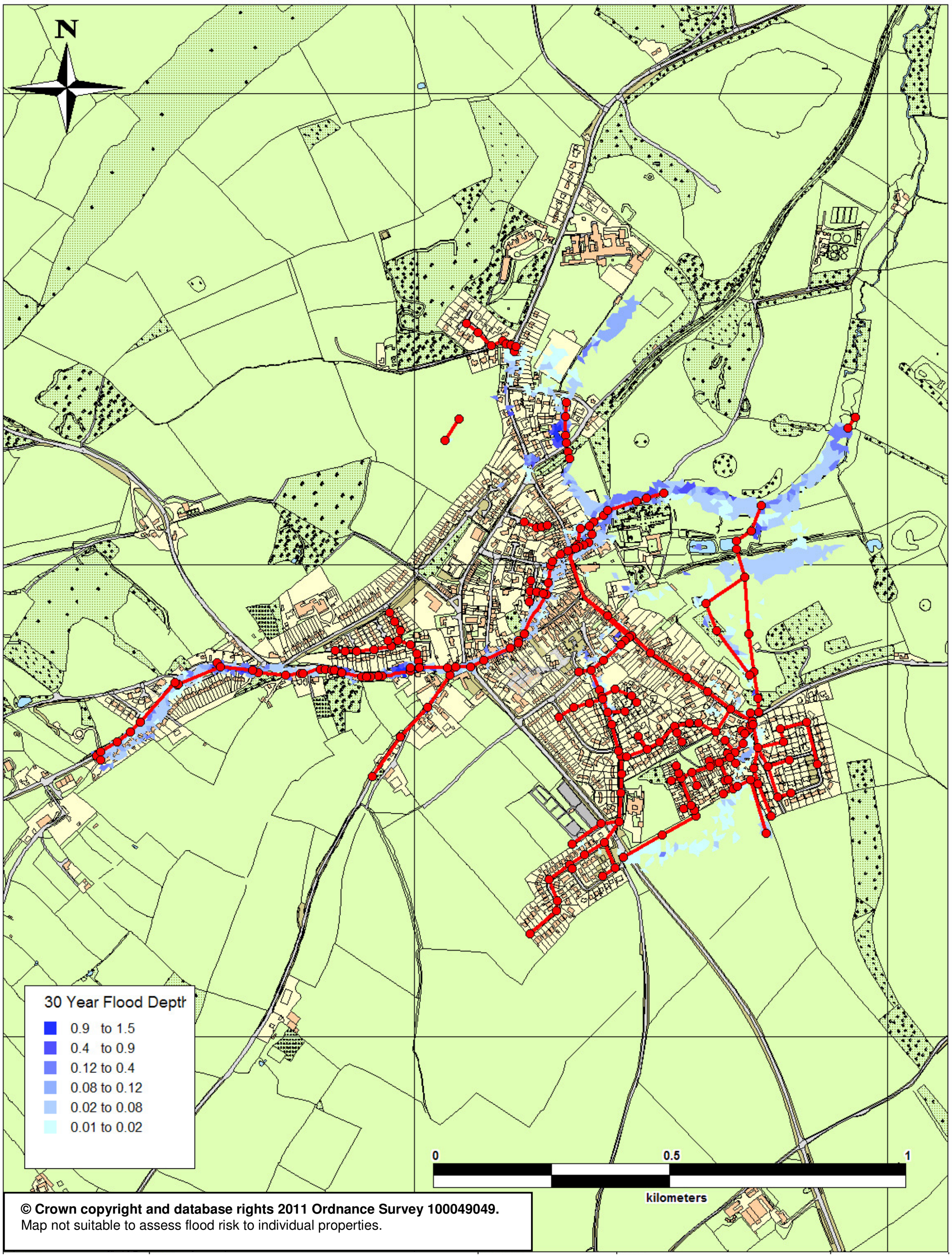
CD	7w Hunters Gate west	8 Outfall Town Culvert	1 – 8 Urban Catchment	9 Ponds	10 Walton Hills	11 Quarry	12 Farley	1 – 12 Whole Catchment
Grid Ref	362700, 299650	362550, 300150	362550, 300150	362900, 300300	362950, 300600	363200, 301450	363700, 302650	363700, 302650
AREA	0.09	0.06	5.45	0.49	1.52	1.26	1.36	10.08
ALTBAR	185	195	204	179	186	159	144	183
ASPBAR	37	74	74	74	30	30	51	45
ASPVAR	0.52	0.43	0.43	0.43	0.43	0.43	0.23	0.23
BFIHOST	0.588	0.635	0.545	0.533	0.552	0.538	0.602	0.557
DPLBAR	0.68	1.89	1.89	1.89	2.06	2.16	2.81	3.93
DPSBAR	77.9	87.4	78.4	63.9	75.6	88.2	107.7	82.1
FARL	1	1	1	0.998	0.999	0.999	0.999	0.999
LDP	1.49	3.83	3.83	3.83	4.3	4.62	5.63	7.15
PROPWET	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
RMED-1H	11.1	11.1	11.1	11.1	11.1	11.1	10.4	11
RMED-1D	33.7	33.3	33.3	33.3	33.4	32.0	32.5	33.1
RMED-2D	41.8	41.5	41.5	41.5	40.6	40.0	40.5	41.1
SAAR	742	732	732	732	744	732	726	732
SAAR4170	778	775	775	775	770	767	766	772
SPRHOST	20.37	27.72	31.36	31.60	24.82	28.32	29.61	28.39
URBCONC	0.75	0.468	0.468	0.468	0.59	0.59	0.589	0.589
$URBEXT_{1990}$	0.1258	0.0509	0.0418	0.0842	0	0.0116	0.0040	0.0341
URBLOC	1.334	0.514	0.514	0.514	0.722	0.837	0.969	1.08
C	-0.027	-0.027	-0.026	-0.027	-0.028	-0.028	-0.027	-0.027
D1	0.361	0.353	0.351	0.354	0.36	0.355	0.356	0.355
D2	0.337	0.344	0.347	0.3434	0.326	0.327	0.3341	0.339
D3	0.326	0.328	0.324	0.328	0.324	0.332	0.321	0.325
E	0.300	0.295	0.292	0.295	0.3	0.299	0.294	0.295
F	2.428	2.436	2.439	2.435	2.430	2.420	2.423	2.432
C(1km)	-0.028	-0.028	-0.028	-0.028	-0.028	-0.028	-0.028	-0.028
D1(1km)	0.359	0.355	0.359	0.359	0.334	0.354	0.406	0.361
D2(1km)	0.338	0.341	0.338	0.338	0.284	0.327	0.386	0.335
D3(1km)	0.333	0.335	0.333	0.333	0.338	0.334	0.134	0.307
E(1km)	0.3	0.299	0.3	0.3	0.295	0.299	0.292	0.298
F(1km)	2.43	2.434	2.43	2.43	2.381	2.42	2.45	2.424
Notes on changes made:		ALTBAR: 204mAOD to 195 mAOD (Town) SAAR: 822mm to 732mm (whole catchment) C,D,E,F (Town)			ASPVAR: -0.13 to 0.43 (09 Ponds)	ASPBAR: -15° to 30° ASPVAR: -0.18 to 0.43 (09 Ponds) SAAR: 715mm to 732mm (whole catchment)		

Appendix C – Flood extent maps of water depth showing 5, 30, 75 and 100 year + climate change return period events for baseline

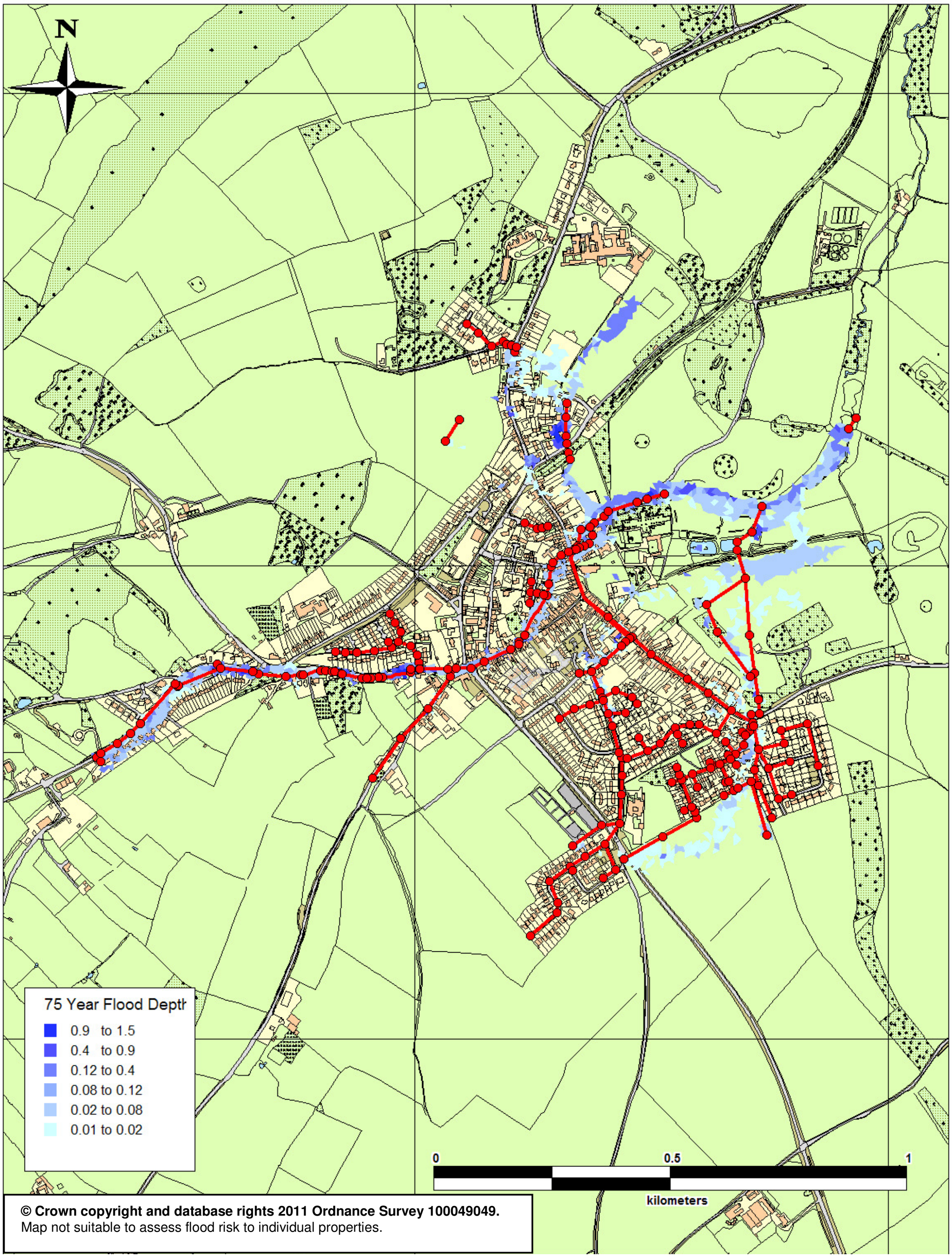
Peak water level for 5 year return period event



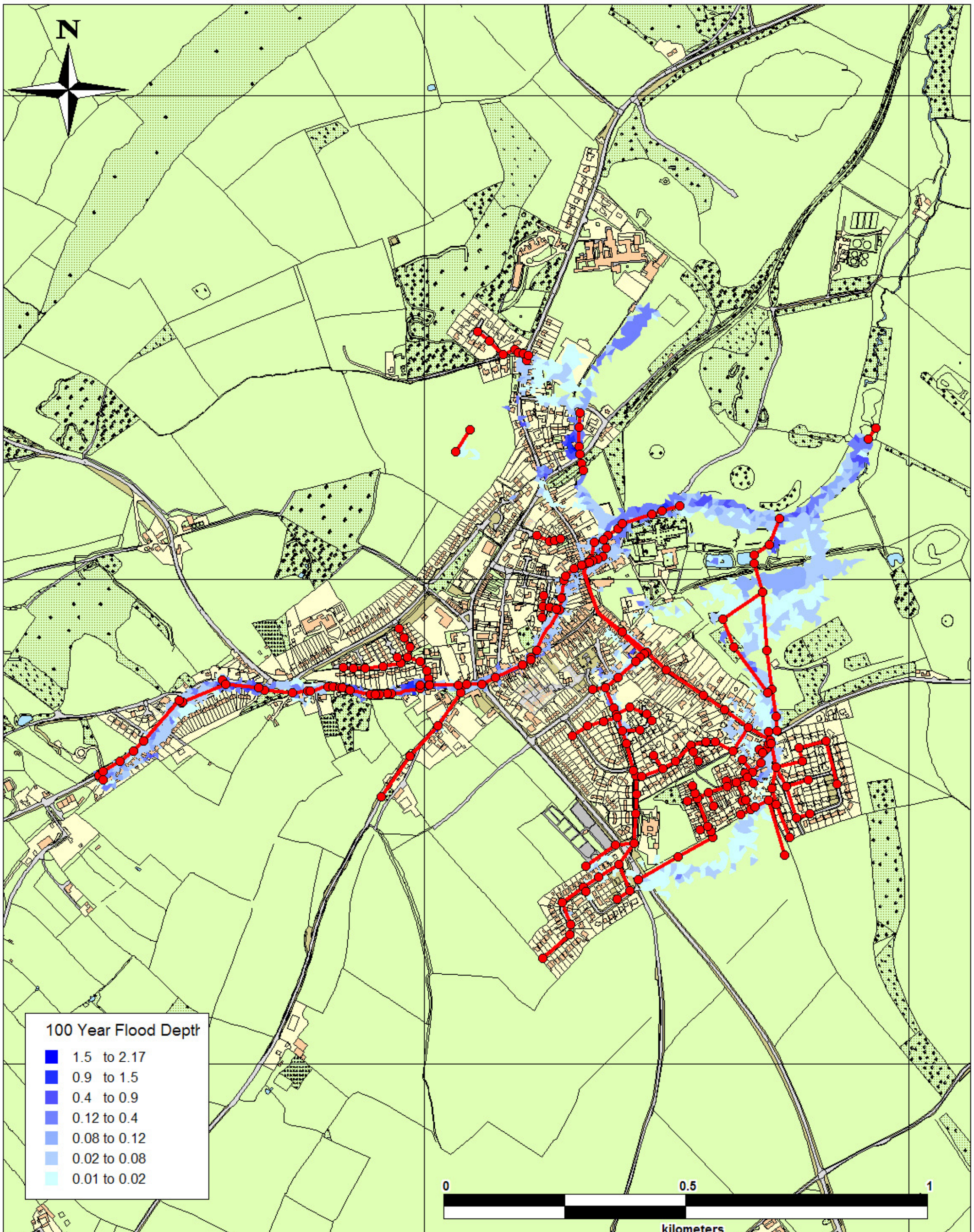
Peak water level for 30 year return period event



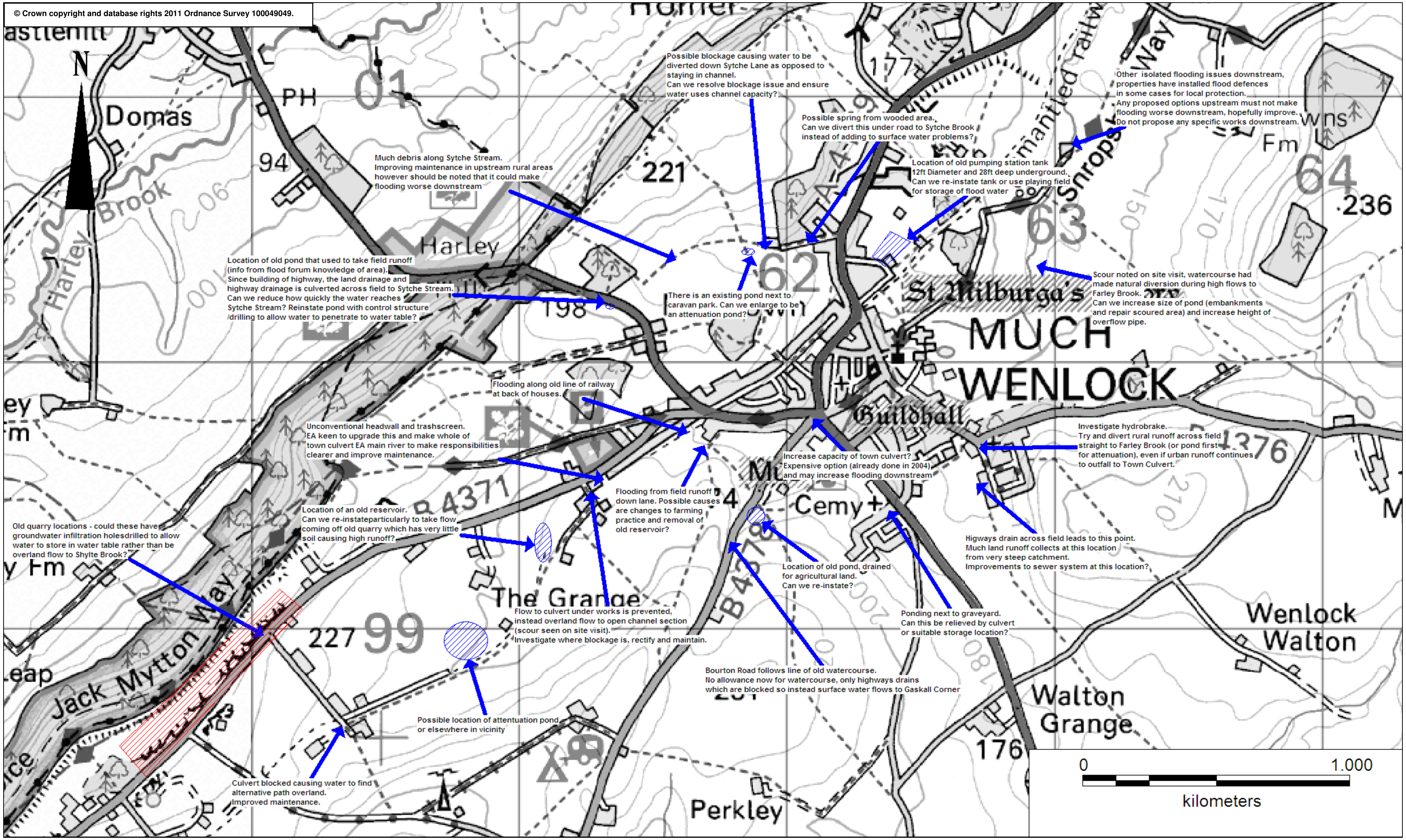
Peak water level for 75 year return period event



Peak water level for 100 year + climate change return period event

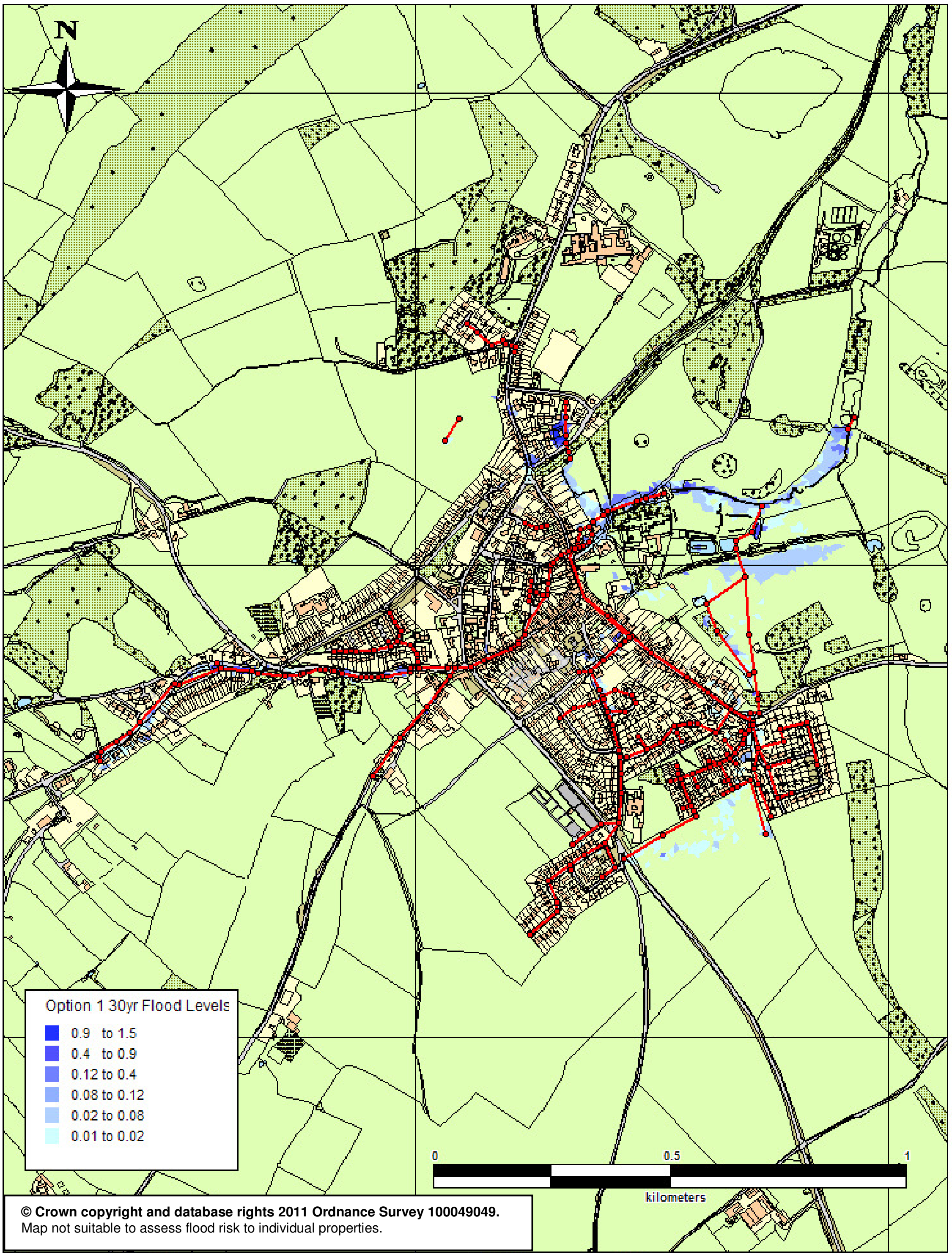


Appendix D – Initial Flood Mitigation Measures

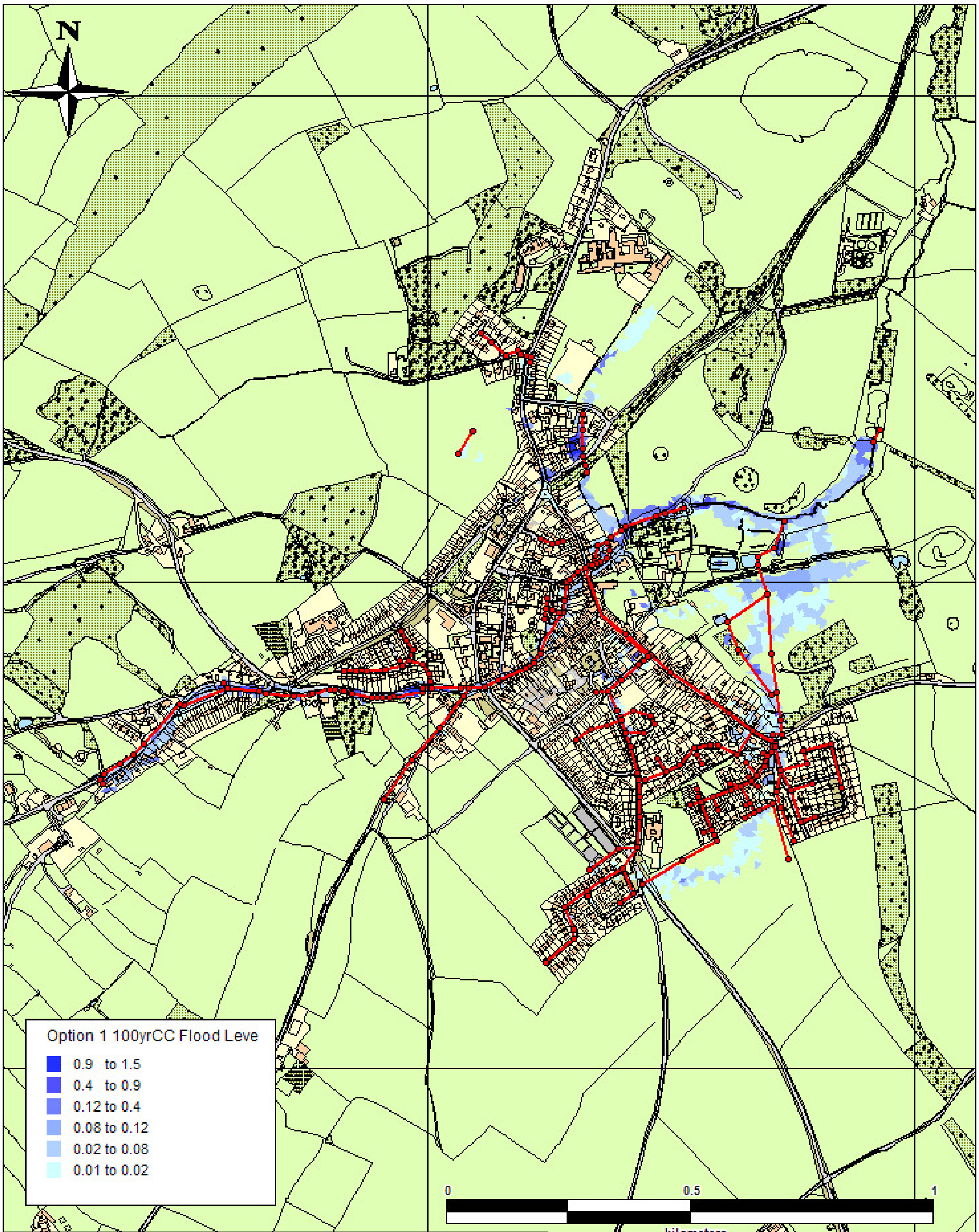


Appendix E – Flood extent maps of water depth showing 30 and 100 year + climate change return period events for 3 proposed mitigation options

Option 1 - Peak water level for 30 year return period event

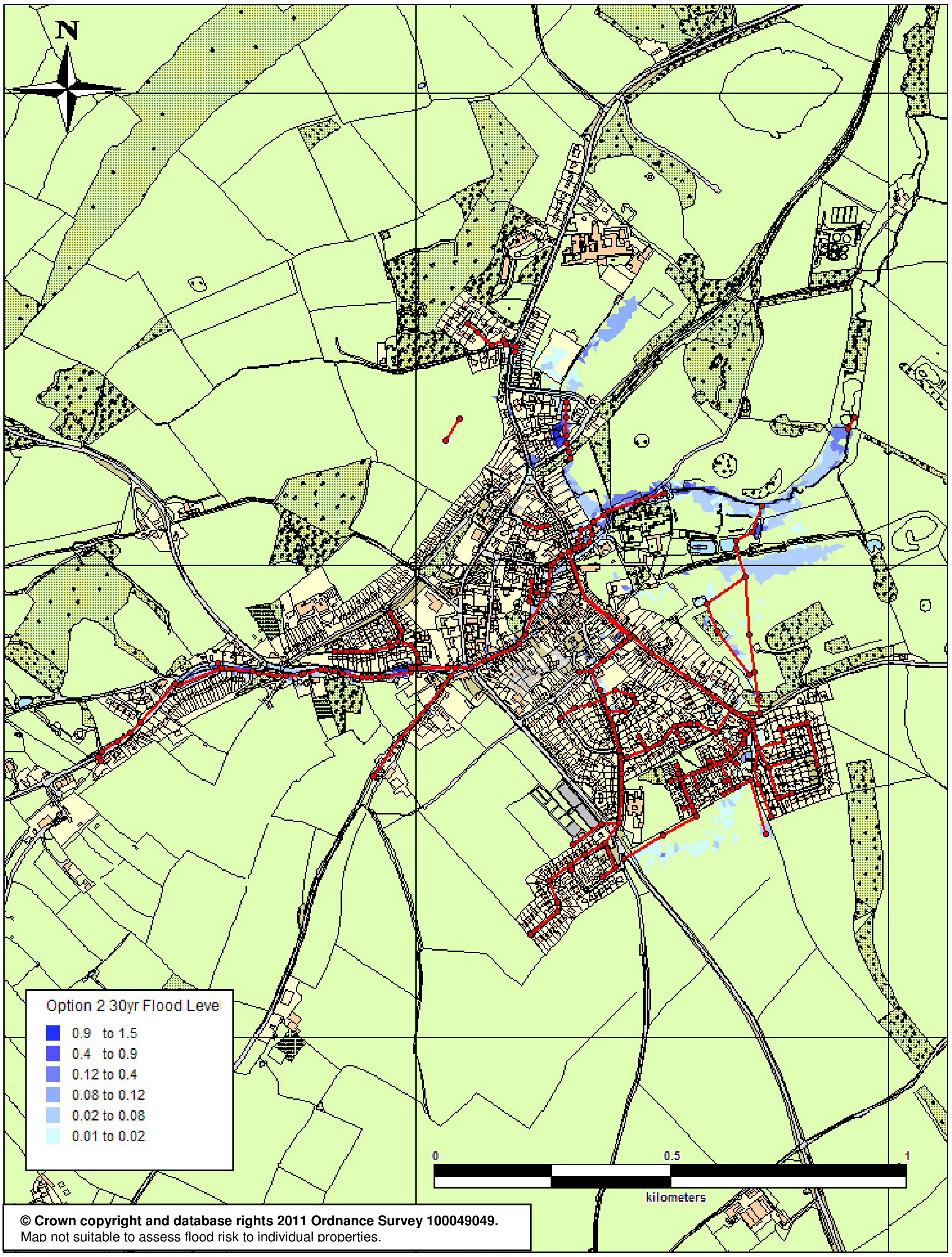


Option 1 - Peak water level for 100 year + climate change return period event

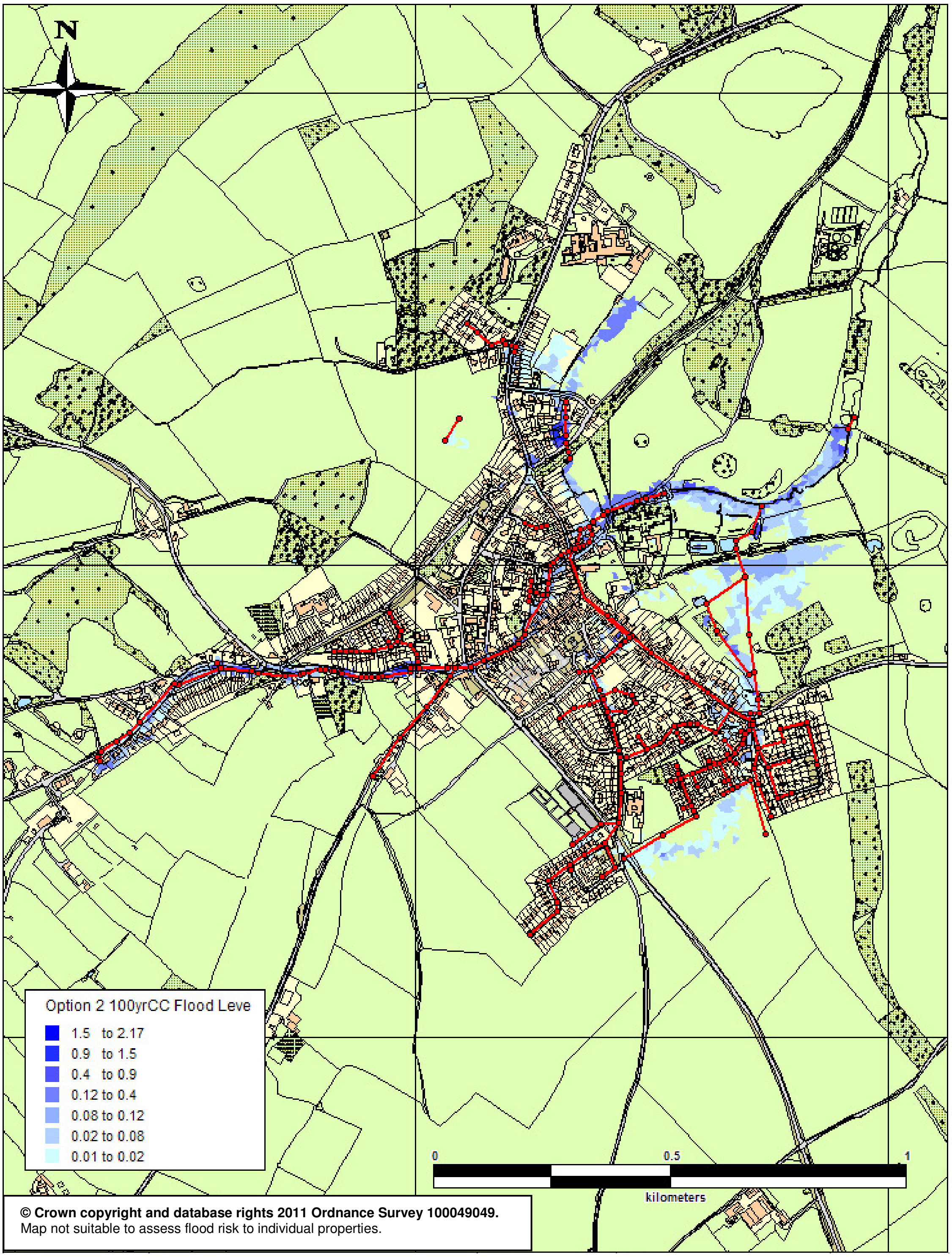


Map not suitable to assess flood risk to individual properties.

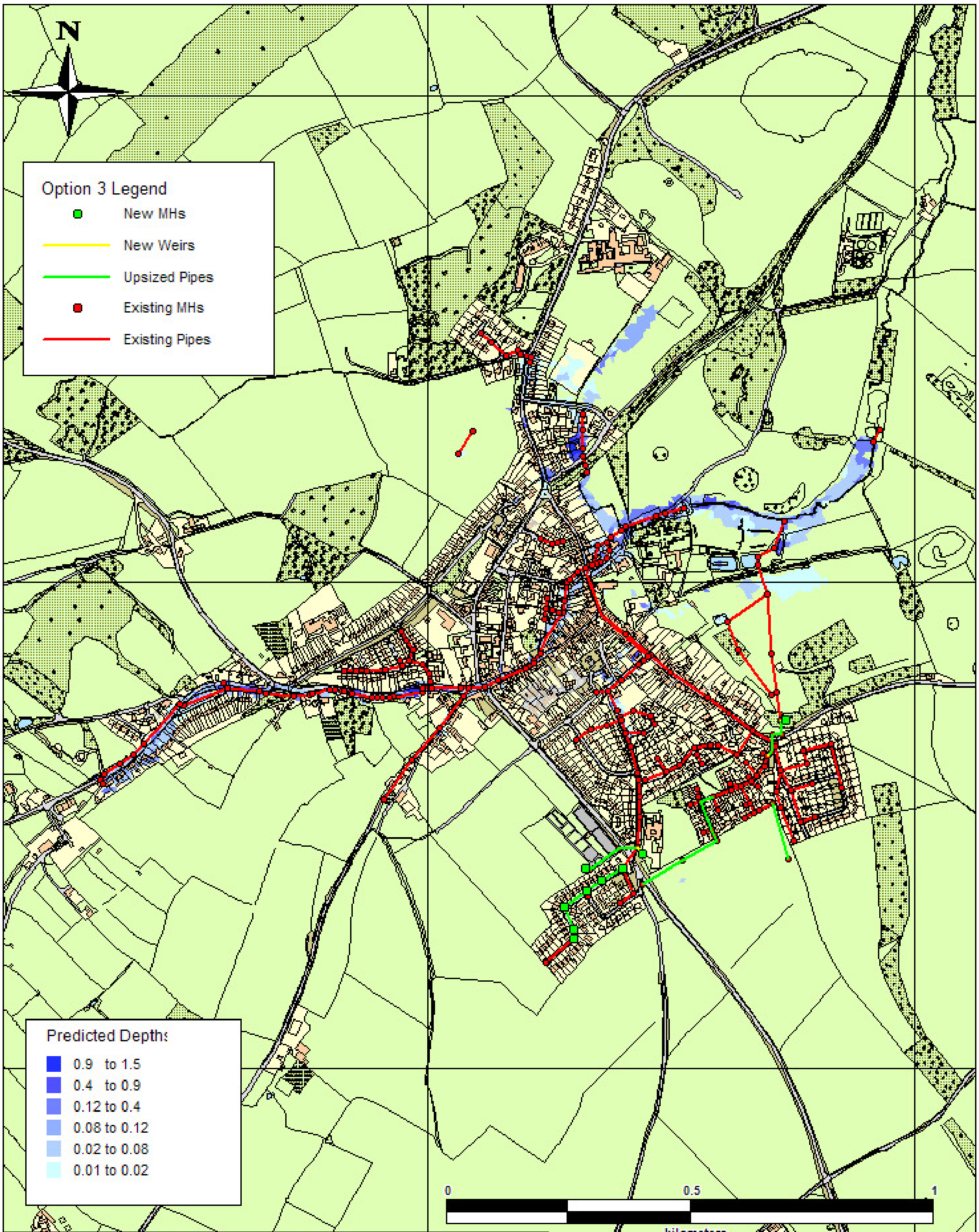
Option 2 - Peak water level for 30 year return period event



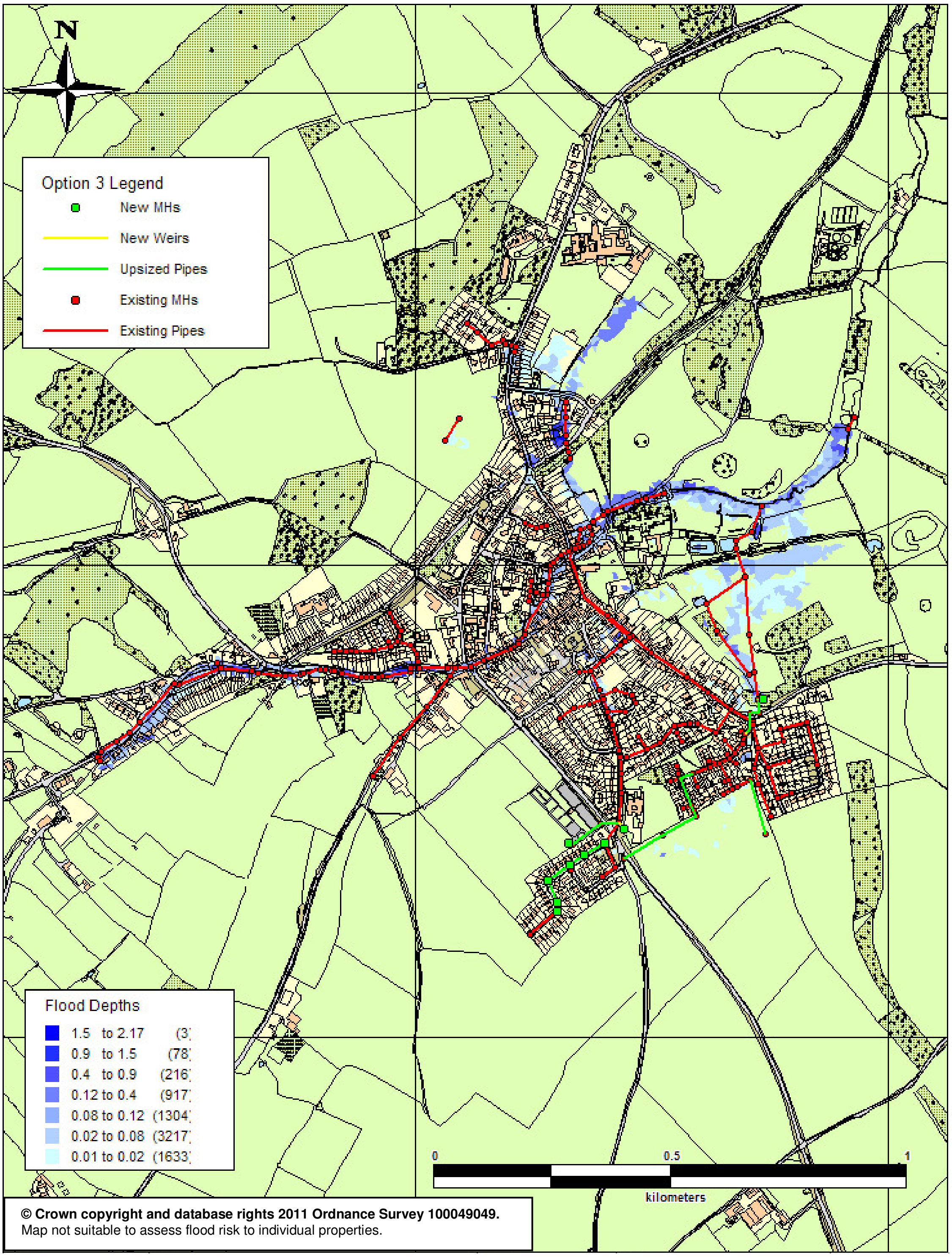
Option 2 - Peak water level for 100 year + climate change return period event



Option 3 - Peak water level for 30 year return period event



Option 3 - Peak water level for 100 year + climate change return period event



Map not suitable to assess flood risk to individual properties.

Appendix F – Costing of Options (ex. VAT)

These costs do not account for other costs associated with design and construction of these options (planned or unforeseen) such as design costs, land costs and other indirect costs which have not been considered at this stage.

Option 1 – Attenuation Ponds and Improvement to Land Practices

The table below shows the sizes of the proposed attenuation ponds for the Sytche Brook and Shylte Brook. The costs are provided based on the average SuDS costs in Table 25.1, from the CIRIA SuDS Manual (C697), and have been included in the Option 1 Capital Costs.

Location	Description	Size (m^3)	Rate (£/m^3)	Cost (£)
Sytche Brook	Near existing pond at caravan site	6,000	20	120,000
Shylte Brook	Upstream of town culvert, near old reservoir	8,000	20	160,000
Capital Cost Total				**£280,000**

The maintenance costs, based on the surface area of the ponds, are assumed to be £1/m^2 of retention pond using Table 25.2 of the CIRIA SuDS Manual (C697). Assuming the ponds are 2m deep then 3,000m^2 and 4,000m^2 are to be maintained for the Sytche Brook and Shylte Brook respectively. Overall, the cost of maintenance for the ponds is estimated to be **£7,000 per year.**

The improvements to land practices are assumed to be undertaken by landowners. Accordingly, no costs have been assumed for Option 1. It is possible that incentives for promotion of such schemes could come from other sources such as the National Farmers Union.

Option 2 – Improved Maintenance and Increased Number of Highway Gullies

The table below shows the increased number of gullies required to reduce the surface runoff in the Stretton Road / Shrewsbury Road / Victoria Road / Bourton Road area (i.e upstream reach of the town culvert). It has been assumed that the capacity of a single gully is 15 l/s. The costs are provided based on the Standard Bill of Rates used by Shropshire Council for its maintenance contractor, extract shown below:

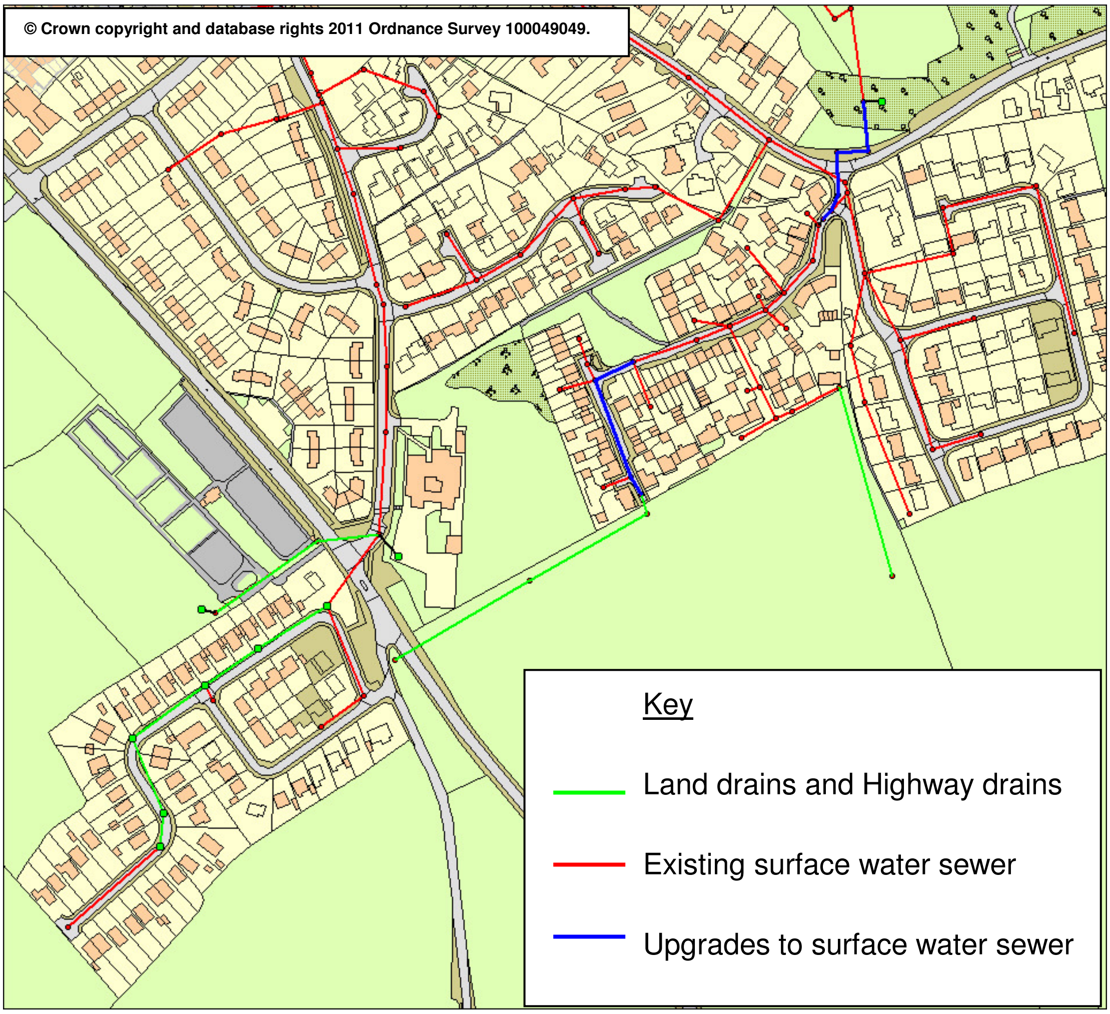
- Group 2 trapped gully = £336.13
- Connection of 150mm diameter. pipe to existing pipe = £66.61

Location	Increased capacity required (l/s)	Increased capacity from maintenance of existing gullies	Increased capacity required from new gullies (l/s)	Number of new gullies required	Rate (£/gully)	Cost (£)
Stretton Road, Shrewsbury Road, Victoria Road and Bourton Road	1700	50%	850	57	403	22,837
Capital Cost Total						**£22,837**

Gully maintenance includes the cost of machinery and operators. It was clear from the site visit that highway gullies in some areas would benefit from additional maintenance. The cost of maintenance includes both the existing and new highway gullies in the area.

Location	Total capacity in area (l/s)	Total number of gullies (new & existing)	Number of gullies per hour	Rate (£/hour)	Cost (£)
Stretton Road, Shrewsbury Road, Victoria Road and Bourton Road	3400	227	10	75	**£1,700**

Option 3 – Changes to Drainage at Hunter's Gate and Attenuation Ponds



Existing and Required Land Drains and Highway Drains

The table below shows the assumed existing sizes for the land and highway drains and the size they are required to be to take the 30 year return period flows. As the existing sizes have been assumed – the cost of the required land and highways drains have **not** been included in the costs of Option 3.

Location	U/S Manhole	D/S Manhole	Assumed Existing Diameter (mm)	Required Diameter (mm)	Length (m)	Depth (m)
Oakfield Park	SO62993252	SO62993251	150	225	20	1.5
Oakfield Park	SO62993251	SO62992351	150	225	49	2
Oakfield Park	SO62992351	SO62993351	150	225	54	2
Oakfield Park	SO62993351	SO62993353	150	225	39	2
Oakfield Park	SO62993353	SO62994451	150	225	50	2

Land Drain	Field_Drain_3	SO62994452	100	150	111	1.8
Field Drain	Field_Drain	Field_Drain_2	150	300	176	2
Field Drain	Field_Drain_2	SO62995401	225	375	12	2
Field Drain	Merrywell_01	SO62997557	225	450	119	1

<u>Surface Water Sewer Upgrades</u>

The table below shows the existing sizes of some of the key surface water sewers in the Hunter's Gate areas and the size they are required to be upgraded to transfer 30 year flows to the downstream hydrobrake chamber. The costs of these upgrades are provided and have been included in the Option 3 costs.

Location	U/S Manhole	D/S Manhole	Existing Diameter (mm)	Required Diameter (mm)	Length (m)	Depth (m)	Rate (£/m)	Cost (£)
Hunters Gate	SO62995401	SO62995402	300	375	12	2.2	140	1680
Hunters Gate	SO62995402	SO62995501	300	375	62	3	150	9300
Hunters Gate	SO62995501	SO62995505	300	375	25	3.1	150	3750
Hunters Gate	H1	H1a	300	600	7	1.9	125	875
Hunters Gate	H1a	H2	225	450	11	2.1	75	825
Forester Avenue	H2	H3	300	450	25	2.3	75	1875
off Barrow Street	H3	H7	300	600	19	2.9	145	2755
off Barrow Street	H7	Pond_1	300	600	30	2.8	145	4350
Total					**191m**	**Total**		**£25,410**

<u>Manholes</u>

The table below shows proposed manholes. The costs of these upgrades to the surface water sewer system are provided and have been included in the Option 3 costs.

Location	Description	Required Diameter (mm)	Number	Depth (m)	Rate (£)	Cost (£)
Hunters Gate	For pipes to 600 dia	1800	5	2.5	1500	7,500
Hunters Gate	Weir @ hydrobrake	1800	1	2.5	2000	2,000
Total						**£9,500**

Ponds

The table below shows the proposed ponds for the Hunter's Gate area. The costs are provided and have been included in the Option 3 costs.

Location	Description	Size (m^3)	Rate (£/m^3)	Cost (£)
Monks Walk	Fields	3500	20	70,000
Bridgnorth Road	West of Road by cemetry	400	20	8,000
Bridgnorth Road	East of Road by school	250	20	5,000
Total				**£83,000**

The overall capital costs for the upgrading of the surface water sewers and construction of the attenuation ponds for Option 3 is estimated to be **£117,910.**

The maintenance costs, based on the surface area of the ponds, are assumed to be £1/m^2 of retention pond using Table 25.2 of the CIRIA SuDS Manual (C697). Assuming the Monks Walk pond is 2m deep and the two small ponds are 1m deep then 1,750m^2, 400^2 and 250m^2 is to be maintained. The overall maintenance cost of the ponds is therefore estimated to be **£2,400 per year.**

Appendix G – Environmental Opportunities and Constraints Maps

Contains maps showing:

- Statutory Classification Areas
- Rights of Way
- Shropshire Council's Environmental Records
- Environment Agency's Environmental Records
- EA Biodiversity Screening Map
- Environmental Record at Sytche Brook (for Option 1 Assessment)
- Environment Record at Shylte Brook (for Option 1 Assessment)
- Environmental record at Monk's Walk (for Option 3 Assessment)